"MENSURA EST MODUS IN RES BIM AEDIFICATORIA" MEASUREMENT IS THE CONSTRUCTION MODE VIA BIM

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ABSTRACT:

The BIM method allows to include topography and remote sensing in important way: it is a continuous dynamic, in itinere, not only before the construction but, also, as design verification, after the construction. Understanding the right level of BIM to use is necessary in order to obtain an Opera constructed exactly as was it designed; and to manage the BIM process during the entire construction. This paper supports a precise thesis: the concept of "measure" as a way of implementing BIM. "Measuring" does not only means exchanging data, between design phase and construction phase but, also, identifying accuracy, reliability, , tolerance, modus operandi, "level" of BIM. Identifying and measuring this level is the" way of BIM", since the design, during the building site work, until the opera's delivery. Predefined ways of applying BIM do not exist it depends on the type of work, context, people, equipment, times and resources, including the human skills. Our research group was asked to support two projects. A public work: the Navy Academy recovery; and a private work: the monitoring via BIM-GIS of the technical components laid in the building site.

1. THINK AS ONE

1.1 Introduction

As known Charles Eastman said that to change the result it is necessary to change the procedure; it can be said - theoretically - that the center of this conception is the unity as a category of thought, which becomes, concretely, unity of process and product; unity among the actors involved; unity between the opera's life phases and above all unity of thought. After years of practice, we understand how the effectiveness of BIM starts from a cognitive change in the way of conceiving the design and construction of a work. Since it is difficult and time-consuming to apply BIM as a unitary method at 360 degrees, it is more immediate to segment the application of the method and reduce it to software, to standard or own interpretation. This does not allow saving resources and quality of the result, because it is necessary that the BIM method is implemented using an iterative way, between the design concept and its constructive verification; and using an interactive way, also, between all the disciplines and the actors involved. The BIM method allows to include topography and remote sensing in important way: not only as a project, before the construction but also as verification, after the construction. It is a continuous dynamic, in itinere, not an ex-ante or ex-post approach.

1.2 Methodology and measure

For a congruent design and a construction management, the BIM model must be made dual to the real: this dynamic does not only imply going from the virtual to the real in the smartest possible way (smart object oriented) but it is, also, necessary "to come back from the real to the virtual", always, first of any next step. There is only one modus operandi to implement this BIM temporal iteration: measuring the built to return from the real to the virtual (Fig. 1). The BIM model is modeled on reality, according to the computer graphics development; the reality returns to the model by measurements, also in automatic manner (Kim, Son, Kim, 2013). Through the measurement, from the construction site (built object) you return to the model (designed object), in an "active" way: the management of the relationship, between model and construction during the entire BIM product-process, becomes fundamental (Braun, Borrmann, 2019). It is not only a control action: if the object is built in discrepancy with respect to the design (the BIM model), must be modified or built again.

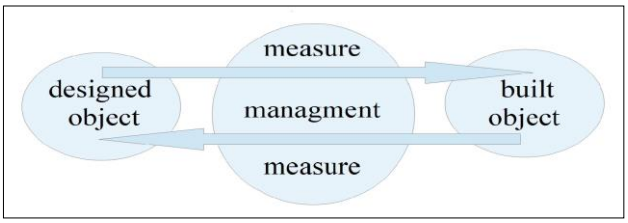

Figure 1. Iterative procedure: model, measure, construction.

The measurement starts from the model and returns to the model itself; and queries, accepts or modifies it. Especially, if the object was made directly in the building site, can be measured and check easy; there isn't need to automatically obtain the ontologies of the objects measured or scanned, necessary and expected, for example, in the research areas such HBIM. In fact, to automatically obtain a BIM survey of the historicized constructions, are necessary more development by the research about neural networks, A.I., deep learning (Koo, Jung, Yu, Kim, 2021).

2. CASE STUDY: A PUBLIC WORK

2.1 The Military Academy Italian Navy headquarters

The first case study (Fig. 2) is the expansion and recovery of the headquarters of the Military Academy Italian Navy. It is an important project (more than 50 million euros) requested by the Navy and entrusted to the Ministry of Transport and Infrastructures, through the "Provveditorato of Public Works" of Tuscany, Marche and Umbria. For both institutions this is one of the first cases of use of BIM and they have requested the support of the University of Pisa: there has been a collaboration

for years between the Provveditorato and the Master in Building Information Modeling of the University of Pisa, www.unibim.it, which has also organized BIM courses for Ministry's Employees. Our BIM research group is required to give support for clarify everyone's tasks and mediate the needs of professionals with the needs of the Works Management.

Figure 2. The Navy Italian Academy, Livorno.

The support was asked to us, regards both design and construction. We have proposed a methodological objective: the BIM approach as a method of expressing the know-how of all the subjects involved in the product-process. We have proposed, also, an objective of content: to identify the specific level of BIM necessary for this specific work, with these specific partners, based on this specific project and according to the BIM knowledge of the specific professionals involved (Eastman, Teicholz, Sacks and Liston, K. 2011). In fact, every Partner have different needs and expectations: the measure of the level of coherence, between the actions of all the actors, is a very complex issue. It is necessary to measure the coherence level between the most important interests of the Partners: for the Publics, is the Information specifications; for the designers, is the project presented; for the construction companies and the suppliers, is the management of their commitment. Based on our experience, measuring this level, during the progress of the work step-by-step, become essential. The whole situation is more complex because in the Project there are two parts: some new buildings construction and the recovery of the main old Building: Palazzo Allievi (Fig. 3). In addition, during the entire construction time, any Accademia activity can be suspended.

Figure 3. The old building "Palazzo Allievi"

We propose to implement an iterative method: between the conception of a step and its verification; and interactive: between the different knowledge of the professionals involved.

2.2 Methodology

To meet the needs highlighted, it was decided to set up a BIM Team, bringing together the different BIM skills of the professionals of the three Public Partners (Fig. 4). The BIM Team is a Control Room of the whole procedure, which must continuously support the Procedure Head (R.U.P.: Responsabile Unico del Procedimento). During the project the Team will interact with all the Private Partners, about every BIM aspect. We understand that the first one necessary requirement is to have a common language; the second one is to identify a data exchange platform where to use this common language.

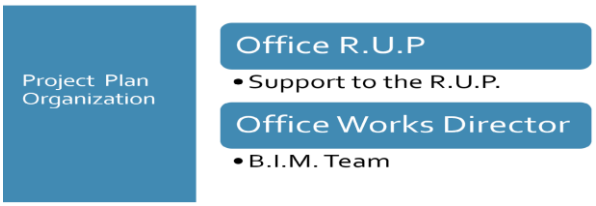

Figure 4. BIM Team position in the Plan Organization

The second step was to clarify a workflow for the professionals of the Public Partners, according to the needs of their internal procedures, to the different tech competences and to the BIM software knowledge. It is very important to plan, also, the h/s resources: in the BIM approach, at every step, it is necessary to know well who is in charge about what and which software he can use. We have suggested our vision and decided a customized management plan: a synthesis scheme of the h/s resources, combined with the actors, is showed in Fig. 5.

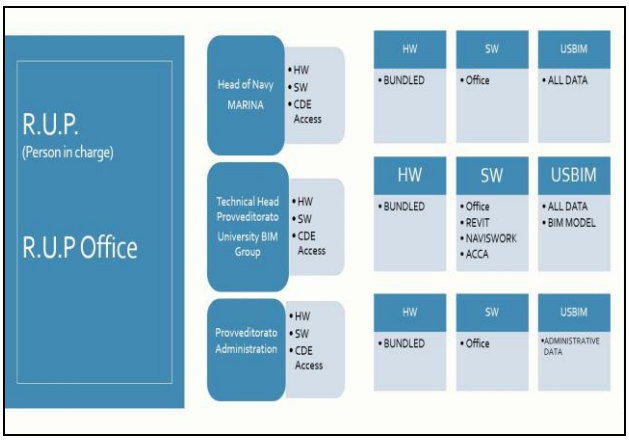

Figure 5. Professionals' commitment and software assigned

2.3 Current BIM procedure of public works (scheme)

We have considered the normal practice about the use of BIM for the public works in Italy, that provides (t =time):

- t = 0: by law, the Public Administration provides bidders with a survey of the "current state" of the buildings and the land (Ministerial Decree 560/2017 MIT);
- t = 1: based on this survey, the competitors deliver their design proposal setup in BIM including the object-oriented 3D model;
- t = 2: the Public Partners (Provveditorato and Marina in our case) receive a copy of the project;
- t = 3: based on this project, start the building field;

- t = 4 the Public Partner checks the progress of the construction work;
- t = 5 at any delivery of scheduled construction works, the Private Partners deliver to the public Partners the improved BIM model, at this step called "as-built".

2.4 Critical aspects and our solutions

We have identified some critical aspects in this practice and proposed some solutions, based on the concept of measurement as a verification of the BIM procedure and model.

1. between the times t = 1 and t = 3, the BIM model verification by the designers and delivered to the Public Partners is totally absent. This model was made at the time t = 0. We observe that the winning bid of the tender was awarded including the BIM model designed at the time t = 0. Therefore, it is an offer based only on the measure of the proponents. All the rest of the procedure, up to the construction of the works (and beyond, the management phase) will be a consequence. In fact, in the BIM process, everything is strictly connected: it is an added value that, in case of beginning errors, can become a weakness. Therefore, we have proposed to the Public Partner a verification of the BIM model from this first initial step. Please note, that Private Partners have checked the survey, received in the call for tender; they have made a re-measurement of the buildings and of the site. In fact, in the BIM method, final quantities, prices and times depend on the correctness of the early stages directly. It is necessary to understand the concept of responsibility for the verification of the model which is very important for the real times and costs, during the development of the construction site.
2. There is a gap between the BIM skills (and economic resources) of Private and Public Partners. We believe that the two previous points can be resolved together. We propose to the Public Partner to have an agreement with the Private Partner about the BIM project at time t = 2.
3. The Private Partner can autonomously carry out this check and assumes the legal responsibility for verifying the BIM model that it delivers to the Public Partner: this model must be a coordinated model (where the clash detection between the architectural, construction and MEP elements have been resolved). Our proposal was accepted by everyone because it is a guarantee for every actor in the process. It is advantageous for private subjects, who can correct errors without paying penalties, and it is advantageous for public subjects, who can obtain a greater guarantee for compliance with the times and the quality of the materials.
4. There is the need of a continuous updating of the BIM model with the exact construction materials. In fact, in Italy by law, the C.I. Capitolato Informativo (Informative Specifications) of the call for tender, can describe only the performance requirements of the materials. The construction component that will really be used, will be chosen by the Private Partners (according to the performance requirements). The main need of the Provveditorato becomes to check the updating of the correspondence, between the construction and the request of the Information Specifications; therefore, it is important that the whole procedure must remain under the R.U.P. supervision.
5. The topic of the effectiveness of BIM in project management (Fazli, Fathi, Enferadi, Fazli, Fathi, 2014.) regards, in our case, a long construction time: four-five years; and a structured and adaptable organization system becomes necessary. Our proposal, for the points 4 and, 5 was a procedure that all Partners had to sign.

2.5 Procedure proposal

We have considered:

- the strategic importance of understanding what extent the model can and should be updated;
- the number and diversity of BIM knowledges of professionals;
- the need to identify the most suitable software resources (and to teach these resources to professionals of the Public Partners, as it was requested to us);
- the executive project by the designer containing more detailed level with respect to the requests of the call for tender: the LOD D for the "executive BIM model" (instead of LOD B); the LOD F for the "BIM as build model" (instead of LOD D); the implementation on Autodesk Navisworks of the detailed time schedule, required only in Microsoft Project.

Based on the described points, the procedure we have proposed can be schematized with the following sequence:

1. BIM "executive" model delivery (verified by the designers).
2. Model checking by the Procedure Head of the Public Partner.
3. Model approval by both Procedure Head and Control Authority.
4. Model validation. Each BIM model element is linked to the acceptance checks, the measure of the built object, the technical data sheets, the reference drawings, the materials brought by the companies (which must correspond to the CI requirements) and every change introduced by the designers.
5. BIM model (becomes "official") uploading in a virtual environment editable only by the Public Partners.
6. Starting of the Construction site.
7. BIM mode requested for any technical component changes proposed by the Private Partners the to the Construction Management.
8. (Under BIM Team control) the accepted proposals are uploaded by the Private Partners professionals in the BIM model that becomes "as built version".
9. The procedure from point 7) is iterative.

According to our procedure proposal, the BIM "as-built Model" grows up step-by-step simultaneously with the construction and everything remains under the control of the Construction Management. If a big variant of the project becomes necessary, will be excluded from this procedure and will checked by the more complex approval procedure requested by the law (Ministerial Decree 50/16). The general framework of our proposal was articulated on more detailed schemes. For example, in the Fig. 6, there is a workflow scheme of the actors involved in the construction phases control. we propose a hierarchy between actors - building site inspectors, head of technical sectors, works Direction - ever biunivocal to the BIM model uploaded. In fact, to upgrade the constructions means to upgrade the BIM model and vice versa. according to our vision,

the way about new research in the area computer graphics/construction will be ever more open (Narahara, 2017). Our procedure, also, answer to the Public Partners request to avoid any (physic) overlap of the actors competence allowing, at the same time, to a continuous link (digital) between them and between their building site reports.

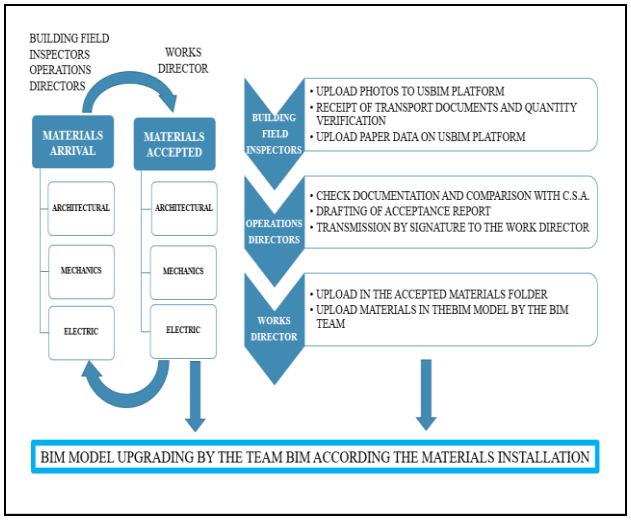

Figure 6. The Procedure proposal scheme

2.6 Data management

Due to reasons of security (there is military Institution) there are different needs for data management by each Partner. We organize a multi-level responsibility plan:

- the Common Data Environment must be setting and/or managed by the Provveditorato and the Navy (consequently by the BIM Team);
- all the Partners can use the CDE programs for viewing the model and for editing the linked electronic job journal;
- for the other CDE parts, the access credentials are assigned based on the level of responsibility of each individual professional;
- the software we have chosen: Primus IFC (economic calculation program), Revit (BIM modelling), Autodesk BIM360 docs (CDE), Autodesk A360 (visualization), USBIM (BIM Management System).

The Public Partner spend many times and economical resources to control the correspondence between the technical elements, planned in design, and which used in the opera. To avoid any mistake, we planned some professionals groups in order to management, easier, the building site works in progress and the correspondent model uploading too. In the Fig. 7 a coordinated scheme of actors, software and workflows. It was not easy, because, generally speaking, in the public Administration people having more building site experience have a limited BIM knowledge. Using the BIM method, the concept of measurement was the base to verify the link between design and construction (previous paragraphs and diagrams). Measure as physical verification and measure as theoretical verification. The first one must characterize, cyclically, the "to build - built" dynamic; for this reason, margins of measure error - about architectural, technical and structural aspects - are foreseen in the call for tender. The first one must characterize, cyclically, the "to build - built" dynamic; for this reason, margins of measure error - about architectural, technical and structural aspects - are foreseen in the call for tender. The second one is connected to the concept of BIM level, which becomes the core of the whole economical, technical and human resources management to allow saving costs and times. Both, management of intangible and tangible assets depends by the manager's BIM mental dimension.

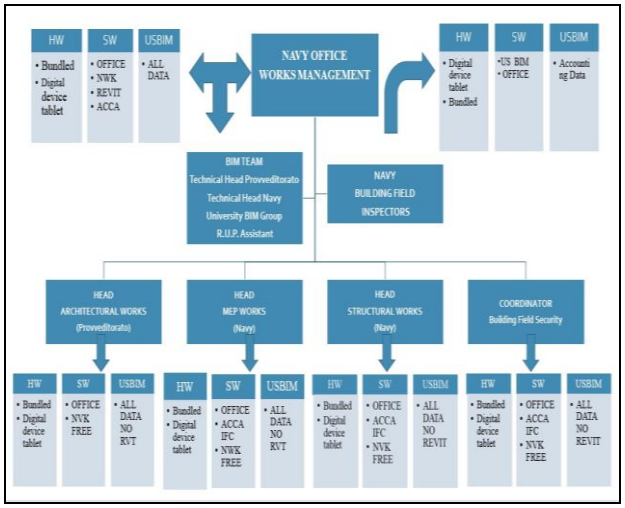

Figure 7. Construction phases: actors, software, workflows.

The correct progress of the project is a consequence of the BIM management which identifies, for example, the certainty margin relating to the quantities of supplies and, at the same time, the knowledge margin of the skills of the actors.

2.7 "How much BIM?"

The concept of measurement can be a way of implementing BIM because, not only it means exchanging data between design and construction, but also because it identifies the accuracy, the reliability, the quantity, the margin, the level of BIM, the modus operandi. The case study proves how the BIM management starts with the ability to identify how much BIM is needed for a specific work: this ability it isn't an option but it is an integral part of the BIM management process during the entire work construction. Identifying this level is the way of BIM. Predefined ways of applying BIM do not exist: the way depends on the work, on the context, on the people, on the equipment, on the time and on the expected result. In BIM dimension, the link between design and construction is not only linear but it is cyclical and it includes, also, the concept of verification by measure (Fig. 8). To sum up, the BIM process and model together, is not a standardized or homologated method: it enhances the professional personality and allows to set up a system work and, more, to be a crew.

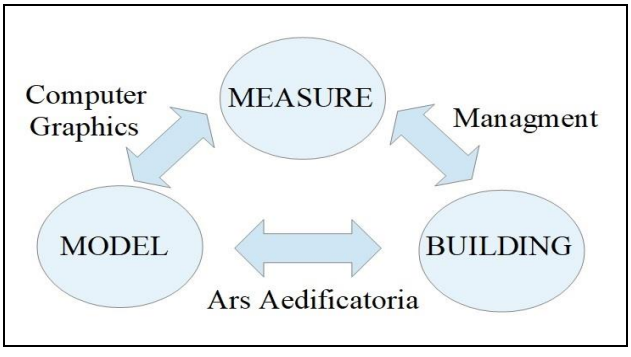

Figure 8. Phases and knowledge: cyclical cognition approach

3. CASE STUDY: A PRIVATE WORK

3.1 Large scale Private Work

In the second case study, an important private Company asked our BIM research group to project a system to support the laid in the building site of their products, independently by the construction company and worldwide (Fig. 9). We have accepted this project, because can become a prototypal case and, also, because we can develop a project proposal in the interesting BIM-GIS area, where there is more and more research. (Deng, Gan, Das, Cheng, Anumba, 2019). In addition, we can document how, in the application of the BIM method, there is not a cognition or practical problem of passage of scale from photogrammetry to remote sensing: the heart theoretical and practical remains the identification of the level of BIM ontology. It is ever necessary to be able to find BIM "tailor-made" strategies and solutions to approach any situation and to manage it day by day (in the office, in the construction site, by remote, physically).

Figure 9. BIM and GIS integrated application

3.2 The Project proposal

During the installation of the construction components, the system must allow to collect certain data and make such data automatically usable by designers, builders and managers. The professionals can be the manager for the construction work, or the manager of the new infrastructure, after it will build, both must have the possibility to manage a series of control and planning activities, on the basis of the data collected by our system. The web app must have 2 levels that we could diversify into the manager user (UM) and the operator user (UO). To respond to these requests, we have created a BIM-GIS system: the main elements are a web app and a coding reported on the construction elements, during their fabrication.

3.3 Usage pattern

The usage pattern is designed for two different users, one is in the building site: the user Operator; the other one can be remotely, working in his office: the user Manager (of the installation Company, of the future management Institution, of the Authority control). This is the sequence we have setting for the user Operator:

1. with his smart device (tablet, smartphone ...) he accesses the web app, using the credentials he has received, from his "user Manager", responsible of the project by remote.
2. with a smartphone, he scans the QR code of the construction component in the building site.
3. the web App recognizes and reads the QR code: it collects data about the information linked to the QR code, to which the web app adds the geolocation, the time and date, the user Operator ID.
4. the user Operator, via web app, sends the data he has acquired to the reserved virtual area of his user Manager.
5. following the sending: the web App, in real time, loads a new line with the data that was acquired on site in the reserved virtual area of the user Manager: IFC BIM model and any documentation related (in addition to the lot information, the GIS geolocation, the date and time of installation, the ID user Operator).
6. When the new line is loaded in the reserved virtual area of the user Manager, the system connects the related certificate.

This is the sequence we have setting for the Manager user generally working by remote:

1. he asks for the activation credentials provided to him when his Company has signed a specific agreement, at the purchase of the construction components (in addition to the number of user Operators on site, who can receive the APP and the duration of validity of all credentials);
2. he accesses via remote PC, the reserved virtual area of the APP and obtains the information that comes from the reading on site, via the QR code: product standard, nominal geometric information, production line, production date and, if requested by the customer, the production lot of components (in addition to the lot information, the GIS geolocation, the date and time of installation, the ID user Operator);
3. he sees the photos in the APP;
4. he downloads the documentation of that component, identified by the QR code from the APP;
5. he downloads, in IFC format, the BIM model of that component, the connected data and the information collected during the installation;
6. he integrates his design/project with this information uploading, also, the App data.

The web App and the BIM technical elements libraries can be used independently or combined (Fig. 10): it depends only on the type of user, because the system is flexible.

Figure 10. The picture explains the concept proposal

Using this App, the Operators can allow users Manager to have access, remotely and in a structured way, to the information collected during the installation. For example, the user Manager can obtain the certificates of the various lots installed, have the geolocation data in order to control work's schedule and check the correctness between the component actually installed and the component envisaged by the design. The design Offices of the Companies, if work in BIM, can achieve maximum performance with the web App: they can integrate their BIM project, in real time, with the BIM data collected during the installation in easy way (via copy / paste). The App allows all the actors (by remote and in presence) to follow the project phases simultaneously.

3.4 Conclusion

This paper highlights a precise thesis: the concept of "measure" as a way of implementing BIM. In supporting the design and execution of the two case studies, we have documented needs that we consider useful to extend the BIM usability. Especially, in the Italian Public Works, legal clarifications would seem necessary to recognize the 3D BIM construction model an appropriate legal value for the benefit of the entire design and construction procedure. An object-oriented 3D model of the work, detailed according to the needs, should be placed at the basis of the public call for tenders (as happens, often spontaneously, in the private sector). We believe that it will be the way, even if, at present, time and dissemination of knowledge is still needed, especially in the State Administrations. A maturity of experience in the conscious use of BIM is documented by the use of the concept of measurement as a verification of the correspondence between what has been built and what has been designed. Interdisciplinary research is more and more open; for example, the computer graphics offers important development opportunity in order to measurement the construction via point cloud (Bassier, Vincke, Mattheuwsen, de Lima Hernandez, Derdaele, Vergauwen, 2019). The first case study documents how different Partners, using BIM, can act like a single team: the BIM model-process verification by an iterative measure, was considered a guarantee of correctness for the benefit of all the actors involved. The Navy Academia Project represents an important example of collaboration between State Institutions: their different needs were coordinated, effectively, towards the common goal. A relevant aspect in the two cases study is the use of IFC as a priority request; people have understood the importance of the interoperability, implemented continuously by the research (Venugopal, Eastman, Teizer, 2015). We have observed that, in the constructive BIM approach, the concept of measurement can have really various levels (Bosché, Ahmed, Turkan, Haas, Haas, 2015). There is a measure of space, "horizontal" and a measure of time "vertical": the case studies showed that these two measures are closely connected in the BIM we have used. For the digital reproducibility of the project clone, the measure is a modular concept: as a measure of the extension of the object (quantity); or more recently, as a measure of density of constructed matter (quantity and quality); or nowadays, as a measure of reproducibility of the constructive concept of a surface (quality): a strategic topic, starting from the HBIM, where current research is oriented across input assumptions, point cloud properties and shape classes (Berger, Tagliasacchi, Seversky, Alliez, Guennebaud, Levine, Sharf, Silva, 2017). For the reasons set out, we think that there will be more and more applications between the BIM method and the world of measurement: two areas of knowledge and research that have in common, as method and contents, transparency and clarity of conception and application.

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