The common data environment features from the building life cycle perspective

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Abstract. One of the conditions for informational support of the construction projects’ life cycle and, in particular, the capital construction projects is the organization of a common data environment or, as it is called abroad, the Common Data Environment. The common data environment, being an integral part of information modeling technologies in construction, is multilevel in nature. The article draws attention to the fact that the aforementioned research object at present is considered mainly from the standpoint of foreign national standards in the field of information modeling in construction, which considers the common data environment mainly at the level of electronic document management in daily work in the design and operation of buildings and structures. Modern domestic technologies for the organization of construction should necessarily consider buildings and structures in the context of their life cycle, and not the life path, as a sequential set of data state phases. This article discusses the common data environment features from the perspective of managing the buildings’ life cycle. Using the analytical method of similarity and the dialectical method to describe the qualitative change in the model at a new consideration level, it is hypothesized that when moving from the considering interactions within the life cycle stage to the level of interactions between the life cycle stages, the concept of “data” gives a way to the “knowledge” concept. And in order to provide a complete ontology of the buildings and structures’ “life cycle” concept, a model using knowledge share is proposed.

1. Introduction

Common Data Environment (CDE), as the information modeling subject area concept in the construction industry, considers buildings and structures (Buildings) in the context of their life cycle (LC). CDE is to provide the information management about the Building in the information model (IM). This is evidenced by Article 3, Clause 2 of the Technical Regulation on the safety of buildings and structures of Federal Law No. 384, adopted more than 10 years ago.

In this connection, the CDE ontological understanding unity is important as the basis of the LC Buildings’ information support and, in particular, the capital construction projects (CCP). For example, GOST R 57311-2016 defines that information management on CCP in the IM composition should be carried out using CDE, which is a single CCP information source and may include server hardware, communication channels, file search systems and other software and hardware [1]. It is important to note that both the current GOST R 57311-2016 and the canceled GOST R 58439.1-2019...
determine CDE as a “single information source”, in this case, a single source of information about the Building.

CDE is interpreted abroad as CDE (Common Data Environment), the international standard offers the CDE definition as “a consistent information source for the collection, management and distribution of each information container through a managed process” (ISO 19650-1: 2018). Fundamentally, CDE is not considered as a “single source of information”.

Current CDE concept at the level of domestic and foreign regulatory documents is developed mainly at the level of electronic document management in daily work in the design and operation of buildings and structures, an example of this is the BS1192-1 A2: 2016 standard (Great Britain), in fact one of the earliest national standards that described the CDE subject area since 2007 (BS1192: 2007) for design and construction. Domestic GOST R 57311-2016 in section 6 essentially repeats the methodology of the above-mentioned standard, but for the operational information model (IM). In general, CDE consists of four phases (areas) through which the data passes sequentially. Data “phases of information development” are the data phases of life (phases of life) of the data. It should be noted that this CDE concept describes the basic level of data interaction illustrated in Figure 1:

![Figure 1. CDE model in electronic document management at the regular collaboration level (BS1192-1 A2:2016, 4.2.2.)](image)

It is possible to formulate the basic principle of this approach - as soon as certain checks of the incoming data are carried out, their further exchange and change become controlled.

But if to go from the CDE level in the LC Buildings stage at the level of interaction stages during LC Buildings, it is possible to see that the above-mentioned concept remains unchanged in terms of the data exchange. For example, the standard PAS 1192-2: 2013 formalizes the term “life cycle of a construction project” and is introduced granularity into LC stages: from the idea and design to construction and operation of an object, but does not change the CDE concept. A number of researchers cite this standard as an information source of CDE [3], [4], [5].

Ontological structure CDE can be presented in the following form (Figure 2):
CDE and BIM are connected through the concepts of “Information” and “Asset”, where “information” is a reinterpreted data representation in a formalized form suitable for transmission, interpretation or processing, which can be carried out by a person or automatically, in turn, an “asset” “object, thing or entity of potential or actual value for the organization” (ISO 19650-1:2018).

The vast majority of CDE definitions and descriptions, starting with BS1192:2007, emphasize the data exchange between the customers, nodes and components with frequent repetitive interactions at the regular collaboration level. But to account for buildings as technical objects in their LC it is necessary to consider the long-term interaction situation of such technical objects with CDE. In this case, the marketing “time-line” of buildings will be calculated by several generations of people, and the interaction of buildings with CDE should move from the data level to the knowledge level.

2. Methods
It is proposed to use the analytical similarity method to scale the existing model and the dialectical method to describe the qualitative change in the model at a new consideration level.

2.1. Primary model CDE at the buildings’ LC level
The CDE concept understanding at the buildings’ LC interaction stages level is shown in Figure 3:

![Figure 2. Ontological structure of CDE and BIM connection based on the international standard ISO 19650-1:2018](image)

![Figure 3. Data Exchange Buildings’ IM with their various states in the Buildings’ LC course [6]](image)
When deciding on the Building utilization: analysis of the physical condition and depreciation of the tangible asset and IM monitoring, LC occurrence in Fig. 3 becomes a fact. During this period, as well as after the demolition, dismantling and reclamation works’ completion, transfer to CDE knowledge and specific experience (best practice) [7], extracted from IM Buildings (red arrows: extracting knowledge and experience from IM indicated by the bi-directional arrow, transfer of learned knowledge to CDE – is indicated by the unidirectional arrow) is performed. Further, the emergence of a mental model can occur in the interaction of man and CDE, taking into account the knowledge and data stored there about the previous Building and, in some cases, on the initiative of a person, CDE can independently create the analytical models based on such knowledge (turquoise arrows). This is the basis for the development of “artificial” intelligence in construction. The non-identity of the “life path” of the Building (including the stages having an industry link) and the “life cycle” of the Building (initially determined and associated with the state transitions of the Building IM) is noted [6].

This approach introduces the knowledge concept into CDE at the LC level, but is focused on the final analysis and knowledge transfer after the physical dismantling, demolition of the Building and the land restoration.

2.2. Advanced CDE model at the buildings’ LC level

It is proposed to apply the principle of similarity to the model in Fig. 1, which describes interactions in CDE in the life cycle stage. The concept of “knowledge” arises in this model only at the last (fourth) phase of the data life - the “Archive”.

In the improved model, there will essentially be two hetero-chronous media: the traditional CDE environment, serving the “life path” of the technical object (Building) [6], [8] and the common knowledge environment (CKE), providing information support to the of a technical facility (Building) “life cycle”. In this context of “knowledge” there are stable correlations between data that can be described by a predicate, thereby defining the properties (characteristics, parameters) of an object or the relationship between the objects. Hence, knowledge is the data with a qualitatively lower level of entropy regarding the complex system functioning. CKE definition as a dialectical CDE development, expressed in display CDE to a higher level of information support for the Building and acquiring a new qualitative character is also possible.

In a living biocenosis, an object that carries information about all previous objects that have contributed to the current one in time is DNA. In the Buildings’ technocenosis [6], [9], such a bearer of “smart experience” is a cybernetic concept, which is currently defined by the majority of the professional community as an “information model” (IM) buildings or BIM in foreign terminology. The ontological relationship of CDE and BIM is shown in Figure 2.
CDE and CKE information support Model for the buildings’ LC

CDE deals with the data in the framework of daily data exchange or interaction within the stages, Building’s “life path” phases, being largely a chronology of its information model (IM).

The life path of the Building consists of the stages (Roman numerals) and phases (Arabic numerals), that is, it has a traditional structure, which is identified with LC. But this structure is linear in time, has no cyclical nature and ends with the Building decommissioning, dismantling and demolition. Between the stages, the data is exchanged with CDE Building information model (“gear”). Based on the stages’ results, bilateral interactions take place with CDE higher levels (state expertise, acceptance, etc.).

CKE is a mapping CDE to the life cycles’ level (longer time periods) and deals with a qualitatively different state of data - with knowledge. CKE does not depend on the number of stages, phases of the Building’s “life path”, but depends on the set of states of its information model (“stars”), being an environment for the conditional “smart experience” exchange for working with this knowledge over time.

CDE and CKE form two heterochronous processes in LC, where CDE meets the operational needs - the “life path” implementation and CKE meets the strategic goals LC - building a “smart experience” of the Building.

Buildings’ IM in general can be in five states:
1. mental model (before alienation to technology);
2. analytical model (dividing the concept into components and their development);
3. synthetic model (combining developments into a single model at a qualitatively new level: a project in the construction industry);
4. implementation model (Building construction);
5. model of changes (operation of the Building until the demolition and ongoing changes relative to previous models, especially the project).

LC IM state transitions and transitions between the stages of the building’s LC may differ chronologically.

Knowledge extraction from IM Buildings and knowledge sharing between IM and CKE happens with the state changes of Buildings’ IM in time. And also, at the end of the Building’s “life path” in the material environment, extracting knowledge from IM is based on a full time period.

Currently, the building information classifier development is almost completed, which will allow obtaining information about all previous technical objects that have contributed to the current Building. The approach is based on a multi-level unambiguous identification of building elements, starting from the “composite element identification code” and ending with the “unique identification number of the investment construction project and the capital construction project” (Stremilov D., competence center FAA “FCS”).

Using the above-described approach and incorporating technologies similar to “block-chain” [11], it becomes possible to analyze and manage knowledge in CKE both at the level of the “life path” of a particular Building, and at the Buildings’ LC level, that is, on the information support temporary scale of knowledge generated by the specific Buildings.

CDE benefits (Figure 1) at the interaction level within the LC stages consist in the following:
- the information ownership remains with its compiler, although the information is shared and reused, only if the compiler can change it;
- sharing information in collaborative development reduces the time and cost of producing the coordinated and consistent information;
- information containers models located in CDE, make it possible to create any number of documents in various combinations for information support of the Building’s “life path” or, in a particular case, to ensure electronic document management.

CKE benefits (Fig. 4) at the interaction level between the LC stages and between Different LC Buildings is as follows:
- providing negative entropy of information over time in knowledge management;
improving the quality of technical objects (Buildings) in the material environment and the
consistency of their information models in a virtual environment;
- even greater reduction in the time of creation of technical objects (Buildings) during collective
development.

3. Summary
1. CDE deals with data in the framework of daily data exchange or interaction within the stages, stages
of the Building’s “life path”, largely being a chronology of its information model (IM).
2. CKE is a CDE mapping for the longer time periods level, it deals with a qualitatively different
state of data - with knowledge, and does not depend on the stages number, Building’s “life path”
stages, but depends on the set of states of its information model (IM) as a medium for the exchange of
conditional “smart experiences” for working with this knowledge over time.
3. CDE and CKE form two heterochronous processes in LC, where CDE meets operational needs -
the Building’s “life path” implementation, and CKE meets the strategic goals being a “smart
experience” for working with this knowledge in time.
4. Knowledge share between IM and CKE occurs when Buildings’ IM state changes in time. And
also, once at the Building’s “life path” end in the material environment, extracting knowledge from IM
based on a full time period.
5. When extracting knowledge from Buildings’ IM the technologies similar to the “block-chain”
should be used so, that every knowledge, like a predicate, can be infinitely tracked over time in
relation to that Building, in which LC it arose.

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