Analysis of Influencing Factors on the Transportation of Military Equipment

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Abstract. This article analyses the necessity of the research on military equipment transportation. Starting with the basic requirements of the equipment transportation design, this paper clarifies the process of equipment transportation. On this basis, it analyzes the transportation influencing factors of equipment from 5 aspects, i.e. designs, production, packaging, loading/unloading, storage and transportation, and lays the foundation for further researches, such as equipment transportation assessment, etc.

Introduction

"Equipment transportation" was first defined by the U.S. military as "the inherent ability of equipment to be efficiently transported by existing or target transport tools in the modes of being towed, self-propelled or carried and by means of railway, highway, waterway and airway." [1] In GJB 5733-2006, it is defined as "the inherent ability of equipment to adapt to transportation" [2] Equipment transportation is also called "equipment transportability" [3] It refers to the equipment's suitability for transport. The higher the adaptability of equipment to the constraints of transportation, the easier it is to transport. The definition of "equipment transportation" [4,5] at home and abroad has one thing in common, that is, transportation is the inherent attribute and design attribute of the equipment. It is designed and manufactured, once the entire equipment is configured, its transportability is determined.

Research by the U.S. military shows that LCC (the Life Cycle Cost of the equipment equals to the sum of the costs incurred in the processes of project identification, design, development, testing, review, procurement, use, maintenance and decommissioning) mainly comes from the development stage, i.e. 85% of LCC of the equipment has been determined at the design stage, and 95% of the total cost has been locked down at the end of the development phase [6]. According to relevant statistical data, the freight rates for the over-limit equipment of Level 1, Level 2 and super level are 1.5 times, 2.0 times and 2.5 times of the normal freight rates respectively. In the light of these considerations, the analysis and research of equipment transportation must start with the development stage to avoid the economic loss and military loss caused by transportation difficulties and failure [7].

Modern warfare features suddenness, rapidity, stereoscopic property, time-efficiency, high expendability, wide combat area, and frequent changes in combat styles. Therefore, availability of rapid, efficient and accurate battlefield replenishment, military supplies reserves at the transition from peacetime to wartime and improvement of the transportation mobility of military equipment has become the key factors in the outcome of war [8].

Good transportation of equipment is the key factor affecting its strategic and tactical mobility. Without good transportation, its mobility can be simply neglected. No rapid deployment of equipment that is not easy to transport can be achieved, let alone the full play of its combat capabilities. It can be seen that the transportation of equipment system is closely related to the rapid mobility of combat troops [9].
To sum up, the improvement of equipment transportation has become one of the bottleneck problems in improving equipment operational effectiveness. To improve equipment transportation, the first issue is to analyze the transportation influencing factors. Since 85% of the equipment transportation performance is determined at the design stage, this paper starts with the basic requirements of the equipment transportation design, and clarifies the equipment transportation process. The transportation influencing factors are analyzed from six aspects, i.e. design, production, packaging, loading/unloading, storage, and transportation, so as to lay the foundation for further researches, such as equipment transportation assessment, etc.

**Basic Requirements for Equipment Transportation Design**

**Equipment Classification**

There are different classification methods for military equipment. From the perspective of transportation, it can be divided into 3 types, i.e. self-propelled or towed equipment, large equipment without traveling device, and equipment (including supplies) after packaging (or containerized)[7].

**Self-propelled or Towed Equipment.** The self-propelled or towed equipment with roll-on-roll-off conditions are normally loaded/unloaded via roll-on and roll-off. This kind of equipment mainly includes combat vehicles, such as tanks, IFVs, armored transport vehicle, all kinds of artillery, general and special vehicles for transportation, command, communication, reconnaissance, maintenance as well as various trailers, engineering machinery, etc. This kind of equipment is the main body of transportation research.

**Large equipment without traveling device.** The large equipment without travelling device (including the equipment with large dimensions which can neither be self-propelled/towed nor containerized, such as various types of naval guns, generating sets, and all kinds of cabins, reflectors, antenna, etc.) are mainly loaded/unloaded via hoisting. Because of its large dimension or weight, this kind of equipment may cause difficulties in loading/unloading and transportation; therefore, its transportation has to be considered.

**Equipment (including supplies) after packaging (or containerized).** The equipment (including supplies) after packaging (or containerized) often refers to equipment and supplies with smaller dimensions, supplies, firearms, ammunition, and instrument. This kind of equipment features great variety, complex characteristics and different shapes, so it is necessary to consider the transportation after packing or containerization.

**Basic Requirements for Equipment Transportation Design**

In general, the equipment should meet the requirements for transportation as a whole. If it is really necessary to split the over-limit equipment for transportation, the time and maintenance conditions required for the splitting and reassembly should be clearly defined.

The transportation design of the first and second types of equipment is generally required to meet the requirements for the corresponding transportation tools, transportation infrastructure, loading/unloading devices, and the technical conditions of the corresponding transportation environment. For the third type of equipment, the requirement for containerized transportation should be added to the above three.

The technical conditions for the corresponding transportation tools to be adapted include geometry, dimensions, mass, center of mass, stowage requirements, loading area and ground pressure, and fixing method.

The technical conditions for corresponding transportation infrastructure to be adapted include railways/road transportation limits, road conditions, platforms, terminals, and airport conditions, etc.

The conditions of the corresponding transportation environment to be adapted to include: mechanical environmental conditions, climate environmental conditions, active chemical material...
conditions, active mechanical material conditions, electromagnetic environmental conditions, etc. [10].

The technical conditions of the corresponding loading/unloading devices to be adapted mainly include the operation capacity of the cargo yard and port loading/unloading devices. Generally, it is not considered to use special auxiliary equipment for loading/unloading, the equipment itself should be equipped with special devices for lifting and fixing.

**Transportation Process of Equipment**

The equipment transportation process is composed of serial activities, i.e. packing, loading/unloading, transportation and storage associated with transportation [8], as shown in Figure 1 below.

Equipment packing refer to a series of activities, i.e. the selection of packing and transportation materials, the determination of protection level of packing, and set up of devices in terms of anti-slip, anti-shock and anti-collision in the packages according to the packing requirements specified in the design plan of equipment transportation.

Equipment loading/unloading activities refer to a series of analysis activities, i.e. equipment lifting environment, loading/unloading methods, determination of lifting position, lifting stacking height, and lifting speed, etc. according to the lifting requirements specified in the design requirements for equipment transportation.

Equipment transportation activities refer to the determination of the average transport speed and freight per kilometer under the specified mode of transportation according to the transportation requirements required by the design requirements for equipment transportation, as well as the attributes of transported objects, transportation modes, transportation routes, etc.

The storage activity of equipment refers to the determination of equipment storage time, storage location, warehouse security conditions, stacking and arrangement methods of stored materials, etc. according to the storage requirements based on the design requirements for equipment transportation.

**Analysis of Influencing Factors of Military Equipment Transportation**

In order to avoid the issues in terms of transportation difficulties or transportation failure after equipment production and distribution, it is necessary to fully analyze the influencing factors of equipment system transportation. This paper analyses the influencing factors of equipment transportation from six aspects, i.e. design, production, packing, loading/unloading, storage and transportation. [11-25].

**Influencing Factors in Terms of Design**

The influencing factors in terms of design mainly refer to the factors that affect the design characteristics of the equipment, including the design characters in terms of geometric, static load, dynamic load, loading reinforcement, environment, and conventional risk factors, as shown in Figure 2 below:

1) Geometric factors include shape, outline dimensions, position of center of gravity, etc. The shape of the equipment mainly affects its stowage fixing on the transportation tools and its stability at the time of operation; the outline dimensions mainly affect the facts, i.e. whether the transportation limits are exceeded, or the interior allowable dimensions/limits of the cargo of the transportation tools (compartments) are exceeded (for example, in aircraft transportation, certain emergency passages must be reserved; or whether the center of gravity affects the stability of loading fixing and operation (for example, when the gravity center height of the equipment exceeds 2 m above the rail surface in railway transportation, the speed limit must be limited).
Figure 1. Transportation Process of Equipment.
2) Static load factors include weight, ground pressure, etc. The weight of the equipment should be less than the rated load of the transportation tool; the ground pressure of the equipment depends on the allowable carrying capacity of the carrying area of the transportation tool.

3) Dynamic load factors include vibration, impact, dynamic stress, etc. Vibration is the main dynamic load in the transportation process, which is caused by a variety of vibration sources. Among them, the vibration of railway, highway and air transportation is mainly random vibration, while the vibration of general transport ship is mainly sinusoidal vibration (that of high-speed ship is random vibration), which is divided into transportation impact and loading/unloading impact. It is a complicated physical process, which will change the state of equipment aperiodically in a short period of time. The process is usually described by the time history of acceleration, velocity or displacement under impact. The equipment should be able to withstand these dynamic loads without being damaged during transportation.

4) The loading/unloading reinforcement factors include roll on and roll-off, hoisting, reinforcement, etc. The equipment should be adapted to the conditions of transportation tools and facilities at the time of roll-on and roll-off. In addition to the adaptation to the loading/unloading ability of the loading/unloading devices, the location, quantity and strength of the lifting points of the equipment itself shall be ensured not to damage the equipment. In addition, the safety of hoisting shall be guaranteed.

5) Environmental factors include the performance of equipment to withstand temperature, humidity, atmospheric pressure, electromagnetic interference and so on.

6) Risk factors include anti-static, anti-radiation, anti-vibration, and other properties of flammable and explosive materials during transportation.

In the process of transportation, the above factors often coexist and interact with each other, which will result in comprehensive impact. Therefore, overall consideration is necessary at the stage of the equipment development. The limits of various factors should be considered especially when it needs inter-modality.

**Influencing Factors in Terms of Production**

The influencing factors in terms of production mainly refer to the ones that affect the transportation of equipment in the production process, including six factors in terms of production preparation, production control, production supervision, quality control, analysis and improvement, and information management, as shown in Figure 3 below:
1) Production preparation includes manpower, raw materials, plant machinery, etc. Production preparation refers to the provisions of appropriate manpower and material resources, etc., thus to ensure the rationality of production and timely supply to the project.

2) Production controls include setting up control points, key process control, and special process control.

Production control is to ensure the normal operation of production, and to control the core process to ensure the normal production.

3) Production supervision includes process supervision, product supervision and customer supervision.

The design scheme of equipment production is judged and improved reasonably by means of the supervision of production the process, equipment quality and user feedback.

4) Quality control includes first piece inspection, batch management, and nonconforming product management. The quality of equipment is strictly controlled through quality control, and in this manner to ensure that the equipment transported to the destination is on specification, so as to avoid wasting too much manpower and material resources.

5) Analysis and improvement includes analysis, improvement and analysis improvement. Improve the product by analyzing the cause of the problem and the results of the improvements, in this manner to iterate the best solution.

6) Information management includes equipment coding and equipment database. Control the equipment by the operation of coding and establish database which contains the equipment data information, in this manner to track and record the whole life cycle of the equipment.

**Influencing Factors in Terms of Packing**

The analysis of the influencing factors of packing mainly refer the characteristics of packing design during equipment development, including packing preparation, packing control, packing supervision, packing design, packing quality and packing information management, as shown in Figure 4 below:
1) Packing preparation includes manpower, packing materials, plant machinery preparation, etc. As the most important transportation control method in transportation, the design of packing container must be focused on various conditions in equipment transportation, so that packing can protect the equipment in the true sense.

2) Packing control includes the design in terms of packing requirements, packing specifications, and packing process. Identify the matters to attention of the entire packing process through the design in terms of packing requirements, packing standard and packing process, and in this manner to achieve the rational control of the entire packing process.

3) Packing supervision includes supervisions in terms of packing quality, packing efficiency and packing process. Packing supervision is used to ensure the reasonable and orderly packing process, and improve packing efficiency and packing quality, thus to ensure the perfect implementation of the transportation process.

4) Packing design includes the design of methods for ex-warehouse, transfer and warehousing. The logistics of the entire equipment packing process becomes smooth and reasonable by means of reasonable packing design.

5) The packing quality includes the development of inspection plan and quality control plan, for example, what kind of sampling inspection should be adopted, and what defective packing rate should be controlled?

6) Information management includes equipment coding and equipment database. Realize precise control of the packing process of equipment by the operation of coding and establish database which contains the equipment data information, in this manner to track and record the life cycle of the equipment.

**Influencing Factors in Terms of Loading/Unloading**

The analysis of the influencing factors in loading/unloading mainly refers to the influence to the equipment transportation from the design of loading/unloading tools and loading/unloading methods, etc. considered during the development stage. It includes loading/unloading preparation, loading/unloading control, loading/unloading supervision, loading/unloading inspection and loading/unloading information management, as shown in Figure 5 below:

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**Figure 5.** Influencing factors in terms of loading/unloading.

1) Loading/unloading preparation includes manpower, packing equipment, plant machinery preparation, etc. Loading and unloading preparation provides the commencement of loading/unloading activities with necessary manpower and material resources to ensure the safe and reasonable accomplishment of the entire loading/unloading process.

2) Loading/unloading control includes the design in terms of loading/unloading requirements, loading/unloading specifications, and loading/unloading process. Make good the matters needing attention in the entire loading/unloading process through loading/unloading control, thus to achieve the reasonable control of the entire loading/unloading process.
3) Loading/unloading supervision includes supervisions in terms of loading/unloading quality, loading/unloading efficiency and loading/unloading process. Loading/unloading supervision is used to ensure the reasonable and orderly loading/unloading process, and improve loading/unloading efficiency as well as loading/unloading quality, thus to ensure the perfect implementation of the transportation process.

4) Loading/unloading design includes the design in terms of loading/unloading methods, arrangement methods and stacking height. The design of loading/unloading is used to ensure the safe and reasonable stacking of the equipment during the loading/unloading process.

5) The loading/unloading quality includes the development of inspection plan and quality control plan. For example, what kind of sampling method is used to check, whether the stacking height meets the requirements or whether the arrangement of the equipment on the transportation tools meets the requirements.

6) Information management includes equipment information and loading/unloading database. Realize precise control of the loading/unloading process of equipment by the operation of equipment coding and establish database which contains the equipment data information, in this manner to track and record the life cycle of the equipment.

Influencing Factors in Terms of Storage

The analysis of influencing factors of storage mainly refers to the improvement of equipment transportation design through the analysis of equipment storage preparation, storage control, storage supervision, storage environment, inspection and maintenance, information management, etc., thus to achieve the goal of efficient transportation. The influencing factors in terms of storage are shown in Figure 6 below:

1) Storage preparation includes the preparation in terms of manpower, arrangement methods, plant machinery, etc. Storage preparation refers to the provision of appropriate manpower/materials, plant and well-designed arrangement methods, thus to ensure the reasonable storage, with which to achieve reasonable inventory to the project.

2) Storage controls include setting up control points, key process control, and special process control. Storage control is to ensure the normal operation of storage, and to control the core process to ensure the normal storage.

3) Storage supervision includes equipment supervision, manual supervision and other supervision methods. Equipment supervision (such as CCTV, etc.), manual supervision (such as appropriate arrangements of patrol), and other supervisions (such as the use of police dogs, etc.) can be utilized during the storage process to ensure the safety of storage of the equipment.

4) Environmental control includes storage temperature, humidity, stress, and other conditions. The appropriate storage environment can be guaranteed through well-controlled environment.
5) The inspection and maintenance includes the inspection plan and maintenance plan. Corresponding preventive maintenance plans are developed according to the characteristics of the equipment, thus to ensure the reliability of equipment transportation.

6) Information management includes storage information database and entry/exit information of the equipment. Realize precise control of the equipment storage information by the operation of equipment coding and establish database which contains the equipment storage data information, e.g. ex-warehouse/warehousing, etc., in this manner to track and record the life cycle of the equipment.

**Influencing Factors in Terms of Transportation**

The analysis of the influencing factors in terms of transportation is used to analyze the impact to the equipment transportation from the perspective of transportation tools, which mainly includes six aspects, i.e. transportation preparation, transportation control, transportation supervision, transportation process, transportation of transfer and information management, as shown in Figure 7 below:

![Figure 7. Influencing factors in terms of transportation.](image-url)

1) Transportation preparation includes transportation analysis, determination of transportation tools, and identification of preparation for transportation. Transportation analysis refers to the analysis of some of the constraints of transportation, which will be used to determine the transportation tools and transportation preparations.

2) Transportation control includes transportation safety control, maintenance and inspection control, as well as time-effectiveness control of transportation. Transportation safety control refers to the control of the safety in terms of vehicle operation and the cargo. Maintenance and inspection control refers to the design of the maintenance and inspection plan for vehicles, which will ensure that vehicles are always in good working condition.

3) Transportation supervision includes product safety supervision, transportation time supervision, and supervision to other aspects. Product safety supervision refers to the appropriate arrangement of personnel, which will be used to control the products on the transportation tools and to prevent accidents such as losses, etc. The control of transportation time means that the transportation time should be well controlled, thus to facilitate the handover and management of cargo. Supervisions to other aspects are only available to special requirements.

4) Transportation process includes the design of methods for ex-warehouse, transfer and warehousing. This section links the entire transportation process, and accomplishes the entire transportation ranging from the start point to the end point.

5) Transfer transportation includes the development of transfer plans and transfer strategy. During the process of equipment transportation, it is difficult to transport the equipment directly to the main transportation tools, instead, in normal cases; the equipment will be transferred to the main transportation tools.
6) Information management includes equipment information database and transportation information database. The control of equipment information and transportation vehicle information are used to achieve the control of the entire equipment transportation process.

Conclusion
The issue of equipment transportation originated from the combat practice of the US military during the Second World War. Over the past decades, the United States has conducted systematic research on transportation-related theories, requirements, design, technology, testing, assessment, management, etc. Eventually, they have developed a set of relatively perfect standard system and legal system. Although the importance of equipment transportation has been noticed in China, and relative researches on equipment transportation has been implemented with some achievements, but it is still in the stage of development and research. We still see certain gaps between us and foreign countries. This article starts with the basic transport requirements in the equipment design phase, analyzes the transportation influencing factors in the equipment design, production, packaging, loading and unloading, storage and transportation, and hopes to provide a reference for related scholars to carry out research on the contents of equipment transport related content. Significance.

Starting with the basic requirements of transportation in the equipment design stage, this paper analyzes the influencing factors of transportation in the process of equipment design, production, packing, loading/unloading, storage, transportation, etc. We hope to provide some references for the relevant scholars to carry out the research of equipment transportation and related projects.

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References


[12] GJB 1181-1991, Packaging, handling, storage, and transportability program requirements (for systems and equipment) [S].


[14] GJB 2683-1996, Item characteristics affecting transportability and packaging and handling equipment design [S].


[17] GJB 145A-1993, Specification of preservation packaging that specifies the protective packing methods, material selection and quality assurance for military products and spare parts [S].

[18] GJB 2818-1997, Quality of wood members for package of military [S].


[23] GJB 5733-2006, Basic requirements of transportability for military equipment [S].

[24] GJB 5689-2006, General requirements for lifting and tiedown provisions of military equipment [S].