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Framework for the Modeling of the Supply Chain Collaborative Planning Process

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***Abstract*—**In this work, a framework to model the Supply Chain (SC) Collaborative Planning (CP) process is proposed. The main contributions of this framework concern 1) the presentation of the decision view, the most important one due to the characteristics of the process, jointly within the physical, organisation and information views, and 2) the simultaneous consideration of the spatial and temporal integration among the different supply chain decision centres. This framework provides the basis for a realistic and integrated perspective of the supply chain collaborative planning process and also the analytical modeling of each of its decisional activities.

***Keywords*—**Collaborative Planning, Decision View, Distributed Decision-Making, Framework.

I. Introduction

In recent years, many researchers have emphasized the importance of the Supply Chain Management [1]-[6]. In this context, processes, traditionally developed in an intra-Enterprise level, should be adapted to be designed and executed by different enterprises, separated and with distinct characteristics, but at the same time belonging to the same Supply Chain. Among those processes, one of the most relevant ones, the Operations Planning Process, (which in collaborative contexts is commonly known as CP Process) is approached in this work.

Many literature definitions about the CP Process concept exist. The CP is defined in [7] as the coordination of planning and control operations across the Supply Chain, i.e., production, storage and distribution processes. Another definition, which has been useful is that of [8], in which several Decision Levels are identified, from the most strategic through the programming level, and in which the Operations to be planned, managed by different "entities" of the SC collaborating among them are placed.

From [8], CP it is defined as a SC decentralised (distributed) decision-making process in which different decisional units (or Decision Centres) have to be coordinated to achieve a certain level of SC performance. But this coordination is narrowed to a tactical level (Agreggate Planning) and to a tactical-operational one (Master Plan), and therefore not including other levels such as the strategic or the programming/sequencing ones. In this CP context, as it will be explained later, the interdependence relationships among the different Decision Centres are of special relevance, either among those placed in the same "decision level" (spatial interdependences) or in different (temporal interdependences). The design, analysis, adaptation, monitoring, control and improvement needs of the CP Process are becoming higher, which has led, mainly since the beginning of this century, to the publication of many works addressing the importance of its modeling, from multiple points of view: functional, analytic, etc. Nevertheless, for an efficient and effective modeling is essential to take into consideration all the aspects influencing it as well as the relationships among them. This justifies the development of a framework aiming to model this SC CP Process in an integrated manner [8]-[13].

Based on those previous works, a framework which addresses two main contributions is proposed. Firstly, it integrates four different modeling views: physical, organisation, decision and information. Together, these different perspectives facilitate the development of an integrated model for the CP process, leading to more realistic and versatile applications that can be incorporated into complex SCs. In particular, the proposed framework uses the decision view as the principal component, but it is complemented and enriched by other views which are necessary as the CP process makes decisions concerning resources/items (physical view) which are specifically arranged (organisation view) and specific information (information view) is required to effectively model the CP process. Secondly, it highlights the importance of distributed decision-making contexts [14], explicitly considering two interdependent types of relationship: temporal (between decision centres belonging to different decision levels) and spatial (between decision centres belonging to the same decision level). It is also important to remark that such framework is not only conceptual, but also analytical, since it includes either all the necessary aspects to conceptually model the CP Process (Macro-Level) or the aspects to facilitate the formulation of Analytical Models as an aid to the Decision-Making of the CP Process (Micro-Level).

This paper focuses on the conceptual part at the Macro-level. Some relevant inputs from other Views are pointed out although only the Decision View is explicitly analyzed (Macro-Decision view). The Decision view is closely related to Decision-Making and therefore to activities of a decisional nature, which mostly define the CP Process. The Macro-Decision view presents all the aspects which allow to model the CP Process itself since a "conceptual" point of view, that is, defining all the Decisional activities and their interdependence relationships.

The rest of the work is arranged as follows. Section II

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describes the framework as a whole while Section III and IV focus on the Decision view and the Macro-Decision view respectively, this latter one explicitly approached to model the SC CP Process. Finally, in Section V, some conclusions and future research is provided.

II. Framework Overview

The CP process is mainly considered a decision-making process since most of the activities within this process are of a decisional nature. Nevertheless, CP decisions are made in a predetermined sequence (decision view) on elements such as physical and human resources, and items (physical view), which are specifically arranged (organisation view), and specific information (Information View) is required to properly model the CP process. Therefore, there is a need to relate all these Views in order to get more realistic and integrated models of the CP process.

The framework identifies the structure and the relevant features of any SC based on the previous four different views.

A brief outline of each view is provided for clarification purposes:

1) *Physical View* identifies how a specific SC is configured, that is, the Resources and the Items taking part ofthe Decision-Making Process.
2) *Organisation View* shows which are the relationships among the resources represented in the physical view, an important aspect which strongly influence the decisional view.
3) *Decision View*: as it will be later explained, it is divided into two sub-Views: Macro-Decision and Micro-Decision views. The first one identifies which are the "Decision Centres", their Interdependence relationships and the Decisional Activities making up the CP Process. The second, strongly influenced by the Macro-Decision view, identifies all the aspects that internally characterize the decision-making process of each Decision Centre facilitating their analytical modeling.
4) *Information View* may be considered as the "integrated view" as it collects and represents the necessary information from the other three views to support the SC CP Process, which implies the information sharing among them.

Due to space restrictions, only the part of the framework which relates to the Macro-Decision view is approached, which in turn allows the SC CP process modeling from a "conceptual" point of view. Therefore, Micro-Decision view aspects will not be considered although all the inputs needed from the other interacting views will be briefly described.

The framework and its four views: Physical, Organisation, Decision and Information, are depicted in Fig. 1.

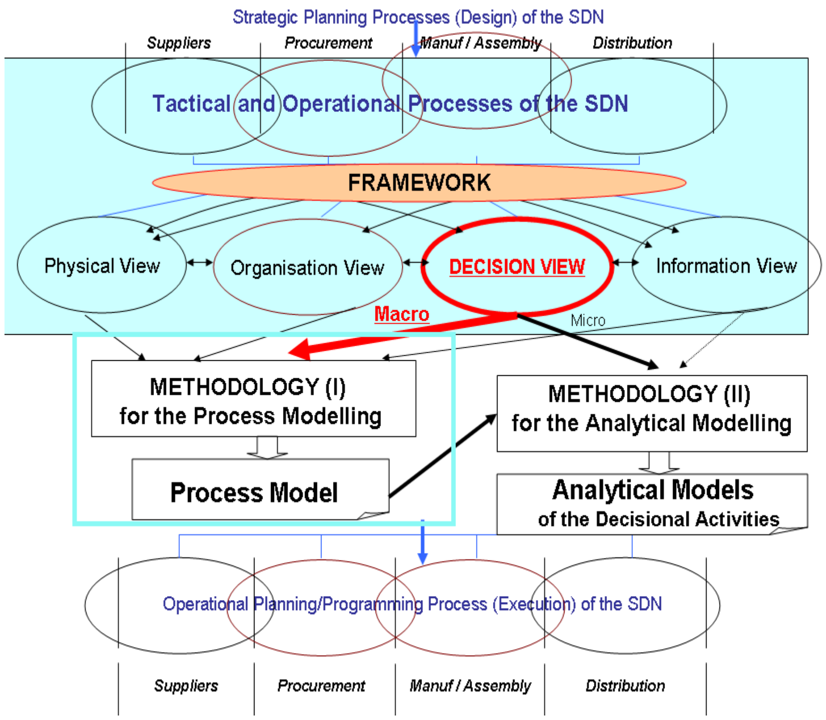

Fig. 1 Framework for the modeling of the CP Process

This framework feeds two Methodologies. Firstly, the Methodology (I), which encompasses all the steps to model the SC CP Process from a conceptual perspective and secondly, the Methodology (II) to develop analytical models in each of its Decisional Activities. These two Methodologies are not approached in this paper.

III. Decision View Description

The decision view is divided into two sub-views: macro-decision and micro-decision views (Fig. 2).

Although only the macro-decision view is considered in the present paper, it is important to briefly indicate some relevant aspects of the Micro-Decision view.

The macro-decision view analyzes which Decision Centres are implied in the Decision-Making Process and, taking into account the Decisional Level where they are placed and their Interdependence Relationships (Temporal and Spatial), which are the Decisional Activities of the CP Process and their execution order. The former allows to set up the basis to respond to the following questions: 1) Who performs the Decision Activity?, 2) When is the Decision Activity performed? and 3) What is performed (at a Macro level) in the Decisional Activity?

The Micro-Decision View individually analyses each of the previous identified Decision Centres, aiming to set up the basis to respond to the following questions: 1) What type of specific Decisions are taken in each Decisional Activity (Decision Variables)? and 2) How is the Decision Activity (Decision Model and Input Information) performed? The micro-decision view presents all the necessary aspects to the detailed definition of the Decision Variables, as well as the Decision Model (made up of a Criteria and a Decisional Field/Contraints) and the Input Information (Fig. 2). Therefore, this micro-decision view, facilitates the development of Analytical Models as an aid for the Decision-Making Process in each Decisional Activity (and consequently in the Process as a whole), taking into consideration the Interdependence Relationships previously identified in the macro-decision view.

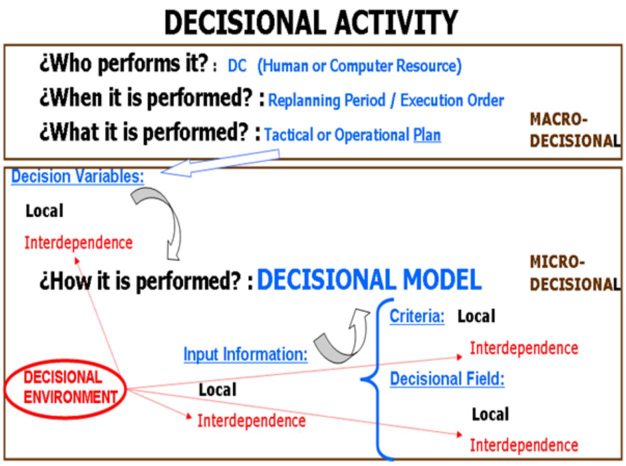

Fig. 2 Macro-Decision & Micro-Decision views of the CP Process

In the next sections, only the macro-decision view is approached.

IV. Macro Decision View

Based on previous works [14], [15] three main blocks at the macro-decision view are considered: definition of the Decision Centres (DCs) implied in the CP Process, characterization of the Interdependence Relationships (Temporal and Spatial) among them and the identification of the Decisional Activities of the CP Process and their execution order.

A. Decision Centres Definition

It is relevant to stress that the Macro-Decision view is based on the fact that the initial Decisional problem of the CP Process may be divided into several sub-problems, belonging to the various DCs. At the same time, a collaborative context implies that those sub-problems are not fully independent but they are overlapped, and therefore, leading to Interdependence Relationships, either from a Temporal or Spatial points of view [16]. At this point, it is necessary, for a better understanding of the DCs definition, to show some concepts of the Physical and Organisation views.

In the Physical view, some concepts such as “Stages” (Suppliers, procurement, Manufacturing/Assembly, and Distribution), “Nodes”, and “Arcs”, which connect dyadic Nodes and represent the flow of items from an origin to a destination node, are defined. Besides, each of these Nodes and Arcs perform the “Processing Activities”: Production/ Operations (P), Storage (S) and Transport (archs).

In the organisation view the “Organisation Centres (OCs)” are defined, which are responsible of the execution and control, and in some cases of the decision-making, of one or more Processing Activities previously identified in the Physical view. These OCs are placed in two “Organisation Levels”, that is the Tactical and the Operational ones.

In the macro-decision view the different DCs are defined (Fig. 3). This DCs definition is strongly influenced by the organisation view. A DC corresponds to a “decisor” (human or computer resource), which in an automated manner or not, is responsible of the Decision-Making of one or more OCs. The made decisions (tactical and operational plans) affect to the “Processing Activities” of which were responsible the OCs.

Once the DCs have been identified and the corresponding organisation level has been assigned (in this case called decision levels), it is time to establish not only the spatial interdependence relationships between the DCs at the same decisional level, but also the temporal ones between the DCs at different decisional levels. This allows to have a first approximation of how centralised or decentralised/distributed is the Decision-Making Process in each of the Decision Levels. This “decisional map” is the input to the second block, in which the DCs Interdependence Relationships are characterized.

B. Interdependence Relationships Characterization

Once the DCs in each of the Decision Levels are defined, in a second block the type of Interdependence Relationships existing among them are determined, either temporally (among Decisional Centres belonging to different Decisional Levels) or spatially (among Decisional Centres belonging to the same Decisional Level).

The fact that more than one DC in a certain Decisional Level exists imply decisions not to be centralised (in this case from a spatial point of view), but does not necessarily imply that these are fully decentralised, but distributed (in case of collaborative contexts). This distributed Decision-Making scenario (more or less hierarchical) is of special relevance when characterizing the DC Interdependence Relationships. At this point, it is important to know how the Macro-Decision view and the Information view are related since these interdependence relationships require the transmition of a certain type of information among DCs. Since a Macro point of view, this information may be of two different origins.

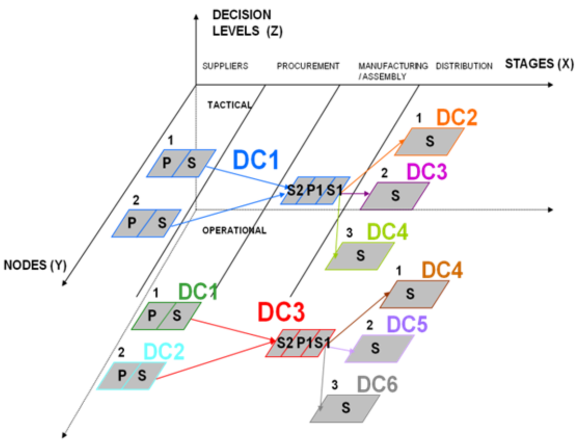

Fig. 3 Macro Decision View_Block 1: Decision Centres definition

In one hand, that information which comes from decisions already made by others DCs and on the other hand, that which concerns to certain attributes characterising different aspects of other DCs. These two types of information are known as Joint-Decision Making and Information-Sharing, respectively.

In Fig. 4, the Information view concepts needed to characterize the Interdependence Relationships between a "Top" DC (DC^T) and a "Base" DC (DC^B) are depicted. First, DC^T sends and Instruction (IN_k) to DC^B, which is composed by one hand of the part of its previously made decision which affects DC^B (known as Global Variables-GV) and by the other hand information which may help in their joint coordination/collaboration Decision-Making Process (known as Global Information – GI). Before sending that IN, CD^T could have anticipated (ANT_k) some relevant aspects of DC^B in order to enhance the Process. Secondly, in non-hierarchical schemes, the DC^B could send back a counterproposal to DC^T within a Reaction (R_k).

There may be several cycles k IN_k-R_k during the joint Decision-Making Process. Finally, both DCs agree and implement their tactical or operational decisions.

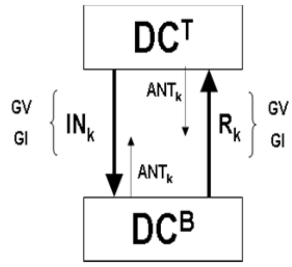

Fig. 4 Information view (Macro) for DCs Interdependence Relationships

TABLE I
MACRO DECISION VIEW_BLOCK 2: CHARACTERIZATION OF THE INTERDEPENDENCE RELATIONSHIPS

Parameters	Attributes
Interaction Nature	*Temporal*: The interaction is produced among DCs placed in different Decisional Levels, that is, Tactical and Operational. Spatial: The interaction is produced among DCs placed in the same Decisional Level.
Interaction Type	*Null*: No interaction exists. That means that DCs are taking their Decisions myopically, that is, there are neither Joint-Decision Making nor Information Sharing, or what is the same, there are neither IN nor ANT. *Hierarchical*: An interaction exists. DC^T inicializes the jointly Decision-Making Process by sending an IN to DC^B . In this case there is no R, so that the "jointly-decision" flow only goes in one direction. *Non-Hierarchical*: An interaction exists. DC^T (in this case it could be the DC which inicializes the jointly Decision-Making Process) sends an IN to CD^B and in this case there is R. In fact, there could be several cycles k IN-R . This case is usual in negotiation processes.
Objectives Sharing	*Organizational*: This is the case when DCs aim to achieve a common goal, previously defined and agreed, but at the same time keeping its own goals. In that sense, they are interacting as if they were a "team", and they are really "collaborating". It is usual the utilization of fictitious incentives and penalties, even other kind of information (shared by means of GI), in order to warn the another DC which consequences has its decision in the overall common goal. In these contexts are usual the "agreements" instead of "formal contracts". *Non-Organizational*: This is the case when DCs don´t aim to achieve a common goal, but at the same time they understand that may benefit themselves of a jointly Decision-Making Process. In that sense they are just "coordinating". It is usual the utilization of real incentives and penalties (shared by means of GI) and the use of "formal contracts". This "coordination" process doesn´t seem suitable for medium and long term relationships.
Anticipation Degree	*Null*: No ANT exists. DC^T doesn´t anticipate any component from the Decisional Model of DC^B (neither from the Criteria nor from Decisional Field/Constraints). The former doesn´t imply that there is type of interaction is null, since at least there is an IN (with GV and probably GI). *Non-Reactive*: An ANT exists. DC^T anticipates some components from the Decisional Model of DC^B, but only from its Decisional Field/Constraints. It is called "Non-Reactive" because it doesn´t depend on the IN. *Reactive*: An ANT exists. DC^T anticipates some components from the Decisional Model of DC^B, but in this case either from its Criteria or the Decisional Field/Constraints. It is called "Reactive" because it depend on the IN. In practice, it is more complex to calculate it.
Behaviour	*Oportunistic*: This behaviour is common in Non-Organizational contexts, in which the DCs don´t aim to achieve a common goal. Besides, not only attempt to achieve individual goals, but it doesn´t exist fair play. Most of the cases come out real incentives o penalties which change the way the DCs behave. *Non-Oportunistic*: This behaviour is common in Organizational contexts, in which the DCs aim to achieve a common goal and obviously there exist fair play. However, this "Non-Oportunistic" behaviour may also appear in "Non-Organizational" contexts.

Based on the concepts explained about Fig. 3, the Macro-Decisional view characterizes the interdependence relationships among DCs within the description of five parameters, being each one of them, in turn, made up of several attributes (Table I).

Finally, the concept of Decision Environment of a DC [17] is also defined, formed by those DCs which have some kind of interdependence relationship with. The Macro-Decision view highlights the fact that the DC Decision Environment of a generic DC^M is formed either by those which interacts temporally (DC^{Tt}, DC^{Bt}) or spatially (DC^{Te}, DC^{Be}) (Fig. 5).

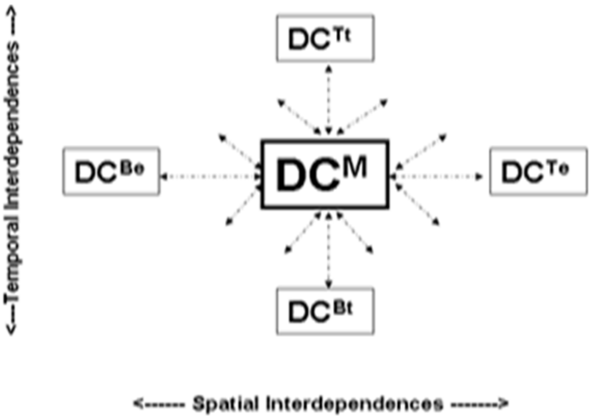

Fig. 5 Decision Environment of a generic CD^M

C. Decisional Activities Identification

In the third block the necessary concepts to identify each of the Decisional Activities of the SC CP Process are identified, as well as their execution order, since in a Collaborative context, they are all interconnected (Fig. 6).

It is necessary to stress that the DCs' definition is not the same as the identification of decisional activities. For example, in the case of a non-hierarchical negotiation process carried out by two DCs, depending on the number of cycles in the decision-making process, a DC may lead to more than one decisional activity as a result of its successive activations generating proposed decisions or plans.

It is assumed that two DCs placed in the same Decisional Level present the same Replanning Period (RP) and Horizon (H). In case not, an initial effort to synchronize them should be made.

Within the RP it is possible to know when a DC placed in any of the decision levels should make its decisions, that is, when it has to be executed or activated, leading, as was noted before, to one or more decisional activities.

This implies that all the Decisional Activities of the CP Process are periodically activated (as it usually happens with the Decision-Making in a Tactical/Operational level). Nevertheless, as they may be several of them being executed at the same time, their priority is based on which DCs are "top" ones (DC^T). The rules to consider a DC as a DC^T are as follows:

1) DCs placed in the Tactical Decisional Level (TDL) are always activated before DCs placed in the Operational Decisional level (ODL), and therefore the last ones are always considered "base" from a temporal point of view (it seems obvious the hierarchy). In this case, the Replanning Periods and the Horizon of the DCs placed in the Tactical Decisional Level are multiples of the DCs placed in the Operational one. Besides, these DCs placed in the Operational Level review their Operational Plans with a higher frequency (shorter Replanning Periods) so that the Decision-Making only matches in determined instants of time.
2) Given one of the two Decisional Levels (Tactical or Operational), a DC is activated before all the "Base" from a spatial point of view. The "top" DC is therefore activated just an instant before despite sharing the same Replanning Period. This is often due to power-related issues.

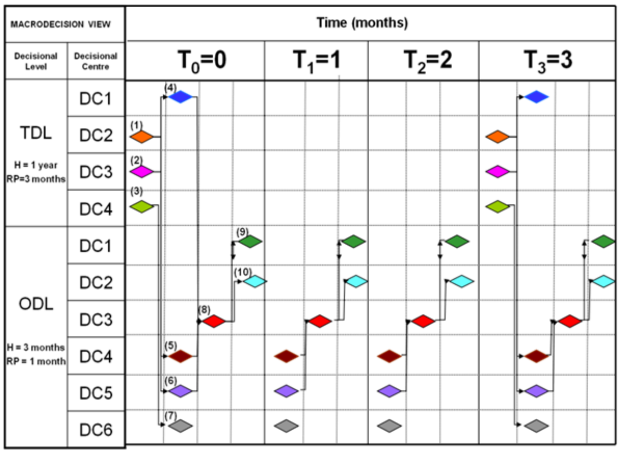

Fig. 6 Macro Decision View_Block 3: Decisional Activities identification of the CP Process

V. Conclusion

The aim of the Framework presented in this paper is to support the integrated modeling of the SC CP process, and particularly, the macro-decisional view.

The main contributions are:

1) The integration of four different modelling views: physical, organisation, decision and information and the relationships between them. This facilitates the development of integrated models of the SC CP process, leading to more realistic and versatile models that can be applied to any complex SC. The decision view is regarded as the principal perspective but is complemented and enriched with the other views. Most other studies have emphasised the importance of the decision view without explicitly taking into account its relationships with the other views.
2) The simultaneous consideration of two interdependence relationships types, temporal (among decision centres belonging to different decision levels) and spatial (among decision centres belonging to the same decision level), both typical from distributed decision-making contexts, in which is embedded the CP process. Studies that address

temporal or spatial integration are lacking. Most of them are only valid for specific situations, and do not cover the necessary and simultaneous integration that may emerge in a CP process. In addition to that, a set of parameters/ attributes to characterize the DCs interdependence relationships are explicitly considered.

It is also important to emphasize that such framework is not only conceptual, but also analytical, since it includes either all the necessary aspects to conceptually model the CP Process (macro-level) or the aspects to facilitate the formulation of analytical models in each of the DCs decisional activities identified in the CP process (micro-level).

Finally, it is remarkable to highlight the lines of research that based on this Framework, are being carried out by some of this paper authors.

On one hand, the development of a Methodology (I) to guide the "conceptual" definition and integrated modeling of new or existing SC CP decision-making situations. This Methodology (I) describes the sequence of the information collected from the different views, that is, physical, organisation and macro-decision and the required details of each one in order to model the SC CP process. The information view is composed of the data captured from all the other views. On the other hand (also depicted in Fig. 1) the development of a Methodology (II) [18], [19] which establishes the steps for the analytical modeling (based on mathematical programming) of each of the DCs decisional activities identified in the SC CP process. This methodology (II) not only takes into account the Framework concepts (mainly in the micro-decisional view) but also the "conceptual" Model of the CP Process previously obtained within the application of the Methodology (I). This methodology (II) assists the model maker in the process of defining the mathematical programming models of each DC by considering their previous characterized interdependence relationships.

Additional research refers to the development of a computer-based tool [20] based on both methodologies (I and II) which is providing further validation of the SC CP Process.

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