Architect's Decision Station and Its Integration with Project-driven Supply Chains

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Abstract

Sustainability poses challenges to building design as it requires the use of multiple and interrelated sources of knowledge and expertise. This paper posits similarities between the building design process and supply chains established on an *ad hoc* basis. The supply chain is project-driven and this needs to be reflected by the associated information network that is used by all members of the chain. From the perspective of the architect and other participants the information environment they function in is complex and dynamic. Their decision-making can be supported with decision stations that are situated in the environment and capable of providing active and comprehensive support. The architecture of the decision station and its situating in the information environment is presented. The stations associated with the project participants form a project-specific network. Its effective functioning depends on the use of multiple ontologies, which make effective communication possible. Decision stations' situatedness, the network, its nodes and the local environments, and the ontologies are illustrated by examples.

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1. Introduction

Design of buildings has always been a complex process involving specialists from such areas as structure, heating and cooling, natural and artificial lighting, wiring, plumbing and water mains, and accessibility.

The difficulties in designing buildings increased significantly with the social responsibility imposed on the architects. It is expected that the architects design buildings with high degree of sustainability and very low environmental impact. New solutions proposed by the industries and experts, overwhelming information, changing contexts from environmental to legal to political (Bossink 2007), and other uncertainties add to the complexities architects face.

In effect both the architects and the domain experts they collaborate with need to know about the most recent developments in all areas related to building design (Malkawi 2004). This includes specific solutions and their inter-dependencies with both the existing and new components.

Such interrelated factors as global warming, volatile weather conditions, and social interest in sustainable development put pressure on building designers and developers to construct green buildings. These factors, in turn, led to a large number of new solutions (Omer 2008), including building materials and technical components.

Information about them is available but highly dispersed. In addition to the trade magazines and shows, the most popular and accessible source is web. Its importance is due to the information currency and the ability of accessing any document and at any time.

The underlying assumption for this work is that building design and construction like many other human undertakings takes place in an electronic environment that is dynamic and heterogeneous. The effective use of information dispersed on the web requires new type of decision support that provides tighter integration and higher degree of direct interaction with the problem domain. But—as Simon (1960) notes—people have quite limited information processing capacity and when the problems are complex they need to decompose them into smaller parts and distribute among other persons. Consequently, building design is distributed among domain experts, who may have to involve other experts and builders.

The building design decentralization is known and established practice. In recent years, however, the above mentioned complexities on the one hand and the associated involvement of more experts than before and the deepening of the collaboration from oftentimes only two levels (architect and domain experts) to three and more levels introduced new challenges (Gangemi, Malanga et al. 2000).

The process of designing buildings shares many similarities with supply chain which is the flow of products and services from their source nodes through intermediary nodes where they are assembled and aggregated to the final node where final product or service is established (Love, Irani et al. 2002). In such a supply chain the source and intermediary nodes may propose various solutions which are tested and integrated in the intermediary nodes leading to the overall building design in the final, architect node.

In this paper we propose a comprehensive solution that integrates information and communication technologies (ict) to support the work of the supply chain members in building design. The solution is leveraging the opportunities provided by the web and semantic web, and it relies on the internet technologies in the construction of systems for all participants of the supply chain.

The supply chain may be established on an *ad hoc* basis and change from project to project. The characteristics of the supply chains established by an architect are discussed in Section 2. The ict-based system that is capable of supporting both the architect and other members of the supply chain is presented in Section 3. This system is a decision station (ds) and it is the main building block of the information network that is used by the supply chain. In order to provide the flexibility necessary due to the nature of an *ad hoc* supply chain, dss need to be situated in their environment. Section 4 presents the concept of situating architect's ds.

There are several key issues associated with the project-driven ds integration. The architecture and main functions of the ds network are presented in Section 5. The functioning of this network is illustrated with an example coming from the architectural design. The issues associated with the dss ability for effective communication and the related use of multiple ontologies are also discussed and illustrated with examples in Section 6. Section 7 concludes the paper and discusses future work.

2. Supply Chain and Decision Support

Supply chain management requires the resolution of issues at both strategic and operational levels. At the strategic level decisions about the construction of selection mechanisms for organizations participating in any given process have to be made. Depending on the project different partners may be needed, for example, it is probable that the architect selects one group of partners for the design of a seaside resort and another group for a tall office building. This selection may be further complicated with the requirement that different criteria be used at different levels of the supply chain. For example, at the high level, the partner's experience and reliability may be the most important, while at the lower levels costs and delivery time may be the key criteria. At the operational levels issues such as production planning and logistics need to be addressed.

The above shows that effective management of a supply chain is difficult. If the environment is dynamic and complex, as it maybe the case with some design projects, then decision support systems may be very useful.

The difficulty is, however, that traditionally these systems have been designed for highly complex but stable problems. These systems also did not explicitly consider the relationship between the decision problem and its context, the implementation environment, and the users' need for active rather than passive support. Several theoretical and applied efforts have been undertaken over recent years to address these drawbacks. One of them is the work on the extension of an active dss into a so called decision station that is capable of providing a complete support environment to the decision-maker (Vahidov 2000; Vahidov & Kersten 2003).

Dss research focused on the providing support to individuals rather than groups and it largely ignored implementation and monitoring phases of decision making processes. The systems built on the traditional dss concept, i.e. Simon's (1960) intelligence-design-choice model, are disconnected from their problem domains.

Inspired by software agent technologies, new frameworks of dss have been proposed, including active decision support and decision station (Vahidov & Kersten 2003). A decision station (ds) provides active support and also monitors decisions implementation and the changes in the problem environment which may necessitate modifications of the decision. It performs these functions through the use of sensors and effectors.

The difficulty in the design and implementation of active and connected dsss was due to the lack of connectivity among different information systems in an organization and between these systems and the organization's environment. The ubiquitous network and pervasive computing demand new approaches that will allow an information system to interact with and use various information environments. A local environment consists of systems, databases and other computing resources which have been designed in a way to allow them sharing resources and exchanging information.

Increasingly, important information is not readily available in the local environment. To obtain such information, software agents and other systems must go outside and actively search in other local environments, which are external to them. This introduces the issue of the systems' capability in operating in and interacting with the "foreign" environments. These systems, however, must be connected to both the decision problem's environment and these "foreign" environments in order to operate effectively and leverage the systems' capabilities.

The goal of a situated, connected and active ds is to provide all services necessary for decision-making and implementation. Thanks to the situating characteristics, a ds is capable of:

– sensing what's going on in the problem domains;
– utilizing traditional DSS facilities to inform decisions;
– making and justifying choices; and
– undertaking implementation and monitoring activities.

3. Architect's Decision Station

The nodes of the supply chain are organizations; they are the members participating in the project. From the information system perspective they represent a network in which we identify decision stations and their environments. To simplify the discussion, we assume that one ds is associated with one node. The information environment consists of other information systems which the dss access in order to obtain information and which behaviour they want to affect.

3.1 Decision station architecture

We are interested in a DS which can interact with other DSs installed in different organizations. Both the architect's decision station (A-DS) and the cooperating organizations' stations (C-DSs), for example, an engineer, a team specialized in indoor comfort, or a ceramic shingle producer supplying the entire pitched roof, may be small or medium enterprises (SMEs). Even if one or more of the organizations are large, we cannot expect every participating organization to use the same ontology. Moreover, both A-DS and C-DSs may need to access organizations which do not participate in the project but have potential useful information. For example, an indoor comfort specialist may need to access information about different products for heated floors.

The necessary capability for every DS is its ability to "understand" the information that its sensors retrieve from the environment and also for the effectors to provide input to the selected systems (e.g., web sites) in the environment in the way that these systems can understand. For this purpose a DS needs access to ontology and a processor which can compare and translate concepts from one ontology to another. Providing DS with ontology also enhances its ability to interact with the user. Another purpose for the introduction of ontology and a processor capable of interpreting documents written with different ontologies is to provide the system with an ability of autonomous search and evaluation of information available on the web. The DS and its key components and functions used in the cooperation with the user and situated in the environment are shown in Figure 1.

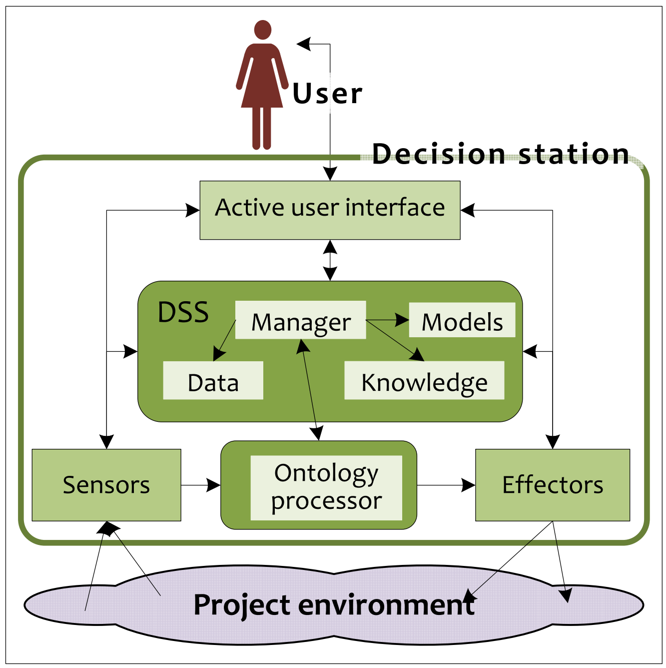

Figure 1. Decision station architecture (adapted from Vahidov & Kersten 2003, p. XX)

3.2 Interface and DSS components

The user interface needs to be active; it needs to be capable of engaging in and facilitating human-machine dialogues. Such interfaces may incorporate synthetic characters, reside on wearable devices, and have learning capabilities. One of important characteristics of such an interface is its ability to adapt to the user and customize the system in ways that match the user's cognitive abilities and needs.

The core of the DS is the DSS which includes the manager, model base, knowledge base and database. The manager organizes and controls the functioning of the DSS. DSS requires a knowledge base (including, business rules), that make the system capable of performing certain the tasks autonomously (without the user intervention). These and also the model- and data-base are standard components of a dss discussed in literature (e.g., Holsapple & Whinston 1996; Carlsson & Turban 2002; Shim, Warkentin et al. 2002).

3.3 Sensors and affectors

Sensors and effectors are key components that situate the DS and differentiate it from traditional standalone DSSs. They are used to interact and affect the environment. The information environment indicated in Figure 1 represents the project environment. It includes all information systems and sources which provide information that may be relevant to the project and its implementation. For example, web sites, including electronic books and magazines containing samples of sustainable solutions; different information related to materials and multilayered solutions; normative references with threshold values that must be respected; software for evaluations/measurements; and sites with information on buildings and constructions, and producers with technical reports and measurements on their own materials/solutions.

We can distinguish two general types of sensors and effectors' capabilities: passive and active. Passive functions must be invoked by other DS components reacting to the user's request or acting independently. Examples of passive capabilities include connecting to external sources, extracting information requested by other DS components and transforming it for the components' use. Sensors also pass information to the environment either by posting it or sending to specific systems (e.g., requests, questions and answers).

Active capabilities include checking the state of the environment and querying and alerting users, adapting and planning.

The DS problem environment could be complex because of the frequent and unexpected changes and the very large number of variables required to describe it. DS was originally envisioned to financial planning and investment decision problems for which the environment was stock exchange (Vahidov 2002). Such an environment is semantically simple; it does not include numerous web sites which may use different concepts and terms. These concepts are extended here into heterogeneous environments characterized by the use of multiple ontologies, data bases, and incompatible software and hardware.

4. Situating architect's decision station

To design a sustainable building choices have to be made about the structure, the building envelope, the internal floors, the plants in the building, and so on. In particular, the thermal behaviour of the building envelope is a key factor for energy saving (Balaras, Droutsa et al. 2005) and all its parts, i.e., the ground floor, the external wall and windows, and the roof, must be appropriately designed.

A layer of insulation material included in the envelope certainly gives a great benefit in terms of thermal resistance (Al-Homoud 2005), while a ventilation layer included in the envelope can help prevent moisture build up (Davidovic, Srebric et al. 2006) and better the summer behaviour by lessening the thermal load (Dimoudi, Androutsopoulos et al. 2006). Consequently, a building envelope can be made by, for example, including a layer of insulation on the ground floor and creating horizontal ventilation. This solution, known as "walls on the ground", includes the wall with insulation on the exterior and the vertical ventilation, and a flat roof with insulation and ventilation. It can be used for the building envelope that fits the general purpose of sustainability while improving thermal well-being of users in every season.

4.1 Accessing and using technical documentation

We illustrate the need to situate a DSS, that is, the DS feature called situatedness, with examples of accessibility and use of technical documents available on the web [1].

Successful sustainable design requires an integrated approach; sustainable buildings must take many factors into consideration on a "whole-building", integrated basis. Envelope design is a major factor in determining the amount of energy a building will use in its operation. In general, it is necessary to build walls, roofs, and floors of adequate thermal resistance to provide human comfort and energy efficiency. Thermal protection must be provided by appropriate levels of insulation and minimal air leakage. At the same time, preventing moisture build-up within the envelope is essential.

The moisture should not only be permitted from entering the building envelope, it should be allowed to escape as well. For example, water vapour that works its way into a wall cavity should have a way to rise to the top of the wall and escape through an attic vent, just as liquid water that condenses within a cavity should have a way to migrate out through a weep hole at the bottom. This ventilation should not be confused with ventilation of the occupied spaces. Cold roof strategies that employ air spaces between the exterior weather barrier and the substrate beyond employ natural ventilation to circulate the outside air. They minimize the heat transfer through the roofing system and eliminate an unnecessary heat gain in the summer.

4.2 Interacting with the producers' portals

Before the supply chain is set up for the particular given project, it is necessary to decide on the materials and components that would be used in the construction. This requires verification that the most recent available information is obtained, as in the following example based on producers' portals [2].

Decisions about insulation are among the most important to make in relation to the environmental impact of buildings. Utilising the best quality insulation systems allow us to provide the most energy efficient building envelopes. A building envelope is the combination of the foundation, wall, and roof assemblies all working together to provide a comfortable and safe environment in a building. However, modern constructions using higher levels of thermal insulation require increased levels of ventilation within the building fabric to prevent the build-up of moisture and condensation.

The insulated ventilated roofing and walling are the utmost living comfort, since control over heat dispersion and disposal of vapour during the winter, and reduce incoming heat flows during the summer. Moreover, with the increasing awareness of hazardous subsoil gases such as radon and methane, the need for under-floor ventilation has become even more apparent.

[1] Based on: *Sustainable Building Technical Manual. Green Building Design, Construction, and Operations*. Produced by Public Technology Inc. US Green Building Council. Sponsored by U.S. Department of Energy. U.S. Environmental Protection Agency (1996), available on the website http://www.wbdg.org/ccb/SUSTDGN/sbt.pdf.

[2] Based on: http://www.foam-tech.com/theory/theory.htm; http://www.bbs-ltd.com/ventilation.htm; http://www.pica.it/news01_en.asp

5. Decision Station Network

The organizations with which the architect collaborates in a given project form a network. This network is project-specific *ad hoc* supply chain because some of its nodes appear only in one project but not in another.

5.1 Network overview

An example of the network set up by the architect is illustrated in Figure 2. From the perspective of the architect, the network has elements of a hierarchy with the architect (A-DS), situated at the top-level. At the second level are those members of the supply chain who communicate directly with the architect. For example, a wall designer (C1-DS) is at the second level. This wall designer may interact both with the architect and a producer of ventilated facades (C4-DS) for ventilated facades. If this producer does not interact directly with the architect, then he is a the third level.

The supply chain and the information network associated with it are established for a given project. They are, however, not stable and we cannot assume that they remain unchanged during the life of the project. The configuration may need to be modified if the architect or the contractors realize the necessity to engage other experts or producers (in Section 6.2 an example of two producers of ventilated facades is given).

There are two more nodes in the network depicted in Figure 2; they are at the second level and represent, for example, a roof designer (C2-DS) and a producer of a specific solution for the ground floor (C3-DS).

All information about the architectural project and related activities, both directly and indirectly, comprise the shared project environment. Separating the environment from the architects DS (A-DS) allows other members to collaborate with and without the architect's involvement.

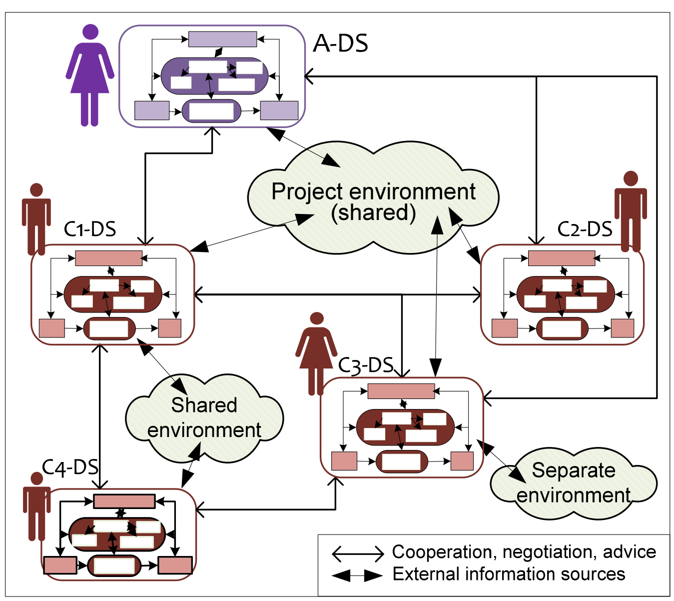

Figure 2. A network of decision stations

One of the characteristics of the *ad hoc* supply chains is that they pull together organizations that belong to other supply chains (which may be highly specialized) and collaborate with other organizations outside of any chain (e.g., research institutes, laboratories and technical associations). The implication is that some of the members access information coming from two or more information environments. This is illustrated in Figure 2; the wall designer (C1-DS) ventilated wall producer (C4-DS) share an environment between them. This environment may allow the members accessing producers of new materials used for ventilated walls. An example of an environment that is used by one member (C3-DS) but not shared with others is shown in Figure 2.

5.2 Example

We illustrate the operation of the establishment of the supply chain and the associated information network with the following scenario. This network is shown in Figure 2.

Architect A has to propose a particular type of ventilating the building, which, because of the unusual design and environment, cannot be one of the typical ventilating solutions.

Architect A consults the internal and external databases and websites and selects one ventilating approach combined with a layer of insulation material, as a means of assuring indoor comfort along all seasons. Consequently, she selects the initial contractors with whom she will collaborate in the project. This selection is based on the competencies and abilities required for this project. Then, after sketching a draft with the main features of the project and the required performances of the building she selects three contractors who will be involved in the building: C1 is responsible for the external walls, C2 for the flat roof, and C3 for the ground floor.

A presents the draft to the three contractors. Based on the architect's draft, contractor C1 decides that he needs a ventilated wall producer. He suggests producer C4, who will be responsible for the technical design of the specific system chosen for the facade as well as the future mounting operation. After the interaction between the two, on the basis of suggestions by the ventilated wall producer, C1 proposes an external wall in the project based on a multilayered solution, i.e., (from inside toward outside), 2.5 cm internal plaster layer, 24 cm layer of airbricks, 10 cm thick layer of polystyrene as thermal-acoustic insulation, 8 cm of a ventilated cavity, and 1 cm of metal external protection.

Contractor C2 studies the problem and proposes a flat roof in the project based on a multilayered solution, e.g., 8 cm layer of stone wool as thermal-acoustic insulation, 6 cm ventilated cavity made by PVC supports, 5 cm layer of reinforced concrete, and a waterproof layer. C2 adds that, depending on the roof's additional usage, other layers may need to be added.

Contractor C3 is responsible for the ground floor; she proposes the following multilayered solution: a 30 cm layer of recycled PVC igloo elements, which create the ventilated cavity, a 12 cm layer of reinforced concrete, a 6 cm layer of stone wool as thermal-acoustic insulation, a sheet of aluminum as vapour barrier, a 5 cm layer of light concrete, and finally mortar and flooring.

Contractors C1, C2, and C3 discuss their proposals with A including the calculations of the solutions thermal-acoustic performances. They also present the proposed components' adherence to the laws and regulations in place.

Architect A considers the proposals made by C2, and C3; who somewhat unexpectedly for A, propose using stone wool for insulation. During the discussions, which could be conducted online, C2 and C3 access technical documentation on the producers' portals and proprietary technical databases. They provide A with the relevant documentation which convinces her and she now wants to use stone wool also for the wall insulation rather than polystyrene, which C1 proposed.

Architect A informs C1 about her discussion with contractors C2 and C3, and asks him to consider using stone wool, or another thermal-acoustic insulation material more environmentally friendly than polystyrene. She also suggests that C1 talks with C2 and/or C3 who have experience in these matters. A requests that C1 provides a solution in which bricks rather than metal be used as external material for the walls.

Consequently, C1 interacts with C2 and C3 to check the use of stone wool in his solution. He also contacts producers of external protection of ventilated walls in materials different from metal (e.g., stone and ceramic). From the interaction between C1 and C2 and C3, but also accessing technical documentation and producers' portals, C1 derives the necessary information for changing the insulation material in his solution. By the contact with producers and again accessing technical documentation and producers' portals, C1 makes a choice for the external protection of the walls, as for example ceramic tiles. Then, he checks the new solution with the ventilated wall producer and finally he proposes the new complete solution to A.

5.3 Control

There are five organizations in the exemplary network; each is represented by one decision station. Because of the nature of the organization, there are both hierarchical and horizontal connections between some of the stations.

The architect's decision station (A-DS) is at the top level because it represents the architect who is the project owner and the top-level coordinator. There are three contractors with their decision stations C-DS, at the second level; they directly collaborate with the architect, and one contractor with C-DS at the third level.

The five stations are engaged in cooperative activities, negotiations, advice and so on. During this initial phase of the design development, the architect plays the major decision making role, acting with a top-down approach. One result of this approach is the selection of the contractors, that is, the specification of the network's second-level membership. At this stage, the architect also allocates tasks to each member. Some members, in order to achieve the goals, may decide to extend the network with third-level members. One such third-level member (C4) is indicated in Figure 2.

After the network has been set up the interactions between members begin. They are based of the common goal, and they are not only required by the architect but also suggested by the members of the network themselves. Moreover, a feedback process begins, that is the bottom-up process is activated. This system of relations has both horizontal and vertical bi-directional flows. These relations increase the flexibility and adaptability of the network in that they allow for: (1) the inclusion of more members in the network at any level; and (2) the evolution and changes of the design.

During the central phase of the design activity, it is likely to have the members in the second and lower-levels proposing their suggestion as the most important for the goal to pursue, thus a competition arises between members, and consequently design solutions. With the design solutions suggested (supplied by the members in the network), the architect has the task to relate the one to the other, beyond the single suggestions, to create a unique solution for the whole design. This final solution is not usually defined after the first attempt, but derives from an iterative process typical of the design activity. In the iteration, the possible solution goes back and forth from the architect to the other members of the network, encouraging a collaborative process helping the definition of the final solution.

6. Understanding and Communicating

We have mentioned that the members of ad hoc supply chains may use heterogeneous and incompatible ICT solutions. They may also use different terminology. Therefore, there is a need for tools that make communication more effective by facilitate shared understanding of the requirements, designs, and their implications.

6.1 Ontology

Effective communication between a DS and its users can be made easier and more effective if the system has access to ontology. An example of such ontology for the building design is given in Figure 3. This example corresponds to the scenario discussed in Sections 4 and 5.

Ontology is used to organize the concepts and the relationships between them. It provides detailed specification of the relationships in a domain.

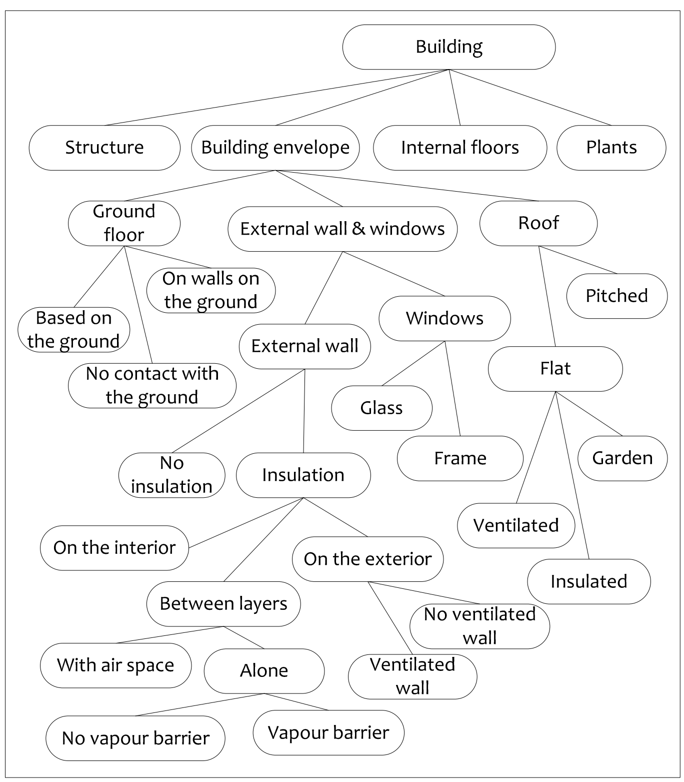

Figure 3. Ontology of a (sustainable) building envelope
(ground floor + external wall & windows + roof)

Ontology may be a component of a DS or it may be external to the system and part of the problem environment. Location outside of the DS allows other systems to use it. In either case, the DS requires an ontology processor which allows it to interpret the requests made by the user and other systems, to interpret information retrieved by its sensors and to prepare output in the ways easy to comprehend by the user. Ontology also helps the DS to give explanation and justification of the choices and assessment made by the system because it provides contextual grounding for the terms used.

6.2 Use of ontologies for communication

In semantically more complex environments, it would be unreasonable to assume that every information source and every collaborating station uses the same classification system and common vocabulary; that is different servers and stations may use different ontologies.

Every person involved in a project has (should have) an understanding of terms that other project participants use. This is due to the common technical knowledge and the participants' expertise and earlier interactions with people from related domains. The use of ICT, however, requires that either all systems use exactly the same terminology or that there are solutions that can translate statements made within the domain of one supply chain member into statements used by another member. The first solution is impractical as it would require everyone to "speak the same language". The second solution involves the construction of ontologies for each domain and equipping the participating DSs with ontology processors. Because, as we mentioned above, such processors are useful in a DS interaction with its users, the second solution is preferable.

To illustrate this we continue with our scenario. Consider that contractor C1 is responsible for the external walls. This contractor contacted two producers[3] (C4a, C4b) and asked to propose solutions for a ventilated wall. He recommended an accurate calculation of the "airspace" in the wall so to obtain appropriate ventilation through the "chimney effect".

The contractor received one draft in which the wall has an "interspace" and is "ventilated by natural convection". The second draft proposed an "air gap" with a specific dimension sufficient for "activating natural ventilation". The contractor knows that all these terms have the same meaning concerning the function. However, if this contractor's decision station C1-DS has to make a decision, then it would have to reject the two proposals sent by C4a-DS and C4b-DS because they use a different terminology than C1-DS. This situation is illustrated in Figure 4.

[3] Based on: http://www.ripabianca.it/paretiventilate/Din Std. asp?COD_PAG=178&grp_col=3&sx=TOP&tp=SX&bg=000000; http://www.estel-company.com/razdel/51/

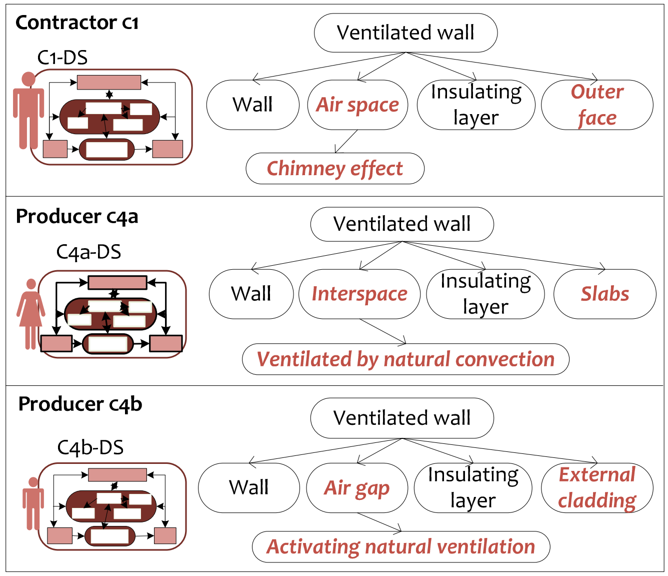

Figure 4. Ontologies of a ventilated wall by a consultant architect and two different producers

The use of different terms requires that the DSs that participate in the supply chain can access different ontologies and compare the terms.

7. Discussion

Recent developments in individual decision support include the provision of active and responsive support functions, and the situating of DSSs in their environments. Building on these developments we propose a network of collaborating DSs that is established when required. This type of a network is the informational equivalent of an *ad hoc* established supply chains.

Architects and their collaborators comprise a supply chain with the membership depending on the project they are involved in. The projects they are involved in are increasingly complex and the supply chain membership may change during the project's life-span Furthermore, the members typically belong to several other supply chains and other associations. All these factors need to be taken into account when systems supporting individual members and the information network for the whole chain are designed. In this paper such a design is proposed and illustrated.

There have been several prototypes of DSs in financial domain. They have shown their usefulness and the design of production-type systems is now considered. In the financial like in many other domains, an introduction of new information systems needs to be carefully planned. It involves the development of small-scale prototypes and their extensive testing. The first step in this work will be the adaptation of the existing DS to architectural domain and the construction of the networked collaborating DSs.

Following the initial prototyping development phase, we move to the architectural context in academia and set up simulation experiments with students representing supply chain members. This should give us insights into the flexibility and robustness of the proposed solutions. Another purpose for this type of testing is the verification of the use and processing of ontologies; we expect that students, being inexperienced will be using different terms for the same concepts.

This work presents research which is evolving and moving from the drafting stage to design and then development and implementation. The purpose is to provide effective and efficient decision support to architects and other organizations involved in designing. Our goal is to provide tools that will aid decision-makers in designing and constructing sustainable buildings. We view decision-support being essential because of the demands placed by the sustainability requirements and the associated with it vagueness and uncertainty (Robinson 2004). The reduction of an information overload that we face is helpful but not sufficient. It needs be augmented with the reduction of the cognitive demands. They are imposed by the complex, dynamic and evolving projects, the necessity of learning about new solutions which number keeps increasing, difficulties in putting together different components, and the necessity of addressing economic, and environmental and social issues which weight is increasing. There are no panacea and o tools that can be universal, but information systems which are media rich, intelligent and capable of communicating with each other and with people are necessary.

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