UDC 004.94

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ASSET INFORMATION MODEL REQUIREMENTS FOR INDUSTRIAL FACILITY

An Asset Information Model (AIM) is increasingly being developed to manage an industrial facility efficiently and safely. Despite many studies and current regulatory documentation, the topical issue is creating the AIM industrial facility requirements. Given the complexity and intensity of processes at an industrial facility's operation stage, the requirements development for AIM creating is an urgent issue. This article is focused on the study of requirements, including three general components: level of development (LOD), level of information (LOI) and level of accuracy (LOA) of model elements. In the research, the key components that should be contained in AIM have been identified, and the LOD and LOI requirements are developed based on research. A new level LOD 550 is introduced to solve deformation monitoring problems. The LOA specification for AIM elements and requirements for the accuracy of determining the spatial position of elements is developed. Lastly, the requirements for laser scanning and modeling objects accuracy are formulated. This study provides insight into a general idea of the AIM requirements and helps developers and users create AIM for solving operation tasks based on this information.

Keywords: *Asset Information model of industry, facility management, level of development, level of information, level of accuracy, requirements, terrestrial laser scanning*
DOI: *10.17580/em.2023.02.23*

Introduction

An industrial enterprise is a complex technological facility with many processes and production tasks. For the efficient and safe management of an industrial facility, modern information technologies are increasingly being used, one of which is Building Information Modeling (BIM). Initially, BIM technology was used only for civilian buildings and construction and for the design and construction stages [1, 2]. Subsequently, BIM technology began to be used for industrial facility [3–5] and at all life cycle stages, including the operation stage [6]. It should also be noted that there is a generally accepted definition for BIM at the operational stage—Asset Information Model (AIM) [7].

AIM of an industrial facility is an information technology-based approach that involves collecting, processing and storing all design, engineering, construction, technological, economic and other information about a site with all its relationships and dependencies of one element on another. AIM technology assumes that objects and everything related are considered as a single object. At the same time, AIM is not just a three-dimensional model (3D model) of an industrial facility. It is a tool that allows extracting, updating, or changing information about the model elements and provides interaction between different production departments.

The creation and updating of AIM are usually carried out gradually from stage to stage of the industrial facility life cycle [5]. For various life cycle stages, AIM updates information about each model element, including the level of development [8–12], level of information, and the level of accuracy [13]. The generally accepted definitions for the detail levels are presented in **Fig. 1**.

It is important to note that LOD, LOI and LOA described detail levels not for the entire 3D model but only for its elements, depending on the tasks being solved. Accordingly, when creating AIM, a balance of LOD, LOI and LOA is needed because, for different tasks, an optimal ratio of these parameters is required.

The creation and application of AIM are widely covered in scientific research. Thus, many studies aim to solve the problem of introducing AIM into the production process, organizing distributed access to AIM [8, 14] and further asset management of the object [8, 15, 16]. In studies [5, 17, 18], the results of using AIM to solve applied tasks at managing various objects are presented in detail. Another large cluster of studies is devoted to collecting information for the subsequent creation of AIM [2, 19–21]. The articles [8, 9, 11, 13] highlight the requirements for the detail levels of AIM depending on the object type and the life cycle stage.

The regulations also cover various requirements for AIM, but in most cases, the standards lack the requirements for AIM of industrial facilities. For example, the British standard BS-8536-1 gives recommendations for making design decisions in the early stages of design and construction, together with future capital construction services. The British Standard PAS-1192-3 defines the information management process for support during the operational stage. However, the standard sections do not provide information about AIM detail level requirements. The sections "Model structure(s)" and "Modeling Methodology" of the British standard AEC (UK) BIM Technology Protocol describe general information about the detail level of the model elements. However, the standard is adapted more for the design and construction stages. In the United States of America, the most developed standard is the National BIM Standard, which regulates the requirements for detail levels through a series of documents AIA E203-2013 BIM & Digital Data Exhibit, as well as the Level of Development Specification and USACE BIM Minimum Modeling Matrix (M3). However, the information provided is intended to form AIM in civil engineering, while the requirements for the industrial facility are not described. Also, several standards of individual countries, where AIM is successfully developed for managing objects, contain only general requirements for the detail level of the model elements. These

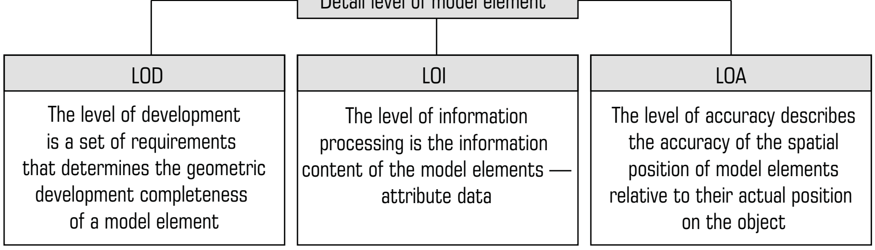

Fig. 1. Detail levels of model elements

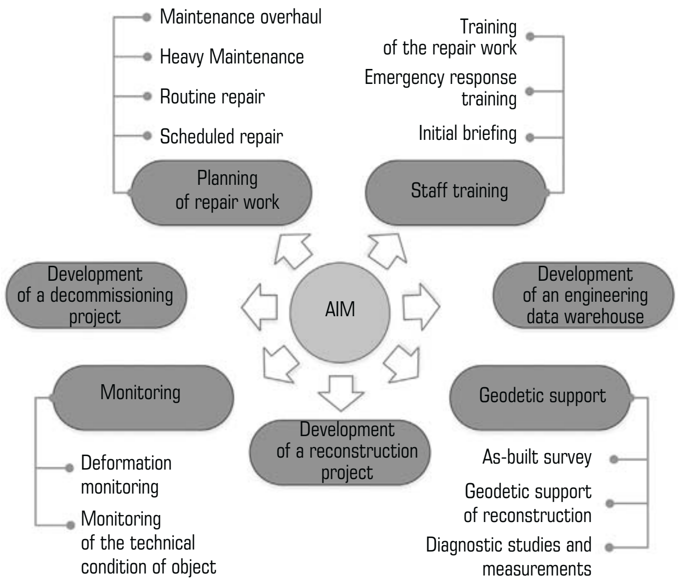

Fig. 2. Production tasks that AIM solves

standards include the Canadian standard BIM PxP Toolkit, the Norwegian standard Statsbygg Building Information Modeling Manual (in general, we note that these documents will be handy only for buildings, and then only for the design stage), the Finnish standard Common BIM Requirements (focused on civilian buildings), the New Zealand standard New Zealand BIM Handbook and others.

Despite many studies and current regulatory documentation, the actual issue is forming requirements for creating an AIM industrial facility. The scientific and regulatory literature does not address the development of LOD, LOI AIM of an industrial facility. Also, questions about the LOA of model elements are not developed. Given that the requirements for the AIM of an industrial facility depend on the types of tasks being solved, the actual issue is the formation of requirements for LOD, LOI and LOA sufficient to solve them [5].

Given this, it is necessary to analyze the tasks that can be solved using AIM at the operational stage. Further, based on the analysis performed, formulate requirements for LOD, LOI and LOA when creating AIM. Moreover, as a result, to form requirements for the accuracy of 3D modeling and terrestrial laser scanning [2, 13, 17, 20] to obtain source data when creating AIM.

Analysis of detail levels of model elements

The Level of Development Specification 2020 is considered the most informative standard in describing the requirements for the detail level of the model elements. Here is a generally accepted levels classification and description based on the analysis (**Table 1**).

Analysis shows that the detailed study of the requirements has been completed only for LOD. It is also worth noting that the current standards describe the requirements to a greater extent for building structures. This fact may be because BIM technology was initially used in civil engineering. At the same time, the requirements for such essential components of AIM as LOI are described superficially, and there are no requirements for LOA. It is worth mentioning that the main asset in the operation of an industrial facility is the process equipment, which has no requirements. Also, given the complexity and saturation of processes at the operation stage of an industrial facility, for the practical AIM application, it is necessary to develop requirements that include three main parameters LOD, LOI and LOA of model elements.

Production tasks at operation stage

As noted earlier, during the operation of an industrial facility, many production processes take place, which includes planning and repairing assets, ensuring the safe operation of the facility, optimizing production processes, managing technological processes, financial management, personnel management and others. It should be noted that source information of different forms and content is required to solve tasks related to various production processes. Since our work aims to develop requirements for AIM in terms of LOD, LOI and LOA of the model elements, we will limit ourselves to studying only those tasks that require the use of AIM (**Fig. 2**).

After analyzing the tasks of the operational stage [22–40], it can be noted that to solve most tasks, the requirements for LOD and LOI must correspond to a high level. Although the requirements for LOD, LOI and LOA may be low for some tasks, it is recommended that the development of requirements proceed from the perspective of using AIM to solve a set of operational tasks and determine LOD, LOI and LOA.

Results and Discussion. Development of requirements for detail levels

Development of LOD requirements. As noted earlier, a detailed study of LOD requirements in terms of regulatory documentation was carried out only for building structures. Since relatively high LOD requirements must be applied to AIM to solve a complex of operation tasks, it can be concluded that the essential components of AIM must comply with LOD 500 according to the general specification. At the same time, equipment and communications are

Table 1. Specification of detail levels

Level of detail	Requirements for displaying model elements
100	The model is made with a low level of detail and a conditional representation of the elements. Model elements do not contain shapes, sizes, or exact positions.
200	The model is made with a low level of detail with a graphical representation of the elements as a general system of objects with approximate sizes, shapes, positions and orientations. Additional information can also be attached to model elements.
300	The model is made with a low level of detail, with a graphical representation of the model elements in a specific system of objects or assembly. Elements in the model are presented with design dimensions, shapes, positions and basic attributes. Additional information can also be attached to model elements.
350	The model is made with an average level of detail with a graphical representation of the model elements in the form of a specifically designed system of objects or assembly, containing information about the number, size, shape, position, orientation and interaction with other systems. The model also contains the elements necessary for interdisciplinary interaction with neighboring or attached elements, such as supports and connections. Additional information can also be attached to model elements.
400	The model is made with a high level of detail, with the most detailed graphical representation and filled with attributive information. Model elements are graphically represented as a specific design system of objects or assembly containing size, shape, location, quantity and orientation information with detailed parts, fabrication, assembly and installation information. Additional information can also be attached to model elements.
500	The model is made with a high level of detail, with the most detailed graphical representation and filled with attributive information. Model elements are graphically presented based on as-built documentation in the form of a specific mounting system of objects or assembly containing information about the exact dimensions, shapes, location, quantity and orientation with detailed information about performance characteristics. Additional information can also be attached to model elements.

essential objects in the operation process, for which clarification of the existing LOD specification is required. In addition, essential from the point of view of the facility's operation is the evacuation routes, the passage of personnel and the movement of equipment (**Fig. 3**), and the geodetic support of the facility, which must also be included in the LOD specification. In this regard, based on practical experience in creating AIM, add-ons to the LOD have been developed that satisfy the solution of various operation tasks (**Table 2**).

In the context of updating AIM based on the requirements specified in **Table 2** and geodetic surveys, the following approach is implied:

—the 3D of AIM is updated automatically in CAD by adjusting the model elements and adding new elements (in the case of an object reconstruction) in accordance with their actual location and dimensions according to the results of laser scanning.

—the attributes of AIM are updated automatically in CAD by entering information from operational documentation or field surveys. It should be noted that the volume of the introduced attributes depends on the required LOI level, determined by the operation's service.

It should be noted that each industrial facility has its specifics in terms of the composition of equipment, communications, and architectural solutions. In this regard, the proposed additions are informative and require clarification depending on the specifics of the industrial facility and the intended use of AIM.

To solve such a task as geodetic monitoring of objects described in the standard LOD specification, the requirements for developing model elements are insufficient. To analyze the development of deformations, AIM should contain information about monitoring results, including their graphical display. In this regard, it is proposed to introduce the next level, LOD 550, in which the objects of geodetic monitoring are reflected with their real deformations and defects. Requirements for model elements corresponding to LOD 550 are presented in **Table 3**.

Development of LOI requirements for AIM elements. As mentioned earlier, the requirements for LOI in the current regulatory documentation are not described in detail. However, in solving operational tasks, LOI plays a key role. It should also be noted that the requirements for LOD and LOI of AIM

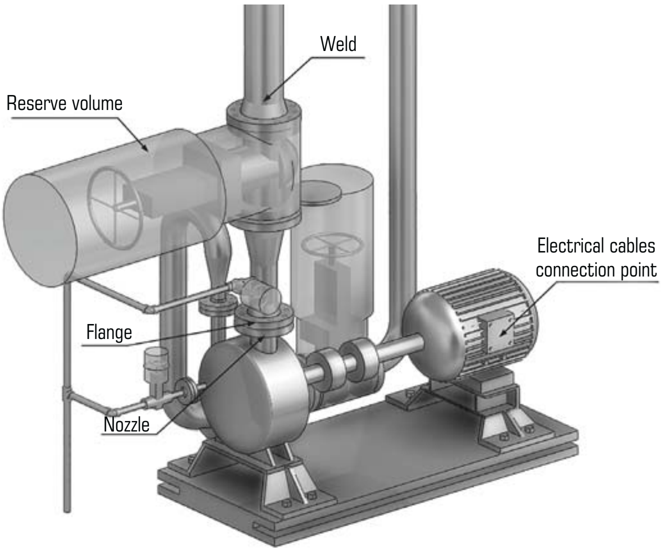

Fig. 3. An example of displaying equipment and pipelines in AIM

Table 3. Requirements for LOD 550 AIM elements

Detail level	Requirements for displaying 3D model elements
550	Control elements in a 3D model are made with a high detail level, with the most detailed graphical representation and filled with attributive information. The control elements are graphically presented based on the results of deformation monitoring, containing information on the exact dimensions, shapes, location, deformations, defects and orientation with detailed information on operational characteristics. Additional information can also be attached to the controls. Structures not subject to deformation monitoring should be modeled at the LOD 500 level.

Table 2. Additional requirements for LOD 500 AIM elements

Model element type	Requirements for displaying 3D model elements
Equipment	The following types of equipment are modeled in AIM in detail: process equipment, fire extinguishing equipment, emergency protection equipment, communication equipment, alarm and fire alarm equipment, gas control equipment. The overall dimensions and technical parameters of the equipment and individual parts of the equipment (nozzle) must correspond to the actual object mounted on the production site and operational documentation. As part of the equipment, electrical ports (points of electrical cables connection, cable trays and routes) should be modeled. As part of the equipment, reserve volumes for equipment maintenance and repair work should be simulated. Elements displaying parts of the equipment (electric motor, pumping unit, etc.) must be combined into groups as part of the equipment. The following should be modeled as part of the equipment: critical welds to be controlled during operation; wall thickness control points; vibration monitoring points.
Pipes	The overall dimensions and technical parameters of pipelines and their elements must correspond to the actual object mounted on the production site and operational documentation. All necessary connection points should be modeled (fittings for drains and air vents, fittings and bosses for instrumentation and control equipment). Insulation should be modeled on straight pipe runs and fittings. The direction of the flow of the medium when modeling pipelines must correspond to the technological schemes. All pipeline segments related to one pipeline must be interconnected through common connection points. All pipelines belonging to the same line must be interconnected through common connection points. As part of pipelines, reserve volumes for servicing shut-off and control valves should be modeled. As part of pipelines, the following should be modeled: critical welds to be controlled during operation; sampling points; control points for pipeline wall thicknesses.
Air ducts	The air ducts' overall dimensions and technical parameters and the elements included in them must correspond to the actual object mounted on the production site and operational documentation.
Cable boxes and trays	Cable boxes and trays overall dimensions and technical parameters must correspond to the actual object mounted on the production site and operational documentation.
Industrial safety	The model should display evacuation routes, storage areas for personal protective equipment, places of shelter, potential accident sites and damage radii, access routes for equipment and personnel, work areas for equipment and personnel. Model elements must be represented by a reserved space with overall dimensions following the industrial safety standards in force at the facility.
Geodetic support	AIM models geodetic grid control points and deformation marks with their precise spatial position. Geodetic network points should display the position of their centers.

elements can be of different levels to solve a specific operational task. It is proposed to form a separate LOI specification independent of the LOD in this regard.

All attributive information characterizing a particular object can be divided into four main groups: general, technical, technological, and operational. Let us form explanations for each group of attributive information (**Fig. 4**).

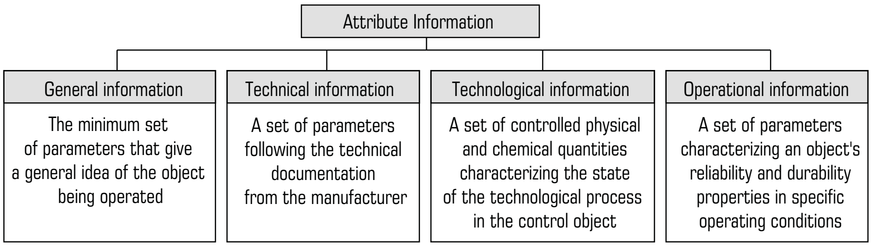

Fig. 4. Attribute information groups for AIM elements

Based on the analysis of operational tasks given in Chapter 2 and the formed groups of attributive information, the following LOI specification is proposed (**Table 4**).

It should be noted that the suggested number of LOI detail levels is less than the number of LOD detail levels. The reason is the lack of direct relationship between LOD and LOI detail levels. For example, the LOI of AIM for development the reconstruction project must be not less than 200. At the same time, to develop an engineering data management system, AIM elements must correspond to the detail level of LOD 500 and LOI 300.

Development of LOA requirements for AIM elements. To solve many operational tasks, AIM must contain up-to-date data on the spatial position of the elements since this subsequently affects the quality of operational decision-making. As noted earlier, the requirements for LOA are not reflected in the current regulatory documentation. In this regard, it is proposed to form an LOA specification and requirements for each level.

LOA requirements should describe the accuracy of the attitude of AIM elements. In this case, it should be taken into account that the requirements are not imposed on the entire element but specific characteristic points on the element's surface. Characteristic points responsible for the behavior of the structure during operation can be determined during design development or determined by the manufacturer. Then the accuracy is defined as an error in the relative spatial position of structures on a real object and AIM elements. In this case, the requirements for accuracy depending on the type of tasks being solved. Based on the analysis of operation tasks, we can distinguish the following degrees of accuracy requirements indicated in **Table 5.**

It should be noted that a direct relationship between LOA and the detail level of LOD and LOI is also not assumed. For example, to staff training, which involves the development of a virtual simulator based on AIM, LOI 200 and LOA 100 detail levels are sufficient. At the same time, to solve the task of deformation monitoring, the detail levels must correspond to LOI 300 and LOA 300.

Laser scanning and three-dimensional modeling accuracy requirements

For forming accuracy requirements for laser scanning and modeling of objects, it is necessary to transit from the characteristics of the accuracy of determining the points spatial position specified in the regulatory and technical documentation (design, construction and operational) to the limiting root-mean-square errors (RMSE) of determining the position of the points and then to the average RMSE for determining the position of points.

The value of the RMSE m_p for determining the position of points relative to the maximum deviation δ of the position of points can be calculated using the formula [41]:

$$m_p = \frac{\delta}{2.5}. \quad (1)$$

If the tolerance values Δ specify the measurement accuracy characteristics, then to go to m_p it is necessary to pre-calculate δ. Considering that the tolerance values is the difference between the largest and smallest limit dimensions of the structure, half of the tolerance is δ. Therefore, the transition from Δ to m_p can be carried out according to the formula:

$$m_p = \frac{\Delta}{5}. \quad (2)$$

It should be taken into account that the following formula expresses m_p:

$$m_p = m_{scan} + m_{3d}, \quad (3)$$

where m_{scan} RMSE of laser scanning, mm; m_{3d} RMSE of 3D modeling, mm.

We assume that m_{scan} and m_{3d} are independent quantities, then, applying the principle of equal influences, according to which the influence of each source of errors on the total error of the function is the same, we finally obtain:

$$m_{scan} = m_{3d} = \frac{m_p}{\sqrt{2}}. \quad (4)$$

It should also be taken into account that the accuracy of laser scanning is determined from the expression:

$$m_{scan} = m_{g.n} + m_m + m_{reg}, \quad (5)$$

Table 4. LOI specification of the AIM elements

Detail level	Requirements for displaying information about a 3D model element
100	Model elements contain general parameters, including technological position, object type, purpose and location.
200	Model elements contain general parameters following LOI 100 and technical and technological parameters. From the point of view of technical information, model elements must contain at least the following parameters: brand, weight, manufacturer, year of manufacture, year of commissioning, component material, main overall dimensions. From the point of view of technological information, model elements must contain at least the following parameters: working pressure, working temperature, name of the medium, aggressiveness of the medium.
300	Model elements contain general parameters according to LOI 100, technical and technological parameters according to LOI 200 and operational information. From the point of view of operational information, model elements should contain at least the following parameters: repair information, condition monitoring information.

Table 5. LOA specification of AIM elements

Detail level	Requirements for displaying 3D model elements
100	AIM elements are located in space following the design documentation, displaying design dimensions. The spatial position of the elements does not take into account deviations from the design documentation.
200	AIM elements are located in space following the as-built documentation or measurement documentation and reflect the actual spatial position and dimensions with the accuracy specified for the as-built survey or measurement work.
300	The model elements are located in space according to the results of deformation observations and reflect the change in the object shape over a certain period with an accuracy set for the performance of deformation observations.

where $m_{g.n}$ is the RMSE for determining the position of geodetic network points, mm; m_m is the RMSE measurements, mm; m_{reg} is the RMSE of registration laser scan data, mm.

Therefore, when preparing work on laser scanning, it is necessary to determine the methodology for performing work, taking into account the instrument, measurement methods and methods for registration laser scanning data, which satisfies the specified accuracy of determining the spatial position of points and perform a preliminary assessment of the accuracy.

When preparing work on developing a 3D model, it is also necessary to determine the method for modeling elements, depending on the requirements for determining the spatial position of elements [19, 31]. Methods for modeling industrial objects can be divided into solid and surface modeling. The method of solid modeling is advisable to use if it is necessary to display the actual dimensions and position of structures on the object. The surface modeling method is the most accurate in describing the shapes and dimensions of an object and is used when displaying curvilinear objects, and deformations are required. In this case, it should be taken into account that the choice of the modeling method should provide the required accuracy in determining the position of the characteristic points of the AIM elements.

Conclusions

The results of the presented study can be formulated as follows:

1. The article analyzes the regulatory and technical documentation governing the creation of AIM and operation tasks, the solution of which involves the use of AIM. As a result, the key components that AIM should contain to solve each of the tasks are identified.

2. Based on the analysis performed, additions to the LOD elements of a 3D model were developed to solve various operation tasks. Namely, additions to the requirements for displaying equipment and communications were developed.

3. For solving the tasks of deformation monitoring, it is proposed to introduce a new level, LOD 550, in which objects of deformation monitoring are reflected with real deformations and defects. As a result, general requirements for the essential elements of the model corresponding to LOD 550 have been developed.

4. Since the requirements for LOI are key in solving operational tasks, it is proposed to form a separate LOI specification that is not related to LOD. Based on the analysis of operational tasks and the formed attributive information groups, the LOI specification of AIM elements was developed, including three detail levels.

5. It is proposed to form a LOA specification of AIM elements to solve several operational tasks. The study found that LOA should determine the accuracy of structures' relative spatial position on a real object and AIM elements. As a result, the LOA specification of AIM elements and the requirements for determining the spatial position of elements at each detail level was developed.

6. The requirements for the accuracy of laser scanning and 3D modeling are formulated. A transition was made from the characteristics of determining the points spatial position specified in the regulatory and technical documentation to the RMSE of determining the position of points, and calculation formulas are given.

The research can be helpful for developers and users of AIM and form a general idea of the requirements for LOD, LOI and LOA when creating AIM for solving various operation tasks.

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