Hierarchical structure of the electronic information model of a ship

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Abstract. This article focuses on approaches based on shipbuilding simulation such as digital shipbuilding, Simulation Based Design (SBD), and virtual shipyard. The article deals with the main aspects of methodology of selecting the type of the hierarchical structure of the Electronic Information Model of a Ship (EIMS). The selection of a particular representation of the EIM structure is ambiguous: on the one hand, the model structure must include the most general elements of the object (ship) hierarchy, encompassing all stages of the lifecycle; on the other hand, as shown above, hierarchical elements of each stage are specific. General principles of structuring EIMS are considered, and influence of essential criteria of EIMS use at different stages of the ship lifecycle is analyzed. The most optimal hierarchical structure of EMIS is selected using the expert estimation method (chosen by investigation), which is based on a combined approach of the analytic hierarchy process introduced by T. Saaty. The expert analysis indicates importance of selection of EIMC structure type prior to initiation of implementing the lifecycle of a particular ship, provided that PLM systems are used.

1. Introduction

The Electronic Information Model of a Ship (the information model, the data-centric electronic model) (EIMS) is a model of a ship represented in terms of information. The information describes parameters and values essential for the object under consideration, relations between those, inputs and outputs of the object. It also enables to model possible object states by submitting into the model the updated information on input values. The information model (in a broader, general scientific sense) is a collection of information characterizing essential properties and states of the object, process, or phenomenon, and their interrelation with the outside world.

Unlike the structure of machine-building industry products, construction industry products and products of some other industries, the structure of shipbuilding industry products must be represented uniquely at different stages of the product lifecycle. Differences in the product structure are obvious and determined by the nature of the work carried out by design entities, shipbuilding entities, ship repairing entities, operating entities, as well as by ship modernization entities and ship dismantling entities. For instance, at the construction stage, the main shipbuilding product hierarchical structure elements are construction site, unit, section, sub-section, rooms, equipment, systems, and so on [1].

From the point of view of an operating entity, the hierarchical elements such as hull, compartment, superstructure, superstructure tier, deck, rooms are of interest. In addition, the model representation for the operating entity must include some part of information needed for operation which is to be introduced at the design and construction stage. Above all, such information may include room
arrangement drawings and system arrangement drawings, operational documentation for particular systems, equipment pieces, elements thereof, as developed by design entities, construction entities or by suppliers and manufacturers of equipment, systems and elements thereof. Data associated with logistical support of the ship in general, ship systems, equipment, with the possibility of not merely getting information of the required ship’s supply elements but also planning to order those elements followed by the order itself, are an important information block, the lack of which would make the operation model incomplete.

However, from a repairing yard’s point of view, a completely different shipbuilding product’s hierarchy representation is of interest. That representation should deal with not only specific objects, but with the availability of the required information to be developed and put into the single information model at design, construction and operation stages.

For ship dismantling, the hierarchy representation of the ship may differ from the above mentioned ones. In that case, the hierarchy representation is predominantly governed by the nature of the work carried out by the ship dismantling entity.

The selection of a particular representation of EIMC structure is ambiguous. On the one hand, the model structure must include the most general elements of the object (ship) hierarchy, encompassing all stages of the lifecycle. On the other hand, as shown above, hierarchical elements of each stage are specific. The existing approach is reduced to the development of a comprehensive branching structure of EIMC (the typical hierarchical structure is shown in Figure 1). In the model of that kind, each stage of the lifecycle is represented with an individual set of hierarchical elements with data relevant to the stage [2].

![Figure 1. The hierarchy of EIMC at lifecycle’s stage](image)

2. A basic concept of the development of the information model
In developing the information model of shipbuilding products throughout their lifecycle, a concept, which can be expressed by the items, listed below, must be developed.

- Throughout the lifecycle, the information model of the product can be represented
simultaneously in different hierarchical structures, which are of interest at a particular stage of the product lifecycle.  
- The information model must contain ALL information of the product and ALL information of the elements of the hierarchical representation THROUGHOUT the lifecycle of the product.  
- The information model must offer the possibility of representing the sample of information required for entities working at different stages of the lifecycle.

The required information samples to be provided to various entities at different stages of the lifecycle must be extracted from a single database upon connecting to that. As an alternative, those information samples must be transferred via export/import mechanisms into entities’ databases. The possibility of further synchronization aimed at providing the entities with the information up-to-the-moment of calling the databases must be ensured.

The information model development and data replenishment seem to be feasible to perform starting from the design stage with further data replenishment during the construction, operation, modernization, and so on. Only then the Electronic Information Model of the Ship (EIMS) will be complete, and the representation of the required information sample for further stages of the product lifecycle will be easily implemented and cost neutral.

A subject - the owner of the information model - is required. The subject is responsible for information updating in case of information replenishing or changing throughout the lifecycle of the product. The model owner can be the manufacturing yard, the principal customer, whichever is applicable (generally, the customer is the model owner).

3. **The hierarchical structure of EIMC**

In EIMS databases, data are kept as tree-structured. The elements are interrelated as Parent-Descendant and in other ways intrinsic to a tree structure. The hierarchy of elements in the tree is illustrated in Figure 2.

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**Figure 2. The hierarchy of elements**
Common hierarchy levels are:

- **PROJECT.** Upon establishing a database, the only element it contains is Project. Each database has an individual project element as the first element of the hierarchy.
- **SITE.** The second hierarchy level arranged just below the level of Project is Site. Site may be regarded as an administrative level allowing logically structure project elements, for example, the entire project or a part of a large project. A set of sites can be established for organizing data in the project.
- **ZONE.** Zone is the level arranged just below the level of Site. Also, Zone is not necessarily used to determine a real area. It is more relevant to use zones to combine similar data for facilitating work, for example, split into zones by disciplines within the same Site.

The level of Site and the level of Zone are included into the project regardless of the discipline in which the expert is performing the work. Those levels are obligatory in the project.

The following alternative representations of the level of Site are possible:

- structural-and-technological representation;
- functional purpose representation;
- architectural-and-planning representation;
- assemblies representation.

In the Structural-and-technological representation of the hierarchical structure levels, the following elements take on the role of sites:

- shipbuilding site;
- equipment modules;
- systems.

In the Functional representation of the hierarchical structure levels, the following disciplines take on the role of sites:

- hull;
- hull fittings;
- arrangements;
- power plant;
- ship systems;
- electrical equipment;
- automation, control, communication;
- navigation;
- special arrangements;
- rigging.

In the Architectual-and-planning representation of the hierarchical structure levels, the following elements take on the role of sites:

- compartment;
- room;
- open space.

In the Assemblies representation of the hierarchical structure levels, the role of assemblies is generally taken on by the completed functional unit. That unit incorporates both hull steelwork and comprehensive outfitting with equipment.

4. **Methodological approach to settling an issue of selecting hierarchical structure of EIMC**

In selecting EIMC structure, the issue can be settled in the following sequence:

- establishment of a set of alternatives;
- determination of the main requirements enabling development of the methodology for further estimation;
• development of the methodology enabling estimation of alternatives;
• determination or appointment of the expert group;
• estimation of alternatives;
• analysis of the results obtained.

5. Criteria built into the methodology
Criteria, against which the numeric variation within the specified ranges will be determined, are as follows:

The Adequacy criterion: the alternatives selected by the expert estimation are ranked from the worst alternative to the best one. The ranking is carried out in terms of formal consistency of the digital model objects description with the actual objects onboard the ship. Estimation of ambiguous interpretation is performed.

The Description Completeness criterion: the alternatives selected are ranked from the worst alternative to the best one. The ranking is carried out in terms of their capability to provide the most comprehensive description of EIMC elements.

The Usage criterion: the alternatives selected are ranked in terms of demand of individual EIMC sites at different stages of the ship lifecycle.

The Data integrity criterion: An approximate evaluation of the probability of data loss in transfer from one lifecycle stage to another is performed. The score of 10 is assigned to the relatively most reliable structure.

The Abstraction complexity criterion: the alternatives selected by the expert judgement are ranked from the worst alternative to the best one. The ranking is carried out in terms of understanding of the purpose of individual sites.

The most important criterion of concept adaption is the quantity which can be obtained by theoretical computations with a reasonable accuracy. Naturally occurring errors due to the lack of consideration of the entire set of included components might take place. Still, the uniformity of determination of estimation “cost” regardless of the alternatives allows the performance of ranking.

6. Methodology of estimating alternatives
Consideration of different methods of estimating multiple-criteria systems indicates that expert estimation methods are the most suitable to solve such tasks. The reason for this is that the input data are generally restricted at the decision making stage. In addition, there is a limited number of systems of this kind worldwide, and therefore there are no collected historical data either. The expert estimation method allows estimating alternatives not only against quantitative criteria, but also take their qualitative features into account. The most suitable approach is the combined approach based on usage of the analytic hierarchy process (AHP) introduced by T. Saaty. That method is used at step one to justify ranking by the degree of importance. It is also applied to determine their corresponding specific contributions into the estimate. The popularity of that method being used worldwide, Russia included, for decision making in the technical field, instills confidence in its high reliability.

AHP is a closed logic structure enabling, by means of simple rules and mathematical computations, to analyze complicated systems in their variety to obtain a reasonable solution [3], [4].

With regard to the issue of selecting the best alternative, the principal problem lies in selection of the alternative which will meet the specified requirements closest of all (see section 5). It should be noted that selection of experts to participate in estimating alternatives shall meet the specified requirements while taking into account their expertise.
Table 1. Determination of criterion weights

| Adequacy | Description completeness | Usage | Data integrity | Abstraction complexity | Row sum | Criterion weight |
|----------|--------------------------|-------|----------------|------------------------|---------|-----------------|
| Adequacy | 1                        | 4     | 6              | 8                      | 10      | 29              | 0.590            |
| Description completeness | 0.25                  | 1.00  | 1.50           | 2.00                   | 2.50    | 7.25            | 0.148            |
| Usage    | 0.17                     | 0.67  | 1.00           | 1.33                   | 1.67    | 4.84            | 0.099            |
| Data integrity | 0.13                  | 2.00  | 0.75           | 1.00                   | 1.25    | 5.13            | 0.104            |
| Abstraction complexity | 0.10                  | 0.40  | 0.60           | 0.80                   | 1.00    | 2.90            | 0.059            |
| **Column sum** |                     |       | 49.12          |                        | 1.00    |                 |                 |

Table 2. Folding. Determination of the best alternative.

| Adequacy | Description completeness | Usage | Data integrity | Abstraction complexity | Sum |
|----------|--------------------------|-------|----------------|------------------------|-----|
| Structural-and-technological | 5.55                   | 10.00 | 8.10           | 8.11                   | 6.41 | 6.78            |
| Functional purpose | 8.04                   | 10.00 | 5.00           | 3.15                   | 10.00 | 7.64            |
| Architectural-and-planning | 9.33                   | 9.00  | 10.00          | 7.66                   | 10.00 | 9.21            |
| Assemblies | 7.23                   | 10.00 | 4.25           | 9.84                   | 3.09  | 7.37            |

The tabular data indicate the following. The total estimates of the Architectural-and-planning alternative are the most promising from the point of view of using a similar schematic of the hierarchical structure of EIMC throughout the lifecycle of the ship.

7. Conclusion
The performed analysis shows importance of selection of the EIMC structure type prior to initiation of implementing the lifecycle of a particular ship, provided that PLM systems are used. Using the expert estimation method, the authors found out the following. The best alternative is the one corresponding to representation of EIMC structure throughout the lifecycle as a conjunction of ship rooms and compartments.

On the other hand, it should be noted that in case of expert estimations against different criteria or in case of a different ranking of the criteria proposed, the obtained result would be different.

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