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Graphical modelling of the physical-organization view for the collaborative planning process*

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Abstract

One of the core processes in Supply Network Management is Collaborative Planning (CP). The importance of this process justifies its modelling. Although CP is fundamentally a decisional process, a complete representation of the CP needs five views: physical, organization, decision, information and function views. The main objective of this paper is to guide the users during the modelling of the physical-organization view by providing the relevant aspects to be modelled, their corresponding modelling elements and the definition of the deployment structure of the physical-organization view that facilitates its understanding and integration. The resulting physical-organization model can be used as a foundation for developing decision making tools that consider these physical and organization aspects.

Keywords: process modelling, physical view, organization view, supply chain, collaborative network

1. Introduction

Collaborative Planning (CP) is one of the main processes in Supply Network Management (SNM) (Albino et al., 2002; Heikkilä, 2002; Stadtler and Kilger, 2002). CP can be defined as *"an interactive process in which both customers and suppliers of a value chain collaborate continuously sharing information about demand for conjointly planning their activities"* (Alarcón et al., 2006). In this sense, the importance of this process in collaborative network (CN) contexts justifies its modelling purpose (Alarcón et al., 2007).

Enterprise modelling (EM) is a generic term which covers the set of activities, methods and tools related to developing models for various aspects of an enterprise or a network of enterprises (Berio and Vernadat, 2001). Berio and Vernadat (1999) indicate that any approach for enterprise modelling must at least deal with four modelling views: function, information, resource and organization views. In Giaglis (2001), it is exposed that the four perspectives (or views) that a modelling technique should be capable of representing are: functional, behavioural, organizational and informational views. In the case of modelling the CP process,

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although it is mainly focused on decisional aspects, the present paper assumes that a complete view of the CP needs five views: physical, organization, decision, information and function views. If it is assumed that the planning process establishes the actions to balance the supply with demand over the planning horizon and to synchronize operations across the network taking into account: the physical resources and their relationships (physical view), the way they are organized (organization view), the objectives of the network members (decision view), and the available information (information view), there is an imperative necessity for connecting the decision view embedded in the CP process with the above mentioned views.

The main objective of this paper is to provide the elements for the graphical modelling of the physical and organization views of the CP process of any network. This graphical representation intends to collect the most relevant features of these views in a readily and understandable manner so that it can help the decision makers during the CP process. The resulting physical-organization model can be used as a foundation for developing CP decision making tools that consider these physical and organizational aspects.

In the literature there are some works that provide a set of criteria, properties or classifications for selecting modelling methodologies, techniques or tools. Neiger and Churilov (2005) propose a list of properties of business process models organized in four sections: the **purpose** of the model, the type of **representation** (graphical or formal model), the **content** and the **characteristics and tools** to support the model. Other works present different classifications of modelling techniques depending on: 1) the modelling objectives and views (Giaglis, 2001), 2) the modelling purpose and the possibility of the model evolution (Aguilar-Saven, 2004), 3) the modelling purpose and audience (Phalp, 1998). However, it is possible that, after performing the list of properties for a particular case, a modelling technique that covers all the properties is not available. This is the case of the integrated representation of the physical-organization aspects of a CN. In this case, it is necessary to define a semi-formal modelling language that tidies up the modelling elements to satisfy the requirements of the list of properties.

In the present paper, a description of the relevant components to model in the physical and organization views is presented. Next, a joint modelling proposal of the physical-organization view is exposed. This proposal is composed by three pillars: 1) the selection of the modelling tool, 2) the definition of the structure and decomposition of the joint physical-organization view in four sub-views that facilitate its modelling, and 3) definition of the modelling elements (notation) for representing the components of each view. Then, a modelling example for the physical-organization view of a CN is illustrated. Finally, conclusions are presented.

2. Description of the Physical and Organization Views

2.1. Physical View

The **physical view** represents how a specific network is configured (designed), i.e., what are the resources, how these resources are structured, and what material flows circulate through it. In the Physical View, two dimensions have been established to facilitate the representation of networks. One dimension is called "**macro physical**" and the other dimension is called "**micro physical**". The "macro physical view" shows how the network is configured and what material flows circulate through it. The "micro-physical view" shows how are structured the resources of each node and what is the composition of the arcs (or transportation modes) that join two different nodes in the network. In this sense, the elements to be modelled in the micro physical view are: *stages* (suppliers, procurement, manufacturing-assembly and/or distribution), *nodes* belonging to each stage, *type of node* (according to the type of activity developed within the node: production-operations, warehousing, selling point or a combination of any of them). In addition, in this view, the *arcs* represent the activities performed by the outbound logistics. Arcs connect dyadic nodes and represent the flow of items from an origin node to a destination node.

Regarding the micro physical view, two levels are distinguished: node level and arc level. The micro physical view at the node level may contain the following elements: *type of shop* (or machine production configuration attending to the type of flow of the jobs) that can be: mono-machine, flow shop, permutation flow shop, job shop, parallel machines, hybrid flow shop or job shop with duplicated machines; *work centres*; *areas*; manufacturing/assembly *lines*; *sub-nodes*; warehouses and/or *selling point area*. The micro physical view at the arc level may include the following elements: *type of arc* (identify transportation modes that may or may not supply all the products and may or may not belong to a specific manufacturing/assembly line). It is classified on: transportation mode that supply all the products between two nodes, transportation mode that does not supply all the products between two nodes, and transportation mode that only supplies products produced by one line within the origin node. In addition, in this view is represented the *type of transportation* (airplane, lorry, ship or railway).

It is important to note that there are more classes of resources at the micro physical node level such as personnel and computer applications. However, they have not been considered in this paper. Likewise, the level of detail in the graphical modelling of the micro physical view will depend on the modelling objectives. Actually, the level of detail of the micro physical view should correspond to the level of detail of the decisions made in the CP at the lower temporal level of the temporal hierarchy; a higher degree of detail is unnecessary, as it does not provide relevant information to support the CP process.

2.2. Organization View

The **organization view** shows the relationships among the resources represented in the physical view. These relationships will condition the manner that the decisions are made (what is represented in the Decision View). In a similar manner to the physical view, the organization view is divided within two dimensions. One dimension is called "**macro organization"** and the other one is called "**micro organization**". The micro organization view shows how are organized the nodes and the arcs that connect them. The macro organization view shows how the different nodes/stages are organized in the network. The micro organization view may have various *organization levels* (typically, strategic, tactical and operational levels) depending on the node organizational hierarchy. However, the CP process is mainly concerned with the operational and tactical levels. At the same time, in each organization level, there would be one or various *organization centres* (OC's) that are *"units with a determined function, formed by persons/resources that perform differentiated and coordinated tasks to contribute to the organization goals"*. In this sense, it is assumed that the aspect that really joins the resources is the function that they perform and this function is coordinated through a responsible centre, called organization centre. In principle, there will be *interdependence relationships* among the organization centres (belonging to the same or different organization level).

The macro organization view should consider all the nodes of the physical view with the objective to define their interdependence relationships what provides an idea of the manner the nodes interact (planning isolated or collaborating). For this purpose, it is defined the *inter-*

organization centres (IOC's) as units with a certain function that act as responsible for organization centres belonging to different nodes. At the same time, these inter-organization centres may be dependent from a superior inter-organization centre.

There are **two types** of interdependence relationships at the micro and macro organization levels:

- **Temporal**: between OC's (micro organization dimension) and between OC's/IOC's (macro organization dimension) of the different organization levels (tactical and operational levels).

- **Spatial**: between OC's (micro organization dimension) and between OC's/IOC's (macro organization dimension) of the same organization level. The interdependence at the macro organization level is the most important for the CP process.

The **four attributes** that define the intensity of the interdependence relationships are:

1. Type of Management (or Relationship): it defines how the decision making is performed for the CP process decision making. It can have the following values:

- **Independent:** the management of the OC's is performed in a "myopic" manner; i.e. totally decentralized or distributed.

- **Interdependent:** the management of the OC's is co-jointly performed. It can be centralized or decentralized.

- **Dependent:** the management of one of the OC's depends on the decision of another OC; i.e. partial decentralization.

2. Trust Degree: indicates the extent to which each part of the relationships will behave non-opportunistically.

- **Null:** it appears normally on independent or interdependent management situations. In the last case, it acts in a totally opportunistic manner.

- **Medium:** it appears on situations with a certain opportunistic behaviour however the objectives of both parts are taken into account.

- **Total:** when both parts behave in a non-opportunistic manner.

3. Goal Congruence: it is the extent to which actions are performed towards a common goal in the relationship.

- **Null:** there is not any desire to co-jointly make decisions towards a "global goal".

- **Moderated:** the OC's do not posses the same objectives, but they are partially compatible, so that it is pursued a "global objective" that also satisfies "individual objectives".

- **Total:** in this case, the OC's share a common "global objective".

4. Information sharing: it is the level of information that the different OC's/IOC's exchange.

- **Total Asymmetry:** there is not information sharing between the OC's/IOC's.

- **Strong Asymmetry:** the OC's/IOC's do not have the same knowledge because of private information. This may appear when one of the centres is unwilling to share (relevant) information due to strategic or trust reasons.

- **Weak Asymmetry:** the OC's/IOC's do not have the same knowledge due to the fact that the state of the information has change during the period of time of accessing to it. This situation happens normally between two OC's/IOC's belonging to different organization levels.

- **Symmetry:** all the OC's/IOC's have the same knowledge; there is not private or delay-phased information.

2.3. Aspects to be modelled within the Physical and Organization Views

From the descriptions of the physical and organization views, it has been obtained the **aspects to be modelled**, i.e., the potential concepts of these views that are to be modelled. The aspects to be modelled within the macro physical view are stages, nodes, type of node and arcs. The aspects within the micro physical view at the node level are: sub-nodes, lines, areas, work centres, type of shop, warehouses (raw material, intermediate and finished product) and selling point areas. Regarding the micro physical view at the arc level, the aspects to be modelled are: origin and destination nodes, type of arc and type of transportation. In the micro organization view, the aspects to be modelled are: organization levels, OC's and their interdependence relationships. Finally, the aspects to be modelled within the macro organization view are: organization levels, OC's, IOC's and their interdependence relationships.

3. Modelling the Physical-Organization View of the CP process

The composition of the modelling proposal for the physical-organization view is made up by three pillars: the modelling tool, the decomposition structure of the physical-organization view and its modelling elements. All three pillars are described as follows.

3.1. Selection of the Modelling Tool

For the graphical representation of the views, the iGrafx modelling tool has been selected. The main reasons for its selection are as follows: 1) it has a wide library of symbols or modelling elements, 2) it provides the option to link different levels of detail by decomposing an element within a diagram into new diagrams and, 3) it is a user friendly tool. In other situations, it is possible to select another tool (that provides similar features) depending on the expertise of the modellers or model users, modelling objectives and/or availability.

3.2. Representation of the Physical-Organization View

After evaluating different options to represent the physical and organization views, it has been chosen to graphically represent **a view that integrates both views**. This has been possible due to the fact that it has been defined a representation scenario in which both views are linked through connecting elements, providing an integrated view for both levels: the micro level (of each node or arc) and the macro level (the Supply Network).

In order to facilitate the modelling of the physical-organization view, it is proposed its decomposition into four sub-views, three of them are fundamental sub-views and the last one is a complementary sub-view. The fundamental sub-views are: 1) **macro physical-organization sub-view**, 2) **micro physical-organization sub-view of the nodes**, and 3) **micro physical-organization sub-view of the arcs.** The complementary sub-view is the **macro-micro organization sub-view**.

In the **macro physical-organization sub-view** is represented, on one hand, the elements (nodes and arcs) that exist at the SN level as well as the relationships among the nodes of the different stages and the flows of materials through them (macro physical view). On the other hand, it is represented the OC's and IOC's of the different organization levels as well as the interdependence relationships among the OC's and IOC's (macro organization view). Finally, in the same view, it is established the dependence/relationship of the elements of the macro physical view (nodes and arcs) with the macro organization view (OC's and IOC's).

The **micro physical-organization sub-view at the node level** identifies in a view the configuration of the internal resources of a node (micro physical view) and their relationships with the node OC's as well as the interdependence relationships among the different OC's (micro organization view).

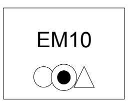
The **micro physical-organization sub-view at the arc level** represents in a view the origin and destination nodes and the different types of arcs and transportation between these nodes (micro physical view). The micro organization view represents the OC's of the different organization levels responsible for organizing the transportation modes as well as the interdependence relationships among them.

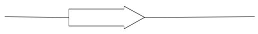
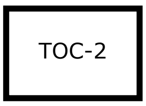
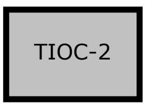
Finally, the **macro-micro organization sub-view** (complementary because it only represents the organizational part, providing additional information to the other sub-views) identifies in an OC or IOC from macro organization level, the OC's that it comprises at micro organization level (within the same organization level).

3.3. Modelling Elements of the Physical-Organization View

Regarding the modelling elements of each sub-view, a notation for each of the aspects to be modelled within the physical and organization views has been defined. Table 1 presents the notation related to each aspect to be modelled of the macro physical-organization sub-view (see Figure 1).

Table 1. Modelling Elements of the Macro Physical-Organization Sub-view

Aspects to be modelled and notation	
	Lower plan (macro physical)
Stages	They are represented by vertical blocks designated according to the stage: "suppliers", "procurement", "manufacturing/ assembly" or "distribution"
Nodes	They are represented by rectangles that include the node *name* and the *type of node*.
	*Name:* it is represented by LE+nº, being LE the Legal Entity and nº the number of legal entity within the SN. If there is more than a node that belongs to the same legal entity, the name will be LE+nº followed by a dash and a number that counts the nodes belonging to the same LE, e.g. EM3-1.

LE1	When various LE belong to the same Enterprise Group (G), in the name it is included G+nº, being G the enterprise group and nº the number indentifying the enterprise group within the SN. The name of the enterprise group precedes the name of the legal entity in this manner: G+nº+LE+nº. When there is only one Enterprise Group, all the LE's that it comprises are shadowed in the same colour so that it is not necessary to include in the name G+nº.
	Type of node: there are three basic types: production-operations ◯ warehousing △ and selling point ⊙. From these three basic types, their combinations may happen.
Arcs 	Identify product transportation modes between nodes that may or may not supply all the products and may or may not belong to a specific manufacturing/assembly line. They are represented by an arrow that joins the origin node and the destination node. If there is more than a transportation mode, the arrow includes a number between brackets that indicates the number of transportation modes. If there is one transportation mode, the number does not appear.
Upper plan (macro organizational)	
Organization Levels	*Name:* the notation "tactical level" or "operational level" is located on the vertical axis, accordingly. If there is more than a tactical u operational level, they are enumerated in a consecutive manner: "tactical level 1", "tactical level 2", and so on.
Organization Centres 	They are represented by a rectangle (with higher thickness than the nodes). Their *name* is TOC or OOC and it stands for Tactical Organization Centre (TOC) or Operational Organization Centre (OOC). The name is followed by a dash and nº indicating the number of OC, e.g. TOC-3. If there is more than a tactical or operational level, the OC includes a number to count it before the dash, e.g. TOC2-1.
Inter-Organization Centres 	They are represented by a shadowed rectangle. Their *name* is TIOC or OIOC and it stands for Tactical Inter-Organization Centre (TIOC) or Operational Inter-Organization Centre (OIOC). The name is followed by a dash and nº indicating the number of IOC, e.g. TIOC-3. If there is more than a tactical or operational level, the IOC includes a number to count it before the dash, e.g. TIOC2-1
Interdependence Relationships	**1. Type of management (or Relationship)**: - **Independent**: it is not represented - **Interdependent**: it is represented by a continuous line - **Dependent**: it is represented by a continuous line including an arrow indicating towards the dependent OC/IOC.
	2. Trust degree is represented by a number: - **Null**: it is not represented - **Medium**: 1 - **Total**: 2
	3. Goal congruence: it is represented by vertical lines placed on the line that represents the type of management:

	- Null: it is not represented **- Moderated:**  **- Total:** 
	4. Information Sharing between OC's/IOC's: **- Total Asymmetry:** it is not represented **- Weak Asymmetry:**  **- Strong Asymmetry:**  **- Symmetry :** 
Connecting Lines of the Macro Physical and Macro Organization Views	
Connecting Lines	They are represented by vertical discontinuous lines that connect the nodes from the macro physical plan and the Operational OC from the macro organization plan.

4. Example of Macro Physical-Organization Sub-view

Figure 1 shows the model of the macro physical-organization sub-view of a SN. The SN operates under a make-to-stock strategy, locating the decoupling point at the warehouses. This means that the nodes placed "downstream" the warehousing nodes are not directly involved in the CP process. Therefore, these nodes have not been represented.

As illustrated on the macro physical sub-view, the SN is composed by seven nodes and three stages: suppliers (two nodes), manufacturing/assembly (three nodes) and distribution (two nodes). The nodes have been designated by their name and belong to four legal entities: LE1, LE2, LE3 and LE4. LE1 is composed by three nodes, two manufacturing nodes (LE1-1 and LE1-2) and a distribution node (LE1-3). LE2 is made up by two nodes, a manufacturing node (LE2-1) and a distribution node (LE2-2). Legal entities LE3 and LE4 are composed by one supplier node. Note that LE1, LE2 and LE4 belong to the same enterprise group; therefore, the nodes are shadowed. Regarding the type of node, supplier nodes (LE3 and LE4) are production-operations/warehousing/selling point. Manufacturing nodes (LE1-1, LE1-2 and LE2-1) are production-operations and distribution nodes (LE1-3 and LE2-2) are warehousing/selling point. The arcs connecting the nodes represent the existence of material/product flows and the transportation modes between the nodes that they join. As there is not a number in the arrow, there is only a transportation mode between each pair of nodes.

In the macro organization view, it has been represented the tactical and operational organization levels. At the operational level, from each node that belongs to the SN, there is an OC responsible for the master planning. For this reason, there are seven Operational OC's (OOC1-7). At the tactical level, from each node that belongs to the SN, there is an OC responsible for the Aggregate Planning. That is the reason why there are seven Tactical OC's (TOC1-7). Regarding IOC's, at the operational level, there is only one IOC (OIOC1) that groups the OOC's: OOC3, OOC4, OOC5, OOC6 and OOC7. At the tactical level, there is also one IOC (TIOC1) that groups the TOC's: TOC3, TOC4, TOC5, TOC6 and TOC7. The interdependence relationships between IOC's and the OC's that embraces (at both tactical and operational levels) are: dependent (type of management), total (trust degree), total (objective congruence) and symmetry (of information sharing). The same type of relationships occurs between both IOC's (TIOC1 and OIOC1). The relationship between TIOC1 and TOC1 is interdependent, total, moderated and weak asymmetry. The relationship between TIOC1 and TOC2 is interdependent, medium, moderated and weak asymmetry.

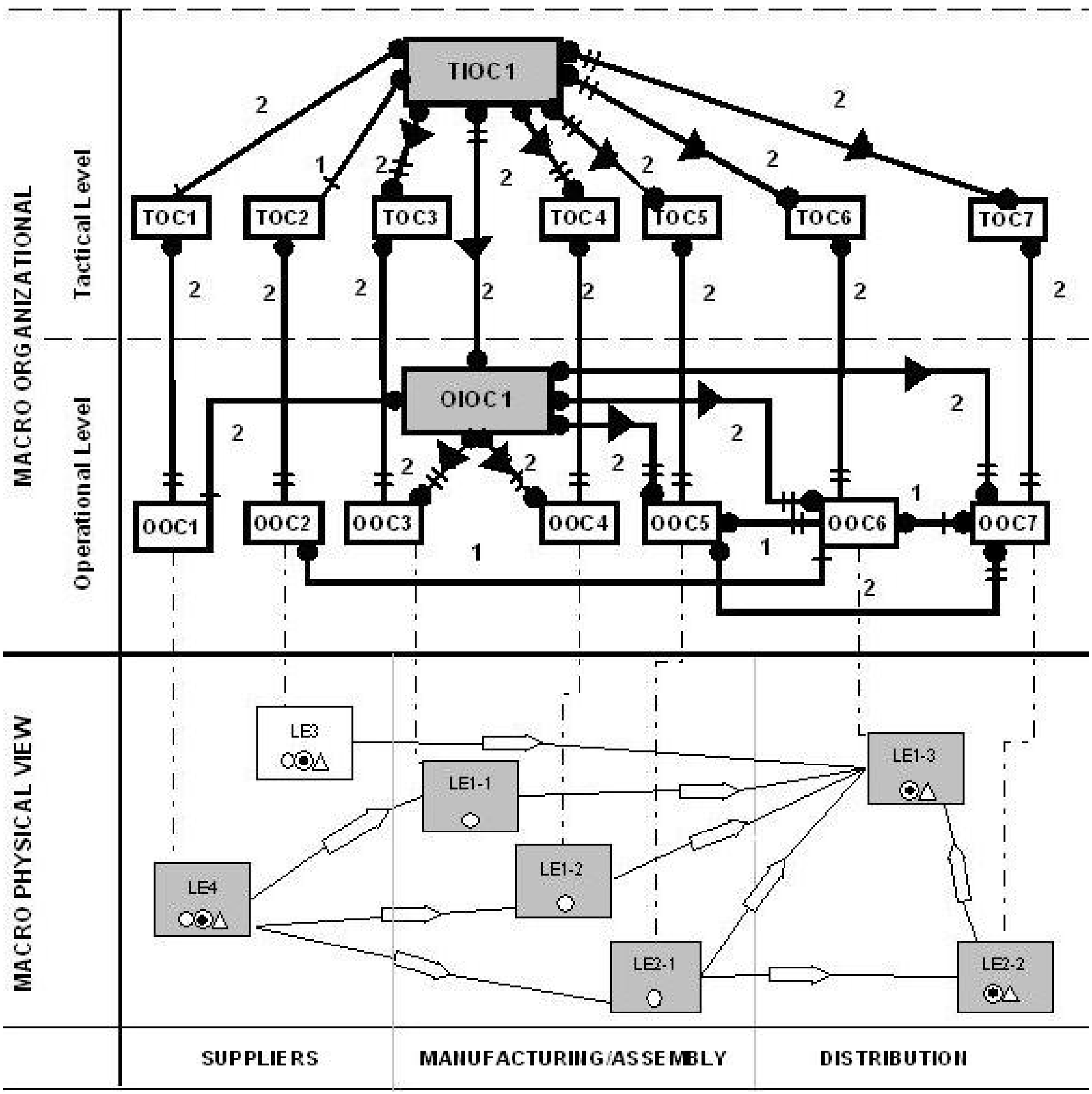


Figure 1. Macro Physical-Organization Sub-view of a SN

In the seven nodes, the relationship between the TOC's (TOC1-7) and their corresponding OOC's (OOC1-7) is interdependent, total, total and weak asymmetry. The relationship between OIOC1 and OOC1 is interdependent, total, moderated and weak asymmetry. Between OOC2 and OOC6, the relationship is interdependent, medium, moderated and weak asymmetry, Between OOC5 and OOC6, the relationship is interdependent, total, total and weak asymmetry. The relationship between OOC5 and OOC7 is interdependent, total, total and symmetry. The OOC6 and OOC7 relationship is interdependent, medium, moderated and symmetry.

Finally, both views are tied together by "connecting lines" that join the nodes of the macro physical view and the Operational OC's of the macro organization view, obtaining the integrated representation of the macro physical-organization view. The different links node-OOC are: LE4 - OOC1, LE3 - OOC2, LE1-1 - OOC3, LE1-2 - OOC4, LE2-1 - OOC5, LE1-3 - OOC6 and LE2-2 - OOC7.

5. Conclusions

In this paper, a graphical modelling proposal for the integrated physical and organization views representation of the CP process is provided. The proposal is composed by three main pillars: selection of the modelling tool, definition of the decomposition structure of the physical-organization view in sub-views to facilitate its modelling and definition of a notation for all the aspects to be modelled within these sub-views. The main objective of this proposal is to guide the users during the modelling of the physical-organization view by providing the relevant aspects to be modelled and corresponding modelling elements within each view, the features of the modelling tool, and the definition of the deployment structure of the physical-organization view that facilitates its understanding and integration. Due to brevity reasons, in this work, it has only been exposed the detail of the notation for the macro physical-organization sub-view. Finally, it has been illustrated an example of SN macro physical-organization sub-view modelling. It is considered as a future research line, the development of a modelling methodology that provides the steps to be followed by the modeller during the modelling of the physical-organization view.

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