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# Product Requirement Information Modeling for the Life Cycle of the Port Hoisting Equipment

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**Abstract**

Port hoisting equipment is associated with numerous salient characteristics like loads variation, complicated product composition and higher safety and reliability requirements. In addition to it, requirements of multiple standards are needed to be met during the entire product life cycle. There is a need of clear and thorough definition of requirements vis-à-vis design of port hoisting equipment, and at each life cycle stage, development activities are to be carried out. This paper discusses the classification of the requirement information of the hoisting equipment and defines the requirement features as well. This study also establishes requirement information model for port hoisting equipment by SysML and elaborates the requirement information within relationship by means of an example.


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*Keywords:* Port hoisting equipment; life cycle; product requirement; information modeling

## 1. Introduction

Port hoisting equipment is a mechanism that moves vertically and horizontally within a certain range. It is often used in loading and unloading operations of bulk cargo or container at port [1]. It is subjected to various loads, including lifting load, weight load, etc. It has complex product composition including operating mechanism, steel structure, power unit and a control system. The requirements for safety and reliability are also very stringent i.e. it has to meet requirements of many standards, such as, design, test and electrical specification, and so on. At each stage of life cycle including design, manufacturing, assembly, sales, transportation, operation and maintenance many unique requirements are put forward. From the perspective of life cycle of the port hoisting equipment, defining a complete and clear requirement information and its relationship and establishing the requirement information model have an important influence on realization of the design. Moreover, it has also a strong influence upon the product development.

Dadfarnia analyzes a product requirement with the system engineering theory, which realizes the design of an ambulance patient compartment driven by requirement model [2]. Subhan discusses the important role of requirement analysis in software system development life cycle, and proposes a new software development method [3]. Baudry discusses the method of requirement analysis driven by model [4] and Chehida makes a security requirement analysis for network applications by UML(Unified Modeling Language) [5]. Also, Cao discusses the method of requirement modeling about the complex products of small batch or single-piece [6]. At home and abroad, the requirement analysis has been launched in many fields, but it has less been involved in the port hoisting equipment.

Systems Modeling Language (SysML) is a standard modeling language for system engineering, which can realize the requirement analysis, system design, function description, system verification etc. of engineering application system.


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Gotoh establishes the equipment model of an intelligent ceiling crane by SysML, which realizes the design driven by requirement model [7]. Karwowski establishes the model of knowledge management system by SysML [8] and Zeng establishes the overall design system of a satellite by SysML, which realizes the overall design of satellite driven by model [9].

This paper studies the construction of requirement information model from the perspective of life cycle process of the port hoisting equipment, analyses the diversified requirement of the port hoisting equipment, defines the feature and property of the requirement information associated with the life cycle process of the port hoisting equipment, and describes the relevant requirement information and its relationship by SysML.

## 2. Product requirement information associated with life cycle

Product requirement information is diverse, most of which is function related, structure related, standard related, execution process related and capability related. When there is more complex product, there should be higher requirement information. Furthermore, the requirement information is not independent; it usually interacts with each other and forms a network of requirement information. For instance, ambient temperature and relative humidity included in the requirement information of the port hoisting equipment, directly affects the selection of the material. While, as soon as the material is finalized, its density affects the weight of the product. Working speed, working range and lifting height makes an impact on the determination of the speed control scheme and logic control scheme of the port hoisting equipment.

Traditionally, requirement information is described by means of document, specification and data table, however, the connections among requirement information are hidden in the information, which makes it difficult for the designer to grasp it quickly. The traditional expression of requirement is limited to the information provided by the user only. But in such a case, flowing downstream stage of life cycle, some major requirements are often difficult to express. For example, the weight and size of assembly parts associated with transportation stage of the port hoisting equipment life cycle are the key requirement parameters, however they are usually delivered among the designers by experience merely, which makes the organization and transmission of the information lack of standardization and makes it easy to cause requirement information missing, so that it eventually affect the design quality. Because of the complex requirement information, a reasonable and standardized classification can make a contribution to a clear expression of the requirement information and its relationship.

In order to have a better organization, requirement information can be organized from the perspective of product life cycle stage, which can not only comprehensively define the requirement information, but also clearly express the corresponding relationships which are the design essentials between life cycle stage and requirement information. Therefore, the designer could understand the design essentials before product design, and several problems are solved at the early stage of product development cycle, which ensures the design quality and avoids much rework or waste. Table 1 presents the requirement information associated with port hoisting equipment life cycle and each one of which should be considered in the development process of port hoisting equipment.

Table 1. Main requirement information associated with stages of port hoisting equipment life cycle.

| Life cycle stage | Main requirement information |
|---|---|
| Design stage | Capability, life in service, target product cost, geometric size, aesthetics/appearance, ergonomics, standards, and quality and reliability, etc. |
| Manufacturing stage | Material type, material properties, working space, wrench space, etc. |
| Assembly stage | Component location reference, the size of purchased parts, lifting point position, etc. |
| Sales stage | User funds, delivery period, etc. |
| Transportation stage | The weight of assembly parts, the size of assembly parts, etc. |
| Operation and maintenance stage | Relative humidity, ambient<br>Temperature, wind speed, etc. |

As shown in Table 1, the requirement information listed in the design phase, related to capability, structure and standards, is the baseline for design and is also the basic requirement information. Normally, among the requirements provided by the user, the ones related to material type and man-machine engineering, such as working space, wrench space, etc., which are not only converted into the information of the structure size and design parameters associated with design stage, but also considered as the requirement factors which should be taken into account for manufacturing process decision, affecting product manufacturing process.

Component location reference, the size of purchased parts and lifting-point position play an important role in equipment assembly stage, for example, an in-appropriate location reference may make it difficult to guarantee the coaxial degree of connectors which are axis related, which makes it hard for the connectors to turn. There is a direct constraint between product cost and requirement information such as user funds and supply period, and this constraint affects designer's selection decision. The weight and the size of assembly parts directly affects the transportation of the product, because, excessive weight or size may lead infeasible transportation. The information of ambient temperature, relative humidity, wind speed, is also the basic requirement information provided by the user, which limits the operating environment of the product, so it is classified as the requirement information associated with operation and maintenance stage.

Different product requirement information is related to each other. For example, relative humidity, ambient temperature and wind speed, has a direct impact on the selection of material type, however, material type and associated properties indirectly affect the weight of components. Moreover, the information of process and

experience can be acquired when the requirement information is utilized in the period of research and development, and it could be considered as a new requirement information which can benefit product design for the next time. The design quality, accordingly, can be improved continuously. For instance, because of an in-appropriate wrench space, the bolt connection may not be achieved, which can make the connection of the parts unreliable and as a result, product operation safety cannot be guaranteed properly. This experience, being the basis for adjusting the wrench space, and can be regard as a requirement information applied to product design for the next time.

## 3. Requirement feature definition of port hoisting equipment

In order to have a more comprehensive expression of requirement information and its relationship, a standardized and normalized method is required to describe and organize requirement information and its relationship. The method of feature information modelling which is based on the definition of requirement feature, can be applied to describe the requirement information, which is a key idea to solve this problem.

The definition of requirement feature depends upon the requirement information associated with the port hoisting equipment life cycle and the requirement information has been arranged in Table1. The main requirement features associated with several stages of the port hoisting equipment life cycle are listed in Table 2.

Table 2. Main requirement features associated with several stages of port hoisting equipment life cycle.

| Life cycle stage | Feature | Definition | Property |
|---|---|---|---|
| Design stage[10] | Capability/Performance requirement | Description of the desired product performance achievement | Lifting weight: Max lifting weight |
| | | | Working speed: speed of working mechanism |
| | | | Working range: Max / Min working range |
| | | | Lifting height: up rail / under rail lifting height |
| | Electrical and electronic control requirement | Description of the requirement for electrical or logical control related indicator | Electrical system: voltage, phase number, frequency |
| | | | Speed control scheme: name, version number |
| | | | Logic control scheme: name, version number |
| | Life in service/disposal | Description of how long the product is in service | Service pattern, and environmental impacts after disposal. |
| | Target product cost | Establishment of whole-life costing | |
| | Size/Weight | Description of the product size and weight | Geometric dimensions and overall weight |
| | Aesthetics/Appearance | Description on the product appearance | Color, shape, form and texture, etc. |
| | Ergonomics | Description on man-machine interfaces | Height, reach, operating forces/torques, etc. |
| | Quality and Reliability | Quality and reliability requirements on product success | Procedures or standards for quality management in product development |
| | Design basis requirement | Description of the conformed design standards and specifications | Design standard: name, national standard |
| Manufacturing stage | Material requirement | Description of product material requirement | Material type: name, national standard |
| | | | Material property: yield strength, density, etc. |
| | Space requirement | Description of the relationship between product structure space and human | Working space: body size, hand working area size |
| | | | Wrench space: bolt size |
| Assembly stage | Location requirement | Description of the requirement for location of component | Component location reference: coordinate of component location reference |
| | Purchased parts requirement | Description of purchased parts related information | Size of purchased parts: dimension of purchased parts |
| | Lifting requirement | Description of the information about the lifting parts. | Lifting point position: lifting point coordinate |
| Operation and maintenance stage | Environment requirement | Description of product working environment | Ambient temperature: Max / Min temperature |
| | | | Wind speed: I, II, III wind speed |
| | | | Relative humidity: ambient humidity |

## 4. Description of the requirement information for port hoisting equipment based on SysML

Requirement information of the port hoisting equipment, which has a wide coverage and interaction with each other, could be considered as a complex system. Using the system engineering theory, this paper proposes to express the requirement information and its relationship of the port hoisting equipment by SysML, depending on the requirement

features which have been successfully defined. SysML could effectively describe complex system in detail.

### *4.1. SysML introduction*

SysML, used in the field of system engineering, makes it possible for complex system to be described, analyzed, designed, verified and confirmed in detail. In order to describe the feature of a model, SysML totally provides 9 basic diagrams which are divided into 4 categories, such as structure diagram, parameter diagram, behaviour diagram and requirement diagram. As a new SysML diagram, requirement diagram is mainly applied to describe requirement model, and it can describe requirement and its relationship [11].

Class is applied to define requirement by requirement diagram provided by SysML, and it has 2 properties, which are "text" and "id". "text" is the description of the requirement and "id" is the identifier of the requirement. SysML inherits the relationships of class diagram from UML2.0. In order to have an abundant expression of the relationships, the requirement diagram defines five more relationships of requirement, such as hierarchical relationship, derived relationship, satisfied relationship, verified relationship and refined relationship.

### *4.2. Expression of the relationship for requirement information based on SysML*

SysML defines requirement as the ability or condition which a system should have. One requirement can have several sub requirements. Each feature listed in Table 2 can be considered as an independent requirement, and each property of a feature can be considered as its sub-requirement, meanwhile the sub-requirement is extensible. Each requirement is uniquely identified by the "id" provided by the requirement diagram of SysML, and is described by the "text" provided by the requirement diagram of SysML. Each sub-requirement is necessary for its corresponding requirement, so the relationship between them is defined as "combination". Then, capability requirement associated with design stage is confirmed. As shown in Fig.1.

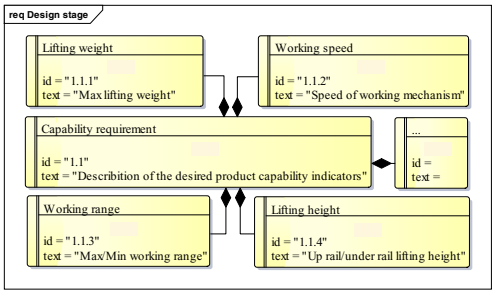


Fig. 1. Capability requirement associated with the design stage diagram.

After all the requirements and sub requirements are defined, they should be packaged, depending upon the stage of product life cycle they are associated. The relationship between different requirements is defined as "derive" which is provided by requirement diagram of SysML. For example, the determination of the component location reference depends on the design specification, i.e. there is a derived relationship between location requirement in the assembly stage and design basis requirement in design stage. Space requirement information limits the space which people need to work in, which in turn limits the component size of the hoisting equipment. A derived relationship also exists between size requirement in transportation stage and Space requirement in manufacturing stage, etc. The derived relationship can be expressed by dotted line with direction provided by SysML in the diagram. Other requirements which have "derive" relationships are also expressed in a similar fashion. Hence, the requirement information model associated with the port hoisting equipment life cycle, is successfully established. As shown in Fig. 2.

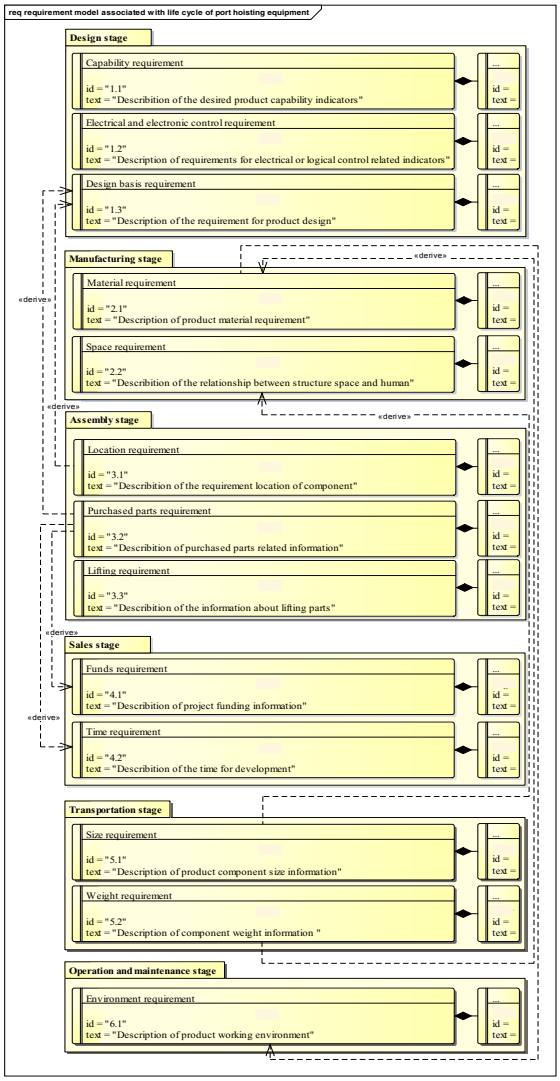


Fig. 2. Requirement model associated with the port hoisting equipment life cycle diagram.

## 5. Case analysis

Portal Crane is a typical product of port hoisting equipment. This paper takes a certain portal crane as an example. Established by SysML, a requirement model associated with product life cycle is applied to instantiate the certain portal crane. Its capability requirement information diagram associated with design stage is shown in Fig.3, The requirements associated with other stages which should be detailed are omitted in this paper.

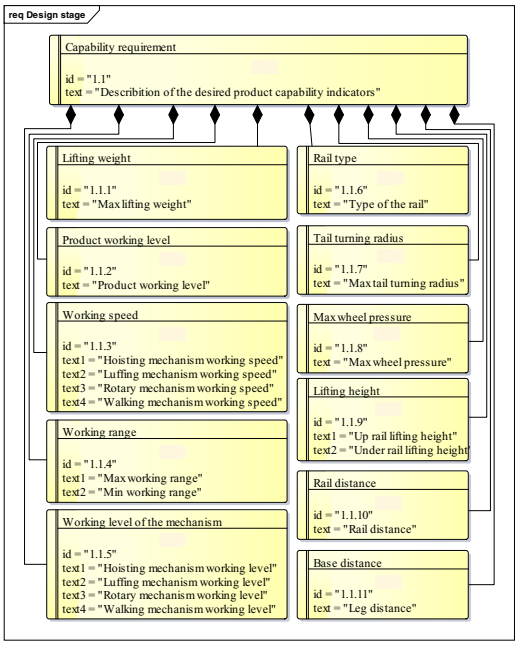


Fig. 3. Capability requirement associated with the design stage of a portal crane diagram.

As shown in Fig.3, depending upon the requirement information model, the expression about the capability requirement of the portal crane is semiformal, which is advantageous to express the information more clearly. For example, each requirement information is uniquely numbered by “id”, which helps easy retrieval of information, and thus facilitates a better management. The requirement information is described by “text”, which create a better understanding for the engineers, and can also lay a foundation for the transformation to function parameters. The relationship between sub-requirement and capability requirement is defined as “combination” provided by SysML, and its graphical expression is given by the solid line with arrow. Consequently, the relationship among the information becomes intuitive and unambiguous, which is not only helping to improve the consistency of the understanding of the same information relationship between different designers, but also helps to improve the design efficiency and the development work of the product.

In addition to this, thanks to the requirement information model for the lifecycle of port hoisting equipment, there is a complete and consistent framework for the development of its requirement information system in future and the integration of the development is eventually guaranteed. Requirement information is packaged by the stage of the lifecycle in the model, which improves its reusability, and avoids repetitive development of the same type of modules in the development of the requirement information system.

## 6. Conclusion

This paper, taking the port hoisting equipment as the object, defines the requirement information associated with product life cycle. By using the theory of system engineering and modelling language SysML, the requirement information and its relationship of the port hoisting equipment is described. A complete and explicit expression of the requirement information and its relationship, makes a good contribution to make a high-quality design task, and it helps the designer to have a better understand of the key design points, at the early period of the product design, which improves the quality of product design.

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