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A STUDY ON THE LEVEL OF DEVELOPMENT OF BUILDING INFORMATION MODELING DESIGN PROCESS

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ABSTRACT : The people in the AEC industry have acknowledged and long struggled to solve the critical low productivity issue of the entire construction industry. Integrated Project Delivery has been suggested as a solution to this problem and to take this into practice many countries have come up with BIM guidelines. In order to make this a success, BIM design process and LOD must be dealt in advance. The following research has selected 3 out of 16 guidelines that specifically describes BIM process and LOD, and intends to fully acknowledge its concept by comparing the approach and definition of LOD in the BIM Design Process.

Keywords: IPD, BIM, LOD, BIM-Guideline, Design Process

1. INTRODUCTION

1.1 Intention

As mankind have thrived with the progress of construction, low productivity issue has emerged throughout the entire construction industry and there has been a worldwide effort to solve this problem. The American Institute of Architects(AIA) has recently suggested Integrated Project Delivery(IPD) to increase productivity.[1] The digital industry has made a worldwide progress and made an impact on almost every aspect of civilization with its IT technology, and as a result, Building Information Modeling(BIM) which is based on digital information and data has emerged in the AEC industry.[2] BIM has lifted IPD to a higher level which is rapidly replacing the traditional design process. In order to apply the new design process within the BIM system, a step by step understanding of LOD is required.

Therefore this research analyzes BIM design process applied to the newly suggested concept of IPD and Level of Development(LOD) by approaching and defining LOD during the course of the Design Process to obtain a precise acknowledgement.

1.2 Procedure

The research uses 3 steps to analyze IPD concept based BIM Design Process and LOD.

Step 1, the research analyzes the current 16 guidelines and the standard guidelines and has selected 3 out of 16 guidelines that specifically describes BIM process and LOD.

Step 2, the research analyzes and compares IPD concept based BIM Design Process with traditional Design process and further more analyzes and compares the process suggested from the 3 guidelines.

Step 3, in order to analyze the change of LOD during the BIM design process, the research analyzes the objects and their attribute during the design Process suggested from the 3 guidelines and the objects dealt within the design process to come up with a result.

2. CONCEPT OF TERMS AND SURVEY SELECTION

The description of terms used in the research, select the BIM design process and LOD to research.

2.1 Concept

Through the application of new technology IPD provides the knowledge of experts from the very start and by lifting the potential of every participants to a higher level it enhances their value during the Project Life Cycle to bring out the best results. AIA California Council's suggests BIM to play this role. The core of IPD are a group of unified and productive teams composed of key project participants. Therefore the research perceives the concept of IPD as expanding the field of experts and participants with newly given roles than simply adding BIM technology to the traditional design process.

The design process based on the concept of IPD is confined as BIM Design Process. Details of collecting information during the BIM Design Process is required. This degree of information collecting is defined as LOD and, the research acknowledges the form and progress of the attributes of LOD depends highly on the communication between the participants.

2.2 Selection of Survey

To choose a survey standard in order to analyze BIM design process and LOD the research has selected 3 guidelines(table 2) from the current BIM guidelines(table 1) that specifically describes BIM process and LOD.

Table 1. Guidelines and Standards for BIM

Study organization	Name of Guideline		Contents		Country
			Design Process	LOD	
Korea Institute of construction &Transportation Technology Evaluation and Planning. (KICTEP)	BIM-Guideline (Ver 2.4)		◆	◆	Korea
Ministry of Land, Transport and Maritime Affairs	BIM Guide for Architecture				
General Service Administration	BIM-Guide Series	Series01 BIM-Guide Overview			USA
		Series02 Spatial Program Validation			
		Series03 3D Laser Scanning			
		Series04 4D Phasing			
		Series05 Energy Performance			
		Series06 Circulation and Security Validation			
		Series07 Building Elements			
National Institute of Building Sciences	National Building Information Modeling Standards			◆	
National Institute of Standards and Technology	General Building Information Handover Guide		◆		
The American Institute of Architects(AIA)	Integrated Project Delivery: A Guide (Ver 1)		◆	◆	
Indiana University	BIM-Guidelines & Standards for AEC		◆		
Build Los Angeles Community College District	LACCD Building Information Modeling Standards			◆	
San Diego Community College District	BIM Standards for A/E/C		◆	◇	
State of Wisconsin	BIM-Guideline and Standards for A/E		◆		
Cooperative Research Centre for Construction Innovation	National Guidelines for Digital Modeling		◆		Australian
Senate Properties	BIM Requirement 2007		◆		Finland
STATSBYGG	BIM Manuals				Norway
Digital Construction BIPS	3D Working Method		◆	◆	Denmark
International Alliance for Interoperability	BIM/IFC User Guide			◆	Germany
AEC-UK	AEC (UK) BIM Standard				England

Table 2. Survey Guidelines

Case	Study organization	Name of Guideline
Case-A	Korea Institute of Construction &Transportation Technology Evaluation and Planning. (KICTEP)	BIM-Guideline (Ver 2.4)
Case-B	building information technology productivity collaboration {Byggeri Informations teknologi Produktivitet Samarbejde(BIPS)}	3D Working Method 2006
Case-C	The American Institute of Architects(AIA)	Integrated Project Delivery: A Guide (Ver 1)

3. DESIGN PROCESS

3.1 Traditional Design Process and Integrated Design Process

The American AIA has also pointed out the critical issue of lack of communication in the current traditional design process and have suggested Integrated Project Delivery to solve this problem. IPD provides an intimate bond among individuals, the system and organization which enables participants to communicate efficiently from the beginning and furthermore eventually bring out the best results from every level possible, saving time and cost that could be easily wasted otherwise.[3]

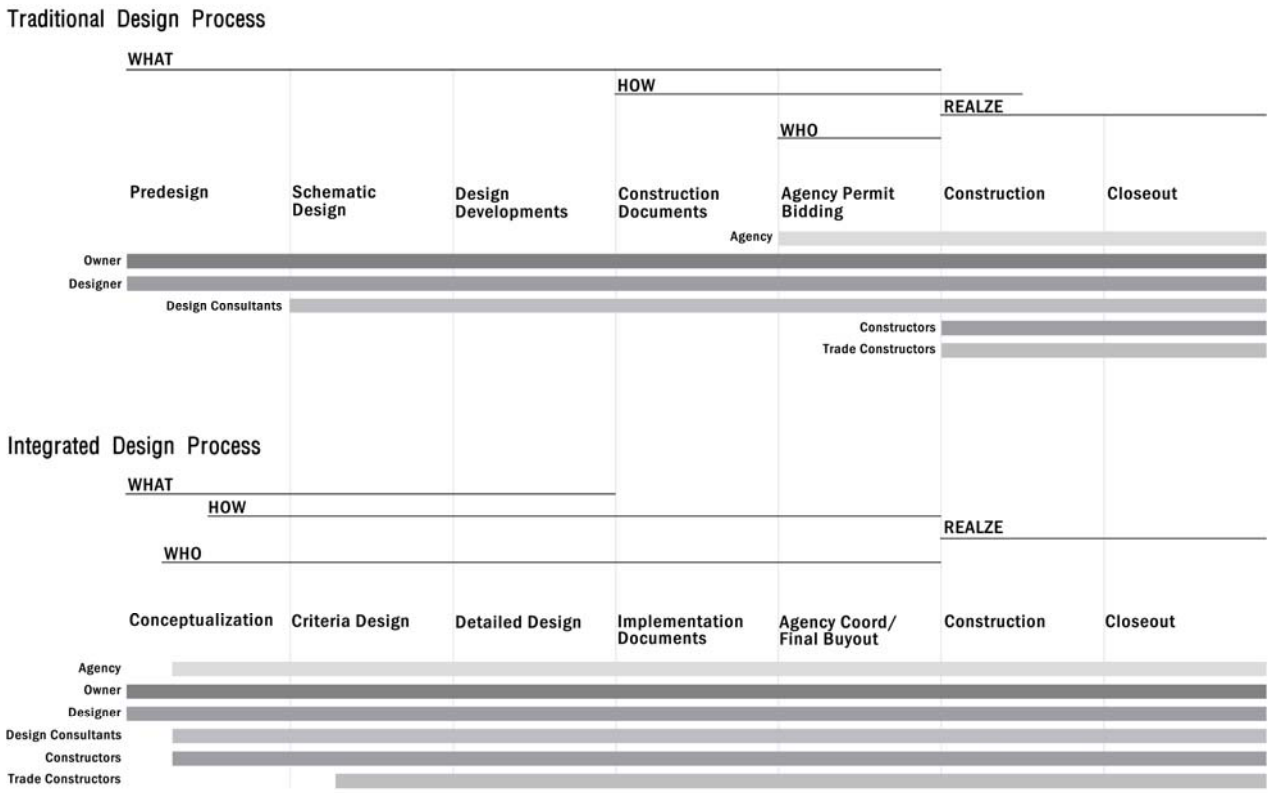

Fig 1. Integrated Project Delivery: Working Definition - AIA California Council's[4]

Fig 1 compares the participants and their roles in the Traditional design process with the integrated design process. The Agency, Design Consultants, Constructors, Trade Constructors that participated from the midterm of the Traditional design process have been taking part in the Integrated design process from the early start. They have been focused on the fundamental basics(What, How, Who) of construction, and have united to solve any related issues from the early project. This has made other experts to join from the start and bring about the best results especially in the Criteria Design and Detailed Design procedure which is expected to save time and overcome any mis-communication and errors easily made in the Traditional design process.[5]

Table 3. Team members and traditional design process in Korea[6]

Team Members		Pre Design	Schematic Design	Design Developments	Contract Documents	Construction
Client	Owner	◆	◆	◆	◆	◆
Design	Architecture	◆	◆	◆	◆	◆
	Structure Engineering			◆	◆	◆
	Mechanical System			◆	◆	◆
	Electronic System			◆	◆	◆
	Civil Engineering			◆	◆	◆
	LandScape Architecture			◆	◆	◆
Construction	Construction					◆

Table 3 shows the Korean Traditional design process and table 4 shows the Korean BIM design process. If you compare the two tables, Team members are formed by 3 parts(Client, Design, Construction). The unique point is that Model Coordinate, Estimate and Energy Analysis are added on the Design Team. The Design and Construction Team both participates from the early start of the Pre Design and Schematic Design process. This indicates that the design process follows the concept of IPD.

3.2 Team Members of BIM design process

To understand the role of Team Members in the BIM design process, I have researched their roles in each process and made up the following Tables 4, 5 and 6.

Team Members are divided into Owner, Designer and Constructor.

In the Design Part the Designer(Case-A), Architecture Designer(Case-B) and Prime Designer(Case-C) are fully

responsible of the design, and in Case-C the Design Consultants also helps out Structure Engineering and Building System Engineering in Case-B, Case-A is divided into 6 specific Teams(Structure Engineering, MEP, Civil Engineering, Landscape, estimate, Energy Analysis). The Project Coordinator(Case-B, Case-C)and Model Coordinator(Case-A) are given a new role to organize communication among team members, in addition to their current tasks of Coordinating overall project schedule, organizing and directing the integrated team.

Table 4. Current participation of team members in Case-A design process[7]

Team Members		Pre Design	Schematic Design	Design Developments	Contract Documents	Bidding & Construction	Facility Managements
Client	Owner	◆	◆	◆	◆	◆	◆
	F/O Management	◆	◆	◆	◆	◆	◆
Design	Designer	◆	◆	◆	◆	◆	◆
	Model Coordinate	◆	◆	◆	◆	◆	◆
	Structure Engineering		◆	◆	◆	◆	
	MEP		◆	◆	◆	◆	
	Civil Engineering	◆	◆	◆	◆	◆	
	Landscape		◆	◆	◆	◆	
	Estimate		◆	◆	◆	◆	
	Energy Analysis	◆	◆	◆	◆	◆	
Construction	Construction		◆	◆	◆	◆	◆
	Suppliers			◆	◆	◆	◆

Table 5. Current participation of team members in Case-B design process[8]

Team Members	Design Brief	Conceptual Design	Preliminary	Schematic Design	Detailed Design	Construction	Operation
Client	◆	◆	◆	◆	◆	◆	◆
Consideration by Authorities	◆	◆	◆	◆	◆	◆	◆
Project Coordinator		◆	◆	◆	◆	◆	
Architecture Design	◆	◆	◆	◆	◆	◆	
Structure Engineering		◆	◆	◆	◆	◆	
Building System Engineering		◆	◆	◆	◆	◆	
Construction						◆	
Supply of Construction Products					◆	◆	

Table 6. Current participation of team members in Case-C design process[9]

Team Members	Conceptualization	Criteria Design	Detailed Design	Implementation Documents	Buy Out	Construction	Closeout
Owner	◆	◆	◆	◆	◆	◆	◆
Agencies	◆	◆	◆	◆		◆	
Project Coordinator	◆	◆	◆	◆	◆	◆	◆
Prime Designer	◆	◆	◆	◆	◆	◆	◆
Design Consultants	◆	◆	◆	◆	◆	◆	◆
Prime Constructor	◆	◆	◆	◆	◆	◆	◆
Trade Contractor	◆	◆	◆	◆		◆	◆
Suppliers	◆	◆	◆	◆		◆	

This shows that the Team Members are participating in the design process from the early start. In Case-B and Case-C, they participate from the Conceptualization(Case-C), Conceptual design(Case-B) process where the ultimate goal of the project is set, and in Case-A they participate from the Schematic Design, which is the start of the actual design process.

They take part from the early start In Case-C and in Case-A from the Schematic Design process, compared to the traditional design process, but in Case-B, construction experts participates from the start of the construction.

Considering the ultimate goal of the IPD, best results will come out when the construction plan is contemplated at the design process. Therefore construction experts are recommended to participate from the very beginning of the design process.

4. LOD

4.1 Object and Attributes

In order to fully understand LOD, a definition of an

object and its attribute is necessary.

There are many ways to set a standard for an object and its attribute. BIM design process and its relation to LOD, the object's function and role, elements of a building, the format of BIM model, etc. It is mainly because there are various points of view about BIM which applies them to define the degree of LOD. This research have analyzed 3cases then came up with 2 similar cases(Case-A and Case-B) and finally covered Case-C.

The objects in Case-A are a Site and a Building, and the Building is parted and defined by Mass, Space and Element. In Case-B there are 6 objects(Construction Complex / Site, Real property, Building, Rooms, Building elements, Finishes).

If you compare Case-A and Case-B, Case-B divides Site in Case-A into Site and Real property. This case-B is because of important factor to think about Real property of the research group 'bips' to manage the assets of the public institutions in Denmark to enforce the Digital Construction. As for Buildings, Case-A divides them into Mass, Space and Elements and Case-B Building, Rooms, Building elements, and Finishes. Case-A's Mass is defined as Case-B's Building, Space are Rooms, Elements are Building Elements and Finishes. In Case-B as a result of considering Finishes as a part of the LOD, the level of building designs are very specific and it shows that they put emphasis on the cost and results based on the contractor's decision at the Finishes part. There are so many various points of view approaching the construction of a building, but the LOD Object can be approached with two big pictures- Site & Building.

Considering the definition of attributes by objects, Case-A defines attributes by Function, Geometry/Location, Supply/Disposal Line data, Building physics data, Production/Process, Operation/Maintenance. These attributes are differently applied compared to the formerly mentioned category. For example, Site covers 3 attributes Function, Geometry/Location, Supply/Disposal Line data and Building covers 5 attributes.

Case-B defines 6 attributes and as the same with Case-A, applies different attributes according to the objects. If you compare the attributes of Case-A and Case-B, Site objects in Case-A and Case-B applies Function, Geometry/Location and Case-A adds the definition of the attributes of Supply/Disposal Line data considering the surrounding infrastructure and the concern of effects resulting from forming BIM.

If you compare attributes of Building objects, Case-A is considers Operation/Maintenance in Space and Elements and Case-B considers Operation/Maintenance only in Building elements and Finishes. This shows the difference in the approach of maintenance after being constructed under the concept of BIM.

The following table 7 shows Object & Attributes analysis of Case-A & Case-B.

Table 7. Object & Attributes analysis of Case-A & Case-B[10]

	Object / Attributes	Site	Building		
			Mass	Space	Elements
Case-A	Function	•	•	•	•
	Geometry/Location	•	•	•	•
	Supply/Disposal Line data	•			
	Building physics data				•
	Production/Process				•
	Operation/Maintenance			•	•

	Object / Attributes	Construction Complex / Site	Real property	Building	Rooms	Building elements	Finishes
Case-B	Function	•	•	•	•	•	•
	Geometry/Location	•	•	•	•	•	•
	Building physics data					•	•
	Production / process					•	•
	Product data					•	•
	Operation & Maintenance					•	•

Case-C divides LOD objects to form the BIM model. The largest difference between Case-A and Case-B is that Case-C is formed focused on the BIM model. Based on the Elements it is categorized into 7 objects and defines each attribute applied to each level. UNIFORMAT□ code is used for the basic data of Case-C. UNIFORMAT Ⅱ code provides a common system to the related construction program, participants and estimation which accelerates the procedure and increases productivity. Therefore the project data of Object and Attributes in Case-C can be systematically maintained, and the roles and responsibilities of each participants can be divided precisely with this code. The following table 8 shows Object & Attributes analysis of Case-C.

Table 8. Object & Attributes analysis of Case-C[11]

Attributes \ Object		Element																	
		A. Substructure		B. Shell			C. Interiors			D. Services			E. Equipment & Furnishings		F. Special Constr. & Demo		Site		
		A10	A20	B10	B20	B30	C10	C2	C30	D10	D20	···	E10	E20	F10	F20	G10	G20	···
		⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Geometry/ Location	area	•		•			•			•			•		•		•		
	height	•		•			•			•			•		•		•		
	volume	•		•			•			•			•		•		•		
	location	•		•			•			•			•		•		•		
	orientation	•		•			•			•			•		•		•		
	size	•		•			•			•			•		•		•		
shape		•		•			•			•			•		•		•		
quantities		•		•			•			•			•		•				
fabrication				•			•												

4.2 BIM Process and LOD

LOD makes a progress during the procedure of the BIM design process. The objects and their attributes advances along with the LOD level process. Table 9 and 10 are analysis of the LOD object definition during the process of Case-A and Case-B.

Case-A undergoes a total of 6 levels of process and the degree of LOD is defined LOD1～LOD6, at each level. During the Pre-design phase, the Site's function and Geometry/Location are defined, and also the building massing with its space-function, Geometry/Location are defined. At the Schematic Design phase, the Site's function and Geometry/Location are fixed areas, and the Supply/Disposal Line data attribute is defined. The Building Massing-function and Geometry/Location, Elements-function are fix areas and attributes of the Space, the Geometry/Location of Elements are defined at this level.

The BIM design process is progressed through this procedure and the degree of LOD becomes more specific.

Case-B undergoes 7 processes and each level from Level1～Level6 defines LOD.

In the Design Brief phase, Construction Complex / Site and Real property Function, Geometry/Location are defined, Building and Rooms- Function & Geometry /Location are defined as Fix areas. In the Conceptual design phase, the object attribute is defined quite the opposite to the design brief procedure. In the Preliminary design phase, the attributes of Construction Complex / Site and Building elements- Function are defined as a Fix area, and Building elements- Geometry/Location are defined.

Case-B also undergoes this procedure and the BIM design process progresses and the degree of LOD becomes more specific.

If you compare the LOD degree of both Cases based on the BIM design process, Object and Attributes which are applied in each process are defined in that level, and the former Object and Attributes become defined as Fix areas at the next process. Through this step by step procedure, Process and LOD make progress. As an exceptional case, the Elements- Function attributes are defined as Fix area from the first process means that the attributes of Elements- Function are essential. The reason why the definition areas of Object and Attributes differ is because it is formed based on each country's own environment and its traditional design process. But the flow of LOD object definition based on the whole process seems to be the same.

Table 9. LOD Object definition based on BIM process of Case-A[12]

◆ Activity area ◇ Fix area

Object		Attributes	Pre-design	Schematic - Design	Design-Development	Construction-Documents)	Biding / Construction	Facility Management
			LOD1	LOD2	LOD3	LOD4	LOD5	LOD6
Site		Function	◆	◇	◇	◇	◇	◇
		Geometry/Location	◆	◇	◇	◇	◇	◇
		Supply/Disposal Line data		◆	◇	◇	◇	◇
Building	Mass	Function	◆	◇	◇	◇	◇	◇
		Geometry/Location	◆	◇	◇	◇	◇	◇
	Space	Function	◆	◆	◇	◇	◇	◆
		Geometry/Location	◆	◆	◇	◇	◇	◆
		Operation/Maintenance		◆	◆	◆	◇	◆
	Elements	Function		◇	◇	◇	◇	◆
		Geometry/Location		◆	◆	◇	◇	◆
		Building physics data			◆	◇	◇	◆
		Production/Process				◆	◆	◆
		Operation/Maintenance				◆	◆	◆

Table 10. LOD Object Definition based on BIM process of Case-B[13]

◆ Activity area ◇ Fix area

Object	Attributes	design brief	Conceptual-design	Preliminary-design	Scheme-Design	Detail design	Construction	Operation
		Level0	Level1	Level2	Level3	Level4	Level5	Level6
Construction Complex / Site	Function	◆	◇	◇	◇	◇	◇	◇
	Geometry/Location	◆	◇	◇	◇	◇	◇	◇
Real property	Function	◆	◇	◇	◇	◇	◇	◇
	Geometry/Location	◆	◇	◇	◇	◇	◇	◇
Building	Function	◇	◆	◇	◇	◇	◇	◇
	Geometry/Location	◇	◆	◇	◇	◇	◇	◇
Rooms	Function	◇	◆	◇	◇	◇	◇	◇
	Geometry/Location	◇	◆	◇	◇	◇	◇	◇
Building elements	Function			◇	◇	◇	◇	◆
	Geometry/Location			◆	◆	◇	◇	◆
	Building physics data				◆	◆	◇	◆
	Production / process						◆	◆
	Product data						◆	◆
	Operation & Maintenance							◆
Finishes	Function					◇	◇	◆
	Geometry/Location					◇	◇	◆
	Building physics data					◆	◇	◆
	Production / process						◆	◆
	Product data						◆	◆
	Operation & Maintenance							◆

Case-C doesn't entirely depend its appliance based on table 8. It merely provides a conceptual definition to understand how the degree of LOD differs according to each process. There are a total of 5 levels of each process and LOD which are divided into how they are expressed, what function they have and roles they are given. In LOD100, overall building massing is used to provide a conceptual definition, in LOD200, model elements are used for an approximate geometry. LOD300 requires more specific and precise geometry. Case-C also undergoes 5 different levels and the BIM process is progressed through these 5 levels and the degree of LOD becomes more specific.

Table 11. LOD Object Definition based on BIM process of Case-C[14]

Process	conceptualization	Criteria Design	Detail design	Implementation Documentation	Construction
LOD	LOD100	LOD200	LOD300	LOD400	LOD500
concept	Conceptual	Approximate geometry	Precise geometry	Fabrication	As-built
description	Overall building **massing** indicative of area, height, volume, location, and orientation may be modeled in three dimensions or represented by other data.	Model **Elements** are modeled as **generalized systems** or assemblies with approximate quantities, size, shape, location, and orientation. Non-geometric information may also be attached to Model Elements.	Model **Elements** are modeled as **Specific** assemblies that are **accurate** in terms of size, shape, location, quantities, and orientation. Non-geometric information may also be attached to Model Elements	Model **Elements** are modeled as Specific assemblies that are accurate in terms of size, shape, location, quantities, and orientation with complete **fabrication**, assembly, and detailing information. Non-geometric information may also be attached to Model Elements.	Model **Elements** are modeled as **constructed** assemblies actual and accurate in terms of size, shape, location, quantities, and orientation. Non-geometric information may also be attached to Model Elements.

5. CONCLUSIONS

By understanding the BIM Design Process of the IPD based 3 guidelines and scrutinizing the LOD applied during this process, we have come by the following results.

a) The Agency, Design Consultants, Constructors, and Trade Constructors that have participated around the midterm of the Traditional design process are taking part in the BIM design process from the very beginning. They are focused on the fundamental basics(What, How, Who) of construction, and have united to solve any related issues from the start.

b) A new role to organize communication among team members has emerged in the BIM design process besides the existing role of Project Coordinator or Model Coordinator.

c) The two methods based on Object and Attributes, and UNIFORMAT Ⅱ which forms LOD have been examined.

d) Each level of the design, applied to LOD during the BIM design process, is influenced by the type of object and the change of its quality.

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