Research and Application of Evaluation System for Military Special Vehicle Cab

Sheng Su[1, a], Min Yan [2, b*], Sen Gu [3, c], Zhiqiang Song [4, d], Ping Liu [5, e]
[a]e-mail: 379084426@qq.com,* Corresponding author: [b]1150351989@qq.com, [c]e-mail: 304772975@qq.com, [d]e-mail: 462641869@qq.com, [e]e-mail: 360012745@qq.com

[1]School of Design Art and Media Xi'an Technological University Xi'an, Shaanxi, China

[2]School of Mechatronic Engineering Xi'an Technological University Xi'an, Shaanxi, China

[3]School of Mechanical & Electrical Engineering Henan University of Technology Henan, Zhengzhou, China

[4]School of Art and Design Xi'an FANYI University Xi'an, Shaanxi, China

[5]School of Design Art and Media Xi'an Technological University Xi'an, Shaanxi, China

Abstract: In order to provide a reference for the future cab design through a comprehensive and effective assessment of the human-computer interaction level of the cab of military special vehicles, the evaluation dimension and evaluation index of the military special vehicle cab are obtained according to the investigation and analysis of the characteristics of the military special vehicle cab, user needs, tasks and environmental needs, and the Delphi method is used to screen and optimize the index, and the weight calculation and analysis of the analytic hierarchy method is used to obtain 1 target layer and 3 evaluation dimensions. Multi-level evaluation index system of military special vehicle cab with 35 index layers; according to the evaluation system, the cab of military special vehicles is evaluated, the evaluation results are summarized and summarized, and the design principles of the cab of military special vehicles are obtained.

Keywords: military special vehicle; cab design; evaluation index; design principle

1 INTRODUCTION

Through the reasonable design of the cab, it can meet the operator's high-quality, efficient and comfortable man-machine needs of the operator, improve the operation accuracy, and better cope with the special combat environment. At present, in the design and evaluation of military special vehicle cabs, Zhou Lin, Ding Chuanfeng, etc. have deduced the spatial positions of other parts according to the eye point position in the humanized design of the cab to design the layout of seats and other components, and use the digital software platform to test, so as to improve the operator's comfort and operation accuracy [1-2]; Chen Jingwei and others put forward the "objective sample experiment-interactive experience design-modeling design -subjective and objective design evaluation" by studying the modeling design optimization of heavy truck blind area, which provides a reference method for the cab design of special vehicles[3]. Ma Yujin etc. optimized the design based on the basic theories of ergonomics, related data analysis, derivation of the emotion model system, and the establishment of a

ICICA 2022, December 02-04, Chongqing, People's Republic of China

DOI 10.4108/eai.2-12-2022.2327949

driving comfort model based on biomechanics, and conducted computer simulation evaluation of the design scheme through the three-dimensional software digital platform [4-5]. To sum up, the current research on the cab focuses on the two fields of human-machine and modeling, and the evaluation methods are different, all lacked a comprehensive evaluation of the cab function and form.

In view of this, this paper constructs a multi-level evaluation index system to solve the above problems. That is, according to the characteristic analysis of military special vehicles, user needs, task analysis and the needs of the task environment, the evaluation indicators are divided into different evaluation dimensions, and the selection and optimization of evaluation indicators, weight analysis and calculation are carried out by methods such as Delphi, and finally a multi-level evaluation index system for the cab of military special vehicles will be established.

2 ANALYSIS OF THE CHARACTERISTICS OF THE CAB OF MILITARY SPECIAL VEHICLES

The military special vehicle cab is a complex human-machine-loop interaction system, and its efficiency in special combat situations depends on the overall coordination and interaction of the human-machine-loop system [6]. Therefore, this paper analyzes the characteristics of military vehicle cabs around the relationship between operators, military special vehicle cabs and combat environment. It is divided into three aspects: static display characteristics, dynamic display characteristics, and task environment characteristics. The summary is as follows:

From the perspective of static display characteristics, the attributes of the cab equipment, such as information elements and interaction modes, will affect the operator's perception of information, affect the cognitive accuracy and speed, and affect the cognition and judgment of the overall battle situation through the field of view. Unreasonable equipment layout will not only increase the number of visual saccades and redundant operation quantity, but also cause the operator to be distracted; the comfort of the seat in the cab will also lead to the operator's attention to a certain extent [7]. Dispersion will affect the accuracy of operation and endanger the health of the operator; as well as the overall style of the cab and the style, color and material of each equipment will have a certain impact on the operator's physiology.

From the perspective of dynamic display characteristics, the operator needs to perform dynamic operation through selective attention and attention distribution [8]. The cab is an important venue for the operator to perform operation and control activities. In the strong time-sensitive combat conditions, if the cognitive operation efficiency of the operator can be improved, that is, the operation speed and accuracy can be improved, it will affect the progress of the task to a certain extent. The operator's field of view in the entire combat state will affect the operator's acquisition and analysis of current information elements.

From the perspective of task scenario characteristics, when the battlefield scenario is complex and task transitions are frequent, the multi-domain operational control activities make the operator's physical and psychological load higher, and the overall layout design should be logically consistent with the operator's subconscious behavior [9]. Through various design methods, it matches the situation cognition elements to provide the operator with the optimal operation interaction mode and the maximum information cognition.

3 OBTAINING EVALUATION INDICATORS

3.1 Evaluation indicators of user needs

In order to fully understand the relevant issues such as cab design factors, specific task performance, and cab human-computer interaction of military special vehicles, we can select indicators that can effectively evaluate the cab. Cognitive walk-through analysis and survey interviews with domain experts, operators, and designers and developers of special vehicle cabs are documented as follows:

Cognitive walk-through analysis: invite experts in the field of military special vehicles to experience the operation in a certain type of special vehicle. During the experience, experts express and describe the problems found in the cab to form an oral record. For example: "The overall operation process is not easy to learn", "It is easy to forget the commands represented by the operation buttons during the task process", "The layout of the equipment is within the reachable area, try to reduce the obstruction of the equipment to the field of vision, and keep the field of vision as wide as possible. "

Requirements for design and development personnel: the cab of military special vehicles needs sufficient space to place special equipment, and an expandable interface is required for later maintenance, upgrading and transformation; the layout of the equipment is easy to learn, understand, recognize and use; in order to reduce the fatigue of the operator, the cab environment and seats should be comfortable; the overall style of the cab design should be unified with the vehicle, and can express the style of the car and improve the overall recognition.

Operator requirements: the equipment in the cab of military special vehicles is easy to operate and learn when it arranged; the overall environment of the cab is clean and comfortable, requiring sufficient seating space and storage space, and the seat can support the waist; minimize the blind spot of vision caused by your own equipment as much as possible.

The common needs of buyers and users are the comfort of the cab environment and seats of military special vehicles, the layout of instruments and consoles are easy to learn and understand, the design style of the cab has characteristics and aesthetics, and the style and atmosphere of military equipment are available.

The user needs are refined and classified into indicators, as shown in TABLE 1.

TABLE 1 Evaluation Metrics for User Needs

Evaluation dimension	Evaluation indicators
validity	Device layout integrity
	Equipment layout operability
	Instrument and Equipment Observability
	In-cab interface scalability

	storage space
	vision
	Seat is comfortable and well supported
	Seat provides other functions
	Equipment layout for ease of operation
efficiency	Cab Equipment Operation Efficiency
	Learning and cognitive efficiency of equipment layout
	Influence of cab environment on operator attention
subjective satisfaction	Cab style is unified with the vehicle
	Cab style with character and aesthetics
	The cab has the atmosphere of military equipment

3.2 Evaluation indicators of task analysis

The research and analysis of the tasks and environments of various types of special vehicles can be obtained: the common tasks can be classified into driving, communication, special equipment operation and accompaniment. In the driving task, the driver needs to operate the driving device with higher accuracy, accept and process the instrument panel information within a limited time, and have a good field of vision to observe the surrounding environment; in the communication task, the operator should place it within the reachable area of the operator, and the communicator modules should be separated from other equipment operation modules to avoid misoperation by operators; in special equipment operation tasks, the layout of the cab and the equipment itself should be reasonable, and should be easy for operators to learn and recognize; in order to reduce the occurrence of reduced operational efficiency or misoperation caused by fatigue and other physiological reasons, it is necessary to ensure that the equipment is placed in the operator's reachability area in a limited space, and the seat has good support and wrapping.

The mission analysis of the above-mentioned military special vehicles is summarized and summarized. The task requirements acquisition evaluation indicators based on task analysis are shown in TABLE 2.

TABLE 2 Requirements acquisition evaluation indicators based on task analysis

task type	task requirements	Evaluation dimension	Evaluation indicators
driving task	Dashboard is easy to read	validity	vision
	good view		seat comfort
	comfortable seat		Communicator Reachability
communication tasks	Communicator is within reach		Special equipment operability
	Differentiate between communicators and other		Ease of operation of special equipment

	Avoid mistakes		Special equipment maintainability
Special equipment operation tasks	Operability of special equipment		Man-machine layout
	Ease of operation of special equipment		special needs
	Maintainability of special equipment	efficiency	Dashboard recognition efficiency
	Layout is easy to learn		Communicator Cognitive Efficiency
	The layout is easy to recognize		error rate
	Reasonable layout of man-machine		equipment learning efficiency
other tasks	Meet special needs		Device Cognitive Efficiency

3.3 Evaluation indicators of task environment analysis

The mission environment includes noise, vibration, glare, bumps, high cold and high heat and other harsh climatic environments. The noise environment mainly includes vehicle chassis and engine noise, special equipment noise, road noise tire noise, wind noise, which will reduce the operator's attention, lead to misoperation, and when it is serious, it will cause tinnitus and deafness, endangering the physiological health of the operator. In military special vehicles, the vibration mainly includes the vibration of the vehicle itself and special equipment, because the military special vehicle has a heavy load, high passability and hard demand, the engine equipped with the chassis is mostly diesel multi-cylinder engine, which leads to greater vibration during operation; special equipment itself generates large vibrations when running. The glare environment, produced by sun exposure and the launch of certain firepower special equipment, can cause intense irritation to the operator's eyes, causing short-term vision loss, ghosting, and even temporary blindness, which are fatal on the battlefield. The bumpy environment is mainly caused by the external environment of military special vehicles and the operation of some special equipment with large recoil force, which will reduce the operation accuracy in this environment. External natural environmental factors such as high cold and high heat are inevitable. The operator is in the above environment for a long time, which will have a physiological and psychological impact on the operator, resulting in misoperation and cognitive errors of the operator.

Summarize the above task environment analysis, see TABLE 3 for requirements acquisition based on task environment analysis.

TABLE 3 Requirements acquisition based on task environment analysis

type of environment	environmental needs	Evaluation dimension	Evaluation indicators
Vibration environment	Reduce the impact of vibration on occupants	The total layout of the device	Vibration effect
	Reduce misoperation rate		bump effect

bumpy environment	Stabilize the occupant's working posture		noise impact
	Reduce misoperation rate		glare effect
noise environment	Reduce noise impact on occupants		climate impact
	Reduce misoperation rate		occupant physical health
glare environment	Reduce the impact of glare on occupants		occupant mental health
harsh climate environment	Reduce the impact of climate on occupants	equipment	Misuse rate

4 CONSTRUCTING THE EVALUATION INDEX SYSTEM OF MILITARY SPECIAL VEHICLE CAB

4.1 Preliminary establishment of evaluation indicators for military special vehicle cabs

According to the characteristic points of military special vehicle cab, user demand analysis, task and task environment analysis, the evaluation index is obtained. Some duplicated indicators are deleted, and the following evaluation indicators are obtained:

The evaluation indicators of the total layout of the equipment include: the integrity of the equipment layout and the field of view; observability of instruments and equipment; scalability of the in-cab interface; storage space; seat comfort and support; other functions provided by the seat; communicator accessibility; special equipment operability, ease of operation, maintainability, man-machine layout, special needs; vibration effects; bumpy effects; noise effects; glare effects; climate impacts; operator physical and mental health; the impact of the cab environment on operator attention.

Equipment evaluation indicators include: cab equipment operation efficiency; learning and cognitive efficiency of equipment layout; operabilityEasy to operate; dashboard reading efficiency; communicator cognitive efficiency; misoperation rate; equipment learning efficiency; device cognitive efficiency.

The overall style evaluation index includes the cab style and the unity of the whole vehicle; the cab style has character and beauty; the cab has a military equipment atmosphere.

4.2 Delphi survey optimization

The Lickert scale is used to select and optimize the structural problems of the initially established index evaluation settings, and 5 levels (corresponding to 1 to 5 points) are set for the 3 evaluation dimensions and 35 evaluation indicators to be "very unimportant", "unimportant", "general", "important" and "very important" for experts to judge. Seventeen experts in the military field were invited to participate in the test, and two rounds of correspondence were completed.

The first round of statistical software analyzes the scores of experts, and analyzes them in three ways: full score, mean of importance, and coefficient of variation. The perfect score rate is the ratio of the number of experts who give a full score to the total number of experts who score that indicator; the mean of importance indicates the concentration of expert scores, which is proportional to the importance of the indicators, the indicators with a mean of importance less than or equal to 3 need to be excluded, the coefficient of variation represents the difference in the experts' judgment on the importance of each index, and when the coefficient of variation is greater than 0.25, it means that the degree of expert recognition is not enough, and it is necessary to re-investigate and unify opinions.

The results of the first round of surveys show that all indicators have an average importance greater than 3, and they are all reserved. Only the C1 equipment layout integrity coefficient of variation value is greater than 0.25. At the same time, 14 experts suggested that the integrity of the equipment layout should be modified or deleted. In view of the fact that during the use of the cab, the role of human-computer interaction in the equipment layout is more important than the equipment layout. The integrity of the layout is more important, so the integrity of the device layout is modified to the ergonomics of the device layout.

The second round of evaluation letter inquiries: experts weighed some of the more controversial indicators, fed back the revised indicator C1 to the experts, and gave back on the average value of the importance of each indicator for the experts to refer to for a new round of scoring. After two rounds of expert investigations, the expert opinions converged and the Delphi investigation was concluded.

The indexes were screened by the limits of the mean value of importance and the coefficient of variation. After two rounds of investigation,35 evaluation indexes were finally determined. In order to confirm the validity of the survey, this paper uses the Kendall synergy coefficient to represent the consistency and credibility of expert opinions in this survey, of which the asymptotic significance is 0.001, which is less than the judgment value of 0.05, indicating that the survey results are highly credible.

TABLE 4 Evaluation of statistical results of various functions of the indicator

Evaluation dimension	**Evaluation indicators**	**Full score**	**Mean of importance**	**Coefficient of variation**
B1 The total layout of the device	C1 Ergonomics of equipment lay out	0.768	4.468	0.252
	C2 The operability of equipment layout	0.412	3.368	0.185
	C3 Instruments and equipment	0.147	3.975	0.104
	Scalability of C4 In -Cab Interfaces	0.253	4.002	0.112
	C5 storage space	0.846	4.000	0.132

	C6 seats are comfortable and well supported	0.365	3.869	0.139
	C7 seats offer additional features	0.249	4.000	0.132
	C8 device layout	0.572	3.975	0.179
	C9 Vision	0.152	4.051	0.043
	C10 Seat Comfort	0.143	3.935	0.021
	C11 Communicator Reachability	0.236	3.753	0.102
	C12 Special Equipment Operability	0.378	4.023	0.021
	C13 Special Equipment Ease of Operation	0.327	4.602	0.145
	C14 Special Equipment Maintainability	0.732	4.000	0.012
	C15 man-machine layout	0.261	4.713	0.099
	C16 Special needs	0.429	4.373	0.101
	C17 Vibration Effects	0.372	3.629	0.173
	C18 bump effects	0.714	4.473	0.202
	C19 Noise Effects	0.710	4.104	0.102
	C20 Glare Effect	0.643	4.371	0.085
	C21 Climate Impact	0.032	4.500	0.014
	C22 Crew Physiological Health	0.625	3.984	0.113
	C23 Crew Mental Health	0.235	3.632	0.015
B2 equipment	C24 Cab Equipment Operational Efficiency	0.178	4.371	0.104
	C25 Equipment Layout Learning	0.419	4.709	0.111
	C26 Equipment Layout	0.351	4.003	0.089

	C27 Cab Environment on Crew's Attention	0.254	4.417	0.170
	C28 driving instrument panel recognition and reading efficiency	0.257	4.271	0.017
	C29 Communicator Cognitive Efficiency	0.024	3.908	0.021
	C30 Error Operation Rate	0.183	4.073	0.084
	C31 Equipment Learning Efficiency	0.673	4.094	0.031
	C32 Device Cognitive Efficiency	0.702	4.634	0.185
B3 Overall style	The C33 cab style is unified with the vehicle	0.461	4.371	0.107
	C34 cab style with character and beauty	0.730	4.013	0.115
	The C35 cab has a military equipment vibe	0.218	4.005	0.035

4.3 Weight calculation

Weights indicate that each factor in the indicator set has different importance. This paper uses AHP to determine the weight of each index. The basic principle of AHP is to decompose the relevant factors into the target layer, the criterion layer and the indicator layer according to different attributes from top to bottom.

The cab hierarchy model of military special vehicle cab is: target layer A, that is, military special vehicle cab; criterion layer B is divided into three evaluation dimensions, namely equipment total layout B1, equipment B2, and overall style B3; the index layer C is 35 evaluation indicators such as "human-eriability C1 of the equipment layout", and the weight of each index is determined layer by layer from top to bottom. In the questionnaire, experts compare the importance of the three evaluation dimensions. According to the 1-9 scale method proposed by American operations researcher Saaty, the judgment matrix is obtained and normalized according to formula (1):

$$P_i = \sqrt[n]{E_{i,1} \times E_{i,2} \times \cdots \times E_{i,n}} \tag{1}$$

In formula (1), P_i is the normalized score of the i-th index; n is the number of indicators for pairwise comparison; $E_{i,1}$, ... $E_{i,n}$ is the pairwise comparison score of the indicators.

Calculate the weight value of each indicator:

$$p_i = \frac{P_i}{\sum_{i=0}^{n} P_i} \tag{2}$$

In order to judge whether there is a logical error between the weight values of various indicators, a consistency check is performed based on the calculated weight values.

The degree of consistency needs to determine its allowable range, so the random consistency index CI is introduced. Among them, the index CI is related to the number of levels. When CI=0, it means that the consistency is completely consistent, which is the most perfect state; when 0<CI<0.1, it means that the consistency is within the allowable range and meets the requirements; when 0.1<CI, it represents a higher degree of inconsistency and cannot meet the requirements. The consistency index formula CI is as follows (3):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{3}$$

consistency check formula is as formula (4):

$$CR = \frac{CI}{RI} \tag{4}$$

In the formula, CR is the random consistency ratio; CI is the consistency index, and RI is the random consistency index.

The test result is that the consistency ratios are 0.013, 0.0302, and 0.0346, which are all less than 0.1, which satisfies the consistency test.

Through the comprehensive analysis of the military special vehicle cab and the selection and optimization of the method index by Delphi, the weight of the index is calculated by the analytic hierarchy process, and the final evaluation index system is shown in TABLE 5.

TABLE 5 Evaluation index system of military special vehicle cab

Evaluation dimension	Evaluation dimension weight	Evaluation indicators	Evaluation index weight	Combined weights
B1 The total layout of the device	0.2537	C1 Ergonomics of equipment Layout	0.3265	0.0916
		C2 The operability of equipment layout	0.0632	0.0104
		C3 Instruments and Equipment	0.2931	0.0665
		Scalability of C4 In -Cab Interfaces	0.3629	0.0561
		C5 storage space	0.4180	0.0152

		C6 seats are comfortable and well supported	0.3241	0.0625
		C7 seats offer additional features	0.0655	0.0163
		C8 device layout	0.1217	0.0168
		C9 Vision	0.1529	0.0647
		C10 Seat Comfort	0.0371	0.0261
		C11 Communicator Reachability	0.0725	0.0623
		C12 Special Equipment Operability	0.0520	0.0105
		C13 Special Equipment Ease of Operation	0.3853	0.0264
		C14 Special Equipment Maintainability	0.0726	0.0375
		C15 man-machine layout	0.7138	0.0852
		C16 Special needs	0.3714	0.0166
		C17 Vibration Effects	0.0713	0.0062
		C18 bump effects	0.1730	0.0206
		C19 Noise Effects	0.6294	0.0037
		C20 Glare Effect	0.4185	0.0052
		C21 Climate Impact	0.2793	0.0163
		C22 Crew Physiological Health	0.0834	0.0113
		C23 Crew Mental Health	0.1632	0.0051
B2 equipment	0.2037	C24 Cab Equipment Operational Efficiency	0.4713	0.0410
		C25 Equipment Layout Learning	0.0709	0.0111
		C26 Equipment Layout	0.1003	0.0908
		C27 Cab Environment on Occupant Attention	0.0417	0.0170
		C28 Dashboard Recognition and Reading Efficiency	0.2271	0.0017
		C29 Communicator Cognitive Efficiency	0.0891	0.0210
		C30 Error Operation Rate	0.1075	0.0840
		C31 Equipment Learning Efficiency	0.0941	0.0301
		C32 Device Cognitive Efficiency	0.5334	0.0158
B3 Overall style	0.6274	The C33 cab style is unified with the vehicle	0.2137	0.0173

		C34 cab style with character and beauty	0.0134	0.0151
		The C35 cab has a military equipment vibe	0.0105	0.0375

5 MILITARY SPECIAL VEHICLE CAB DESIGN PRINCIPLES

According to the construction of the evaluation index system, the cab of military special vehicles with certain characteristics and universality is analyzed and summarized from the three dimensions of effectiveness, efficiency and subjective satisfaction, and the following design principles are derived according to the ergonomic principle:

1) The total layout of the equipment: to ensure the human-computer interactivity of the equipment, under the condition of not blocking the operator's field of vision, so that the operator can comfortably and efficiently complete various tasks and obtain information in the effective operation area; the remaining space except for the layout of the equipment should be reasonably divided into storage space and reserved equipment expansion interfaces.

2) Cab internal equipment: dashboards and consoles can minimize the process of learning and memory for operators, and can operate and obtain information quickly, accurately and subconsciously in the process of task execution; the seat needs some elasticity, support and wrapping to ensure that the operator can cope with a variety of extreme environments under safe and comfortable conditions, and the size is modified according to the influencing factors when designing the size.

3) Overall style: to ensure that the interior design of the cab is consistent with the style of the overall vehicle, but with a certain degree of recognizability and military atmosphere; distinguish different functions of the equipment in the form of appearance or color, but pay attention to color matching to avoid confusion during operation; the selected material should consider physical factors such as strength and heat insulation to avoid psychological discomfort of the operator due to the material.

6 CONCLUSION

According to the characteristics analysis of the cab of military special vehicles, the analysis of user needs, the research and analysis of the task and task environment, the Delphi method, the analytic hierarchy method and other methods, a military special vehicle cab evaluation index system containing a target layer, 3 evaluation dimensions and 35 evaluation indicators is constructed, according to the index system, from the user's point of view, comprehensively and effectively evaluate the human-computer interaction level of military special vehicles, analyze and summarize the evaluation results, and summarize the cab design principles. To provide a useful reference for the optimal design of the cab of future military special vehicles, how to make the evaluation index more comprehensive and more scientific is also the goal of future research.

Acknowledgment. This study was funded by the Humanities and Social Sciences Program of the Ministry of Education in 2020. (20YJAZH092).

REFERENCES

[1] Zhou L, Qin Y.F, Sun H.m. (2016) Research on H-point design of cab seat of engineering vehicle[J]. Agricultural Equipment Technology, 42(04): 58-61.

[2] Ding C.F. (2018) Optimization analysis of cab structure of engineering vehicles based on ergonomics[J]. Mechanical Design and Manufacturing, (10): 176-179.

[3] Chen J.W. (2019) Optimal design of cab interior of heavy commercial truck based on blind zone experiment[D]. Jilin University.

[4] Ma Y.J. (2017) Design and optimization of heavy truck cab based on ergonomics[D]. Chang'an University.

[5] Zhang P. (2017) Research on cab design of electric logistics vehicle based on ergonomics[D]. Taiyuan University of Technology.

[6] Liu W, Li L.L, Fu G.Y. (2021) Research on Operational Command Software Interface Evaluation Index System Based on IPO Model[J]. Journal of China Electronics Research Institute, 16(10):1060-1066.

[7] Hu J.Q. (2017) Research on the optimal design of armored vehicle cab based on ergonomics[D]. Chang'an University.

[8] Qiao Y, Yu D.H. (2016) Research on interior design of military vehicles[J]. Journal of Ordnance Engineering, 37(S1): 152-158.

[9] Xu Z.M. (2019) Construction of Evaluation Index System for Mobile Libraries[J]. Journal of Sichuan Library, (05): 16-20.