A METHODOLOGY FOR SUPPORTING PRODUCT SELECTION FROM E-CATALOGUES

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SUMMARY: *This paper reports on going work to explore the role of electronic product catalogues in design management and new opportunities offered by e-commerce applications related to building product information in the construction industry. An approach based on the performance-concept in order to facilitate product selection from e-catalogues is described. In this approach product selection is facilitated by conducting predefined (virtual) experiments in which products from electronic product catalogues are 'tested' to determine their performance in a given design context. Performance indicators are used to rank the performance of product selected by the system.*

KEYWORDS: *performance indicator, e-catalogue, virtual experiment, product search.*

1. INTRODUCTION

Simultaneous dissemination of product information using paper and electronic media has become a routine practice for most manufacturers of building products and product information brokers. While a seemingly endless debate over the benefits of each medium continues, it cannot be denied that access to product information on-line is now expected of a product manufacturer. In order to meet this demand, manufacturers and product information brokers, alike, are merely offering 'electronic paper' versions of the old catalogues using convenient presentation formats such as PDF and HTML (Augenbroe, 1998). These presentation-based formats, that are not amenable to computer processing, not only limit the usefulness of e-Catalogues but also offer little advantage over their paper-based counter parts for product selection.

Detail technical design of building components occurs at various moments during the design evolution. At any particular stage of the design decision making process this may involve different granularity, different design contexts and different stakeholders. Routinely, no attempt is made to come up with a new technical solution. Instead, one relies on, 'off-the-shelf', manufactured building products. In essence, this selection process is driven by the need to match a given set of design requirements with the performance of candidate products in catalogues while meeting all applicable design constraints. In such instances, the design problem is reduced to selecting the best available 'off-the-shelf' product.

Although the benefits seem obvious, there is very little understanding on how the move from paper-based catalogues to electronic catalogues will influence the selection of 'off-the-shelf' products. The building industry has mainly focused on creating e-Catalogues that duplicate their existing paper-based counterparts. There is little evidence of industry efforts related to studying how designers search for product, the processes that are used for evaluating and selecting products, and how manufacturers and information brokers can provide information and on-line tools to assist these searches.

This paper presents a three-fold approach to address these issues. First, we provide an analysis of the process involved in product searches and product selection. Then, we examine the limitations of current e-Catalogues and search methods in supporting these processes. This is followed by an overview of a performance-based approach upon which we will build our methodology for product selection from e-Catalogues. An example of a suspended ceiling is used to demonstrate a systems approach for identifying performance requirements of a building product. We conclude with the description of a new content broker service that uses the performance concept to search and rank candidate products for the suspended ceiling example and discuss issues related to standardization, e-Catalogue content, and future directions.

2. PROCESS ANALYSIS

2.1 Our Approach

To better, understand the business processes dealing with building products we conducted on site interviews with building product manufacturers (supply side) and architectural firms (demand side) in the South East region of the United States. IDEF-0 process-modelling method (Hunt, 1996; KBSI, 1996) was used to represent the business process as a set of related activities. For the complete report see (Jain et al., 2000).

2.1.1 Supply Side: Manufacturers

As one would expect, business practices differ widely from one manufacturer to the other. However, there are similarities, see FIG. 1, in how each manufacturer deals with product information:

- the four primary channels for distributing product information are - paper based catalogues, CD-ROM, internet sites, and sales agents;
- in most cases electronic (CD-ROM and internet) product information is essentially a reproduction of the paper catalogue with limited search capabilities;
- while most of the product information generated by manufacturers is in electronic format it is externalised in paper format (catalogues, spec sheets, product binders, advertisements, and brochures);
- manufacturers have little or no idea who is using their product information, how it is being used, or if it has even reached the users.

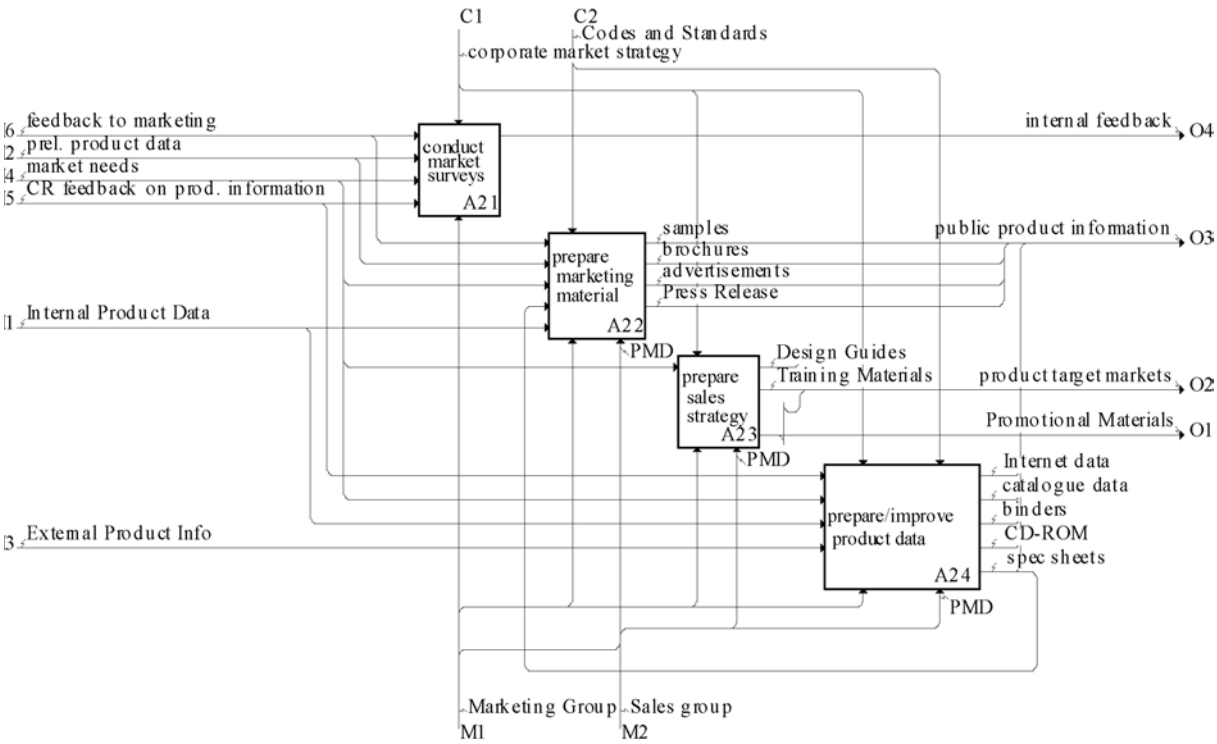


FIG. 1. IDEF-0 diagram representing activities dealing with product information in a manufacturing company.

2.1.2 Demand Side: Design Firm

Within the demand side use of product information, there are some common themes in the way product information is accessed and used during the course of a project in design firms.

- firms maintain an library that maintains subscriptions to a broad range of magazines, journals, and product catalogues from various manufacturers;
- lunch seminars organized by sales agents provide information about new products;
- construction Specification Institute (CSI) MasterFormat® (CSI, 1997) is the classification system of choice for organizing product information and books in the library;
- there was some debate regarding the use of CD-ROM's for distributing product information, the issue being, the ability of a firm to keep the older versions out of circulation;
- project participants typically had to use a number of channels to obtain the correct and up-to-date product information - library, internet, telephone calls to sales agents and manufacturers, archived projects FIG. 2;
- there was concern regarding how up to date and correct the product information was on the internet;
- most employees (network and IT administrators) were concerned about 'push' technology inundating their network and personal computers with junk email and unnecessary promotional product information and product updates.

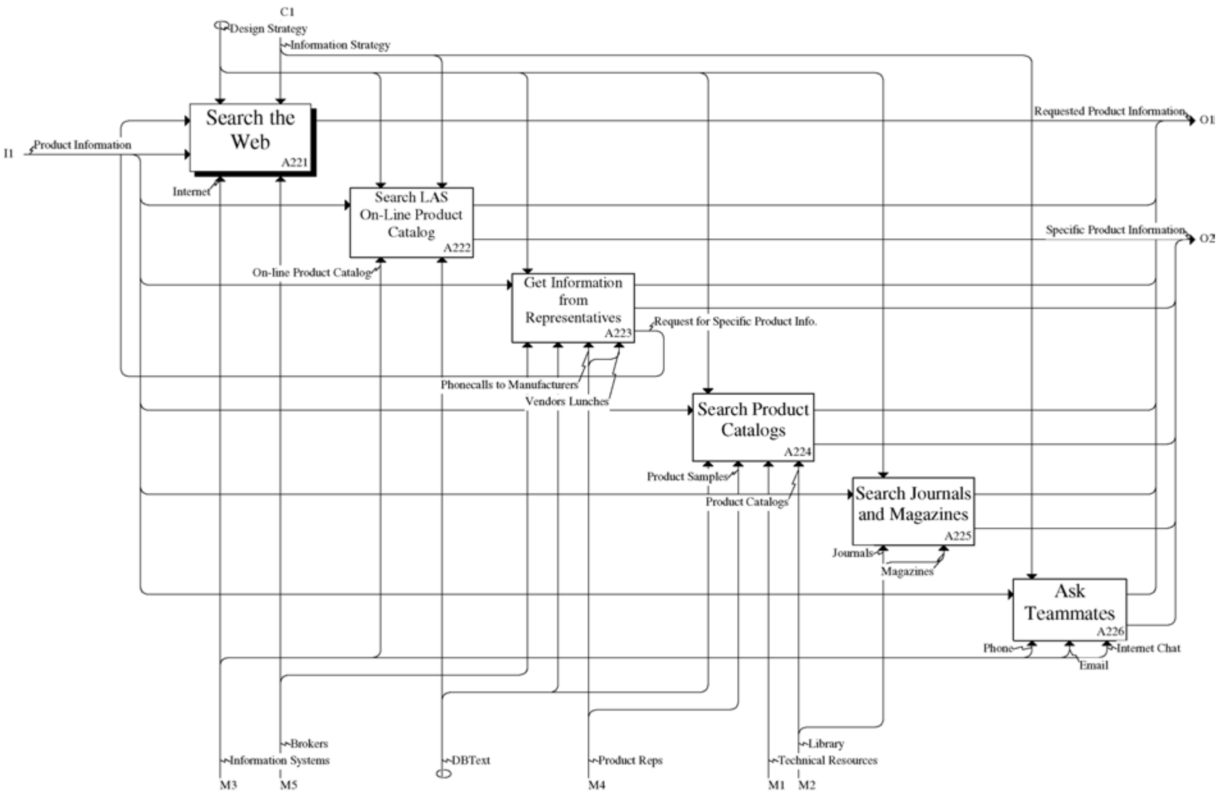


FIG. 2. IDEF-0 diagram representing activities dealing with product search in an architectural firm.

2.2 Summary

Product information flow through an architectural office is very dynamic and occurs during all phases of the design process. However, in most cases product selection is typically made during the early stages of design. The two main stages when the demand for product information is typically very high is during the pre-design and the schematic design phases of the design process. The granularity of the information sought at this time is typically very broad in scope and as such may address only a product type (concrete block, brick, stone, wood, etc.) with some general specifications and cost information. During the design development and construction document phase concrete decisions are made regarding product selection (fire rated concrete block, brick type, etc.) It is in these two stages that most of the construction documents are developed and architectural details are drawn. Hence, in the design development and construction document phase architects are looking for products by certain manufacturers and require complete specifications, cost estimates, and geometry. The last phase of the design process in which the actual specifications are written, require complete specifications of the product for bidding, costing, and construction purposes. Typically, this final document serves as the contractual agreement between the architect, client, and the successful bidder.

3. SEARCH METHODOLOGIES

3.1 Search Methods

There are two approaches commonly used for finding products in e-Catalogues: (1) descriptive searches, which are based on matching text strings, and (2) attribute-based searches, which are based on matching product attributes.

A Descriptive or keyword search is the most common method used in the industry today. The search process, which is based on matching 'string' values typically, produces large sets of product listings that may or may not be relevant. Usually one has to be very precise in describing the product in order to find relevant products. Moreover, products still have to be evaluated to determine if they are capable of fulfilling design requirements. The descriptive search method, in most cases, is an inefficient method for finding products that fulfil design requirements. It is typically time consuming and offers little or no advantage over traditional searches methods used in paper-based catalogues.

Attribute searches assume that products can be selected solely on the basis of their attributes. Attribute-based searches make a number of assumptions about the information available to the user during the search process: (1) the user has knowledge of the attributes on which to search, (2) the user is aware of the acceptable range of values for each attribute, and (3) the user understands the significance of each attribute in the design context. While attribute searches are an improvement over descriptive searches, they are more suitable during the construction phase of the building project when detailed product specifications are available.

Different models have been developed for standardization of product information in e-catalogues. These are described below.

3.2 Not Standardization Driven

Manufacturer web site: user finds web site either through information broker web site, by conducting a web search using popular search engines, or through other means. At the suppliers site, users are typically presented with one of the above search methods for finding products. FIG. 3.

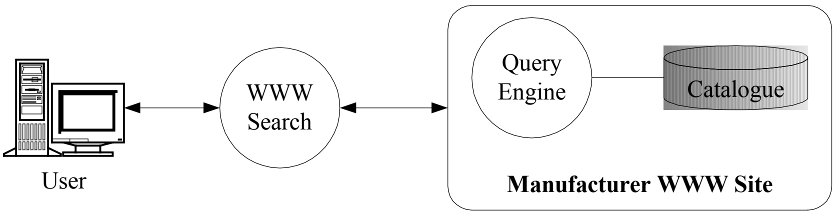


FIG. 3. Independent web site found through WWW search.

The CONNET (CONstruction information services NETwork) (Amor, 1999) is a project funded by ETTN (European Technology Transfer Network) used information technology to address the many varied needs of the construction industry. The CONNET "virtual technology park" provides the European construction industry with five Internet based services: technical information center, waste exchange center, manufactured product services, calculation and software center, and a newspaper service. While the CONNET project does not standardize on product information, it uses several standards for including product meta-data, classification systems, and API's for searching products and services through its gateway (portal).

3.3 Product Information Standardization at Source Side

Product information brokers require independent manufacturer/supplier to provide product information in standardized formats. Typically enforced through a subscription process or at the governmental level. Users query the information brokers web site using one of the two search methods described above. FIG. 4.

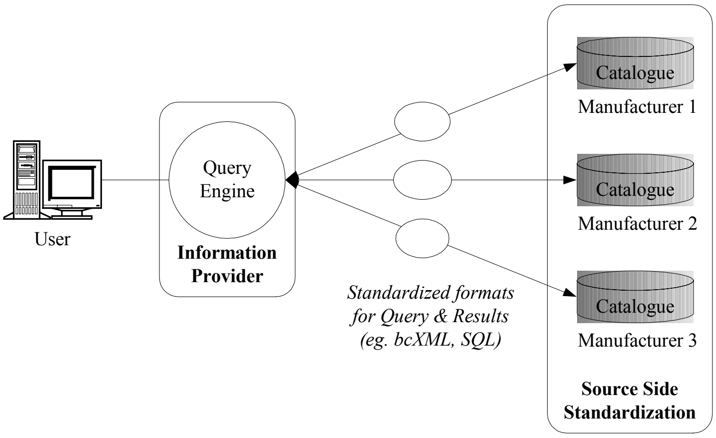


FIG. 4. Source side standardization.

ARROW (Amor et al., 1999) is a UK initiative, which provides a single point of access to any construction manufacturers' product information through virtual warehouses. Product information in the catalogues is stored in a standardized format determined by ARROW project team. This allows a centralized search engine to query databases of different manufacturers using standard product attributes or by product classification.

The e-Construct project (Woestenenk et al., 2002) is developing a building construction XML schema to enable access to up to date product information. The project aims to use the schema, called bcXML, to integrate product information with e-Procurement and e-Commerce applications to support procurement, billing, and purchasing building products across national boundaries within the European Union. e-Construct use bcXML as a neutral standardized format for product information in catalogues. Suppliers and manufacturers for building products use the schema to map their native databases to the bcXML schema thereby allowing users to search for product using a very extensive standardized vocabulary that has been developed using the LexiCon (Woestenenk, 1999).

3.4 Product Information Standardization on Broker Side

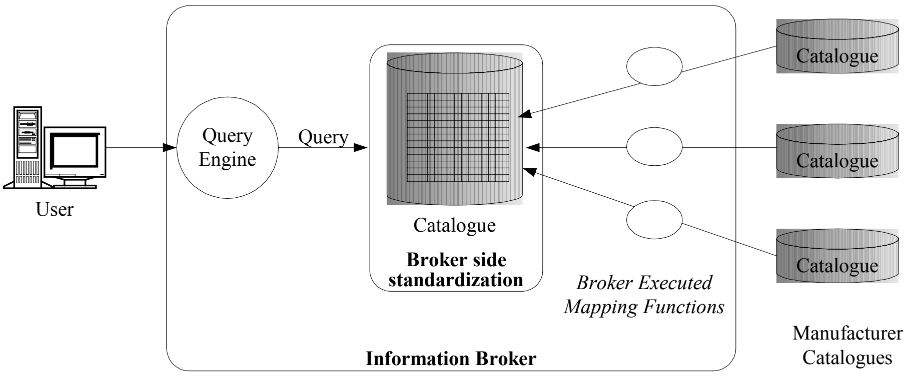


FIG. 5. Broker side standardization.

Independent manufacturer/supplier uses information broker to disseminate product information. Typically done via a subscription process, wherein the information broker uses mapping functions to map manufacturers product information and convert it to a standardized database schema. The exchange of information between the two parties is done via a static or dynamic link. Users query the information brokers web site using one of the two methods described above. FIG. 5.

3.5 Our Approach

While the above methodologies allow users to search for similar products from different manufacturers, there are a number of drawbacks with these approaches.

- Source side standardization is not always possible as it puts an added burden on the manufacturers to restructure their databases to a standard formats.
- There is no agreement on standards for product database schemas.
- Updates and modifications become increasingly difficult to administer when the number of providers increase.
- The implementation of these approaches in the two projects described above is based on searching by product attributes.
- Finally, these approaches only deal with searching products from multiple catalogues, they do not address issues related to product selection. None of the methodologies described above allows designers to search for products that are capable of fulfilling building functions for which they are being selected.

In order to facilitate such product selection, a performance-based approach is required. This requires three essential pieces of information: (1) a functional goal that must be achieved, (2) a quantitative statement that specifies the level of performance that is required to achieve that goal, and (3) methods for quantifying the performance (Gross, 1996). The next section presents a methodology for determining these requirements.

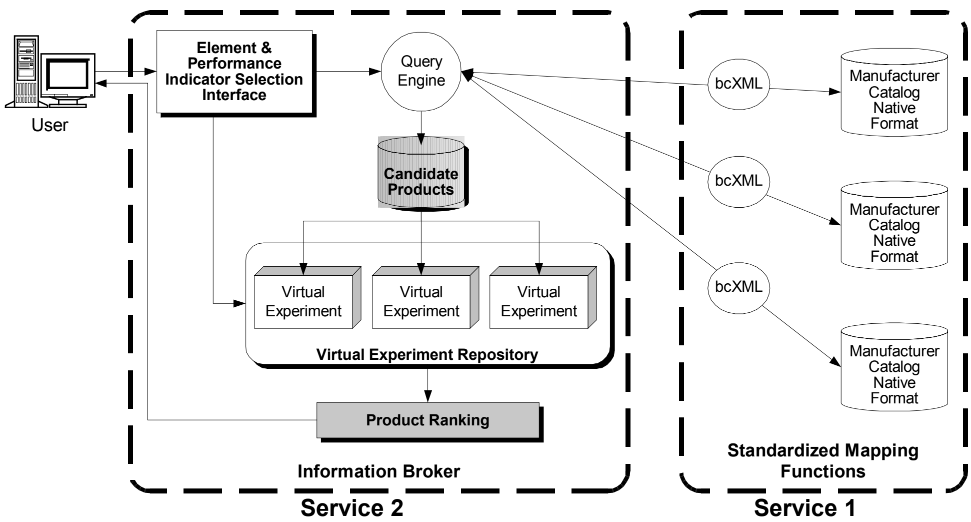


FIG. 6. Performance-based standardization.

The proposed approach extends the e-Construct approach by adding a new service. This new service, service 2, uses a performance-based approach to facilitate product selection from product catalogues. Illustrated in FIG. 6, in this approach the user first selects the elements that it is interested in. The interface then presents the user with available choices of performance indicators for evaluating the performance of the element. After the user has selected the elements and performance indicators, a query in bcXML format is submitted to participating manufacturers who in turn return a bcXML formatted list of products that meet the functional requirements of the elements that are being requested. These candidate products are stored in a database. Next, for each selected PI, a virtual experiment is conducted in which products from the candidate products database are substituted, tested, and ranked according to their performance in the virtual experiment. Using this approach the user can apply an incremental approach for ranking products by choosing a range of performance indicators.

This approach assumes that product type information on the source side is standardized based on a functional taxonomy provided by the information broker and that the information source is capable of responding to the query from the information broker using standardized protocols (bcXML) .

The remainder of the paper elaborates on the performance-based approach used in the second service.

4. THE PERFORMANCE APPROACH

Wim Gielingh in his General AEC Reference Model (Gielingh, 1987) describes a design process in which the design problem is reduced into smaller manageable units (FU). For each of these units a designer looks for a solution (TS) that satisfies the functional requirements of the unit. When no solution is found, the design problem is restated with a new set of functional requirements, or a new solution is developed to meet the functional requirements. Solutions to more complex design problems are obtained by reducing the design problem into smaller design problems. These smaller design problems are themselves new FU's that require new TS's. This iterative process continues until solutions have been found for all FU's.

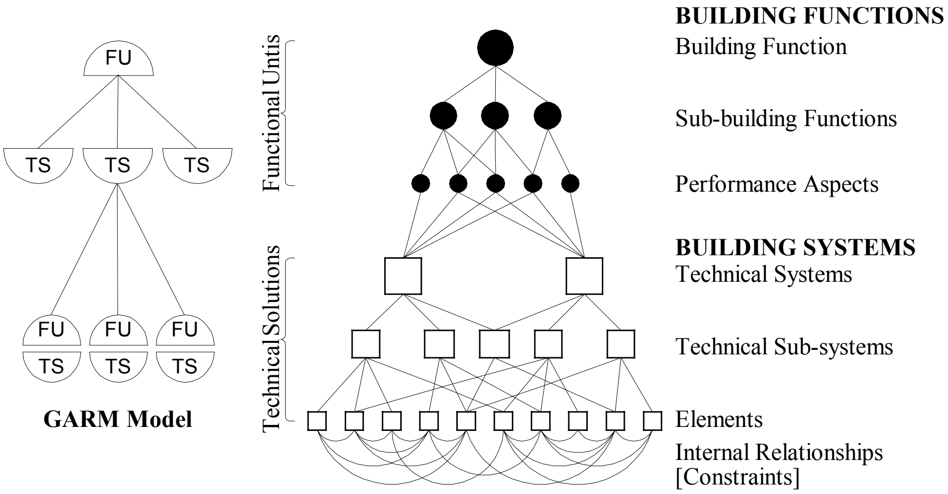


FIG. 7. Overview of a functional systems approach for product selection.

Performance-based searches can be thought of as a method for finding the 'meat' between the FU's and TS's in Gielinghs' “hamburger” model.

The systems approach (Ridder, 1996) to building design divides the design into two distinct, but related views: (1) the functional view, which addresses the functional aspects of the building design, and (2) the building systems view, which deals with systems that are designed or selected to fulfil the functional aspects of the building. At the highest functional level is the main function (purpose) for which the building is being designed. The main function of a building can be decomposed into lower level functions such as safety, habitability, and sustainability. Subsets of these lower level building sub-functions have been identified by various standards bodies such as ISO and ASTM. In many cases additional functions will need to be defined, as part of service 2. A number of performance aspects can be identified for each sub-function. These performance aspects can then be used to evaluate the performance of a sub-function.

At the building system level, functional systems form the highest level. Functional systems fulfil one or more performance aspects of building functions. They are aggregations of lower level building sub-systems. Elements are the smallest decomposition of a building system. Elements may belong to one or more sub-systems. There exists a constraint relationship within elements of a system and between elements of different sub-systems. This systems view is illustrated in FIG. 7

The goal of the performance approach to building design is to provide a mechanism by which one can measure how well a building system is capable of fulfilling the requirements of the building functions that it serves. In order to do this, the performance approach to building design addresses building requirements in terms of performance based on test results, rather than dimensions, specific attributes, or specific materials. This allows any material or product that meets the performance requirements to be considered for use (Gross, 1996). There are seven main concepts in the performance approach (Foliente et al., 1998; Vanier et al., 1996), see

FIG. 8:

1. Goal (occupancy) is usually a qualitative statement that addresses the needs of the user-consumer and

determines the required level of performance.

2. Functional requirements are the mandatory requirements that must be fulfilled to ensure users are satisfied with the facility.
3. Performance requirement are the user requirements expressed in terms of the performance of a product. Performance requirements are measured by "Performance Indicators".
4. Performance indicators (PI) are quantifiable indicators that adequately represent a particular performance requirement. A PI, by definition, is an agreed upon indicator that can be quantified using a verification method.
5. Verification methods are used to evaluate whether the performance requirement has been met. Verification methods can be experiments (tests), calculations, or a combination of both. Each PI has its own verification method. A number of verification methods may exist for measuring the same performance requirement.
6. Functional elements are parts of a building that fulfil one or more functions to meet user requirements. Functional elements can be materials, construction, and products from a product catalogue, even non-physical entities such as building spaces.
7. Agents, alter the ability of functional elements to satisfy the functional requirements.

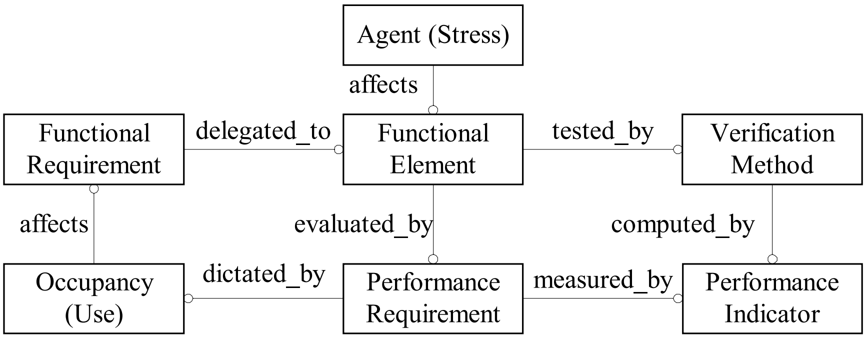


FIG. 8. Relationship among concepts in the performance approach. (Adapted from (Vanier et al., 1996)*).*

The first two concepts provide the functional goals that must be achieved. The relationship between the performance aspects and the building systems defines the level of performance that is required to achieve that goal. Performance indicators are used to quantify the performance requirement to determine whether a particular product satisfies the performance requirement. Context information required by the verification method is provided by the functional system that represents all the properties and all the relationships of all the elements in that system.

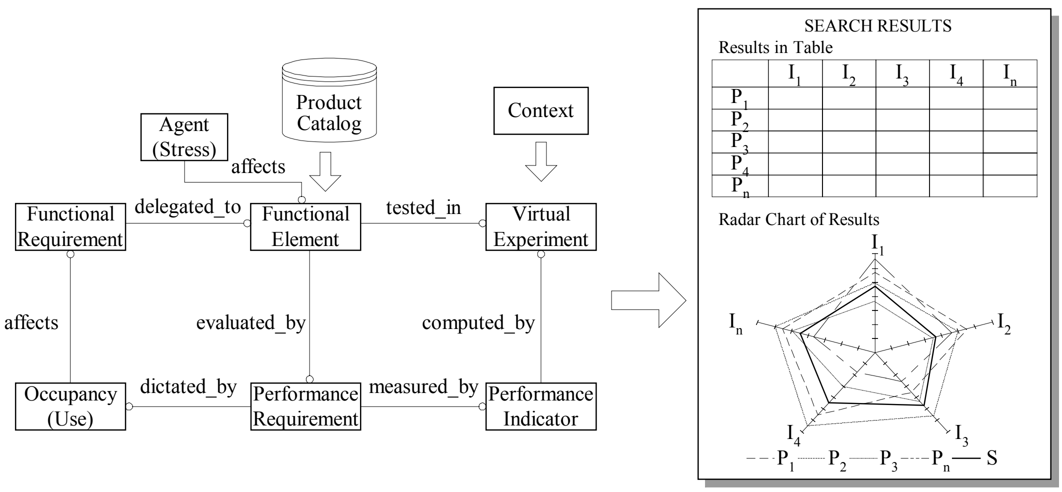


FIG. 9. Performance-based searches (P: Product, I: PI, S: Standard/Code).

Illustrated in FIG. 9, performance-based searches are an extension of the performance concept. The search process is conducted by selecting key PI's to evaluate performance requirements. Each PI is linked to a virtual experiment that computes the value of the PI. Products from one or more manufacturers e-catalogues are substituted in the virtual experiment to evaluate their performance. The resulting PI values can be compared to user requirements to determine if a product has satisfied the functional requirement. The virtual experiment is, in itself, a parameterised building model that can be instantiated at any time with values of the current design context.

5. SUSPENDED CEILING EXAMPLE

We now present an example of the systems approach described above to identify performance requirements that must be fulfilled when selecting elements of a suspended ceiling. A suspended ceiling in a typical office building shown in FIG. 10 will be used in this example.

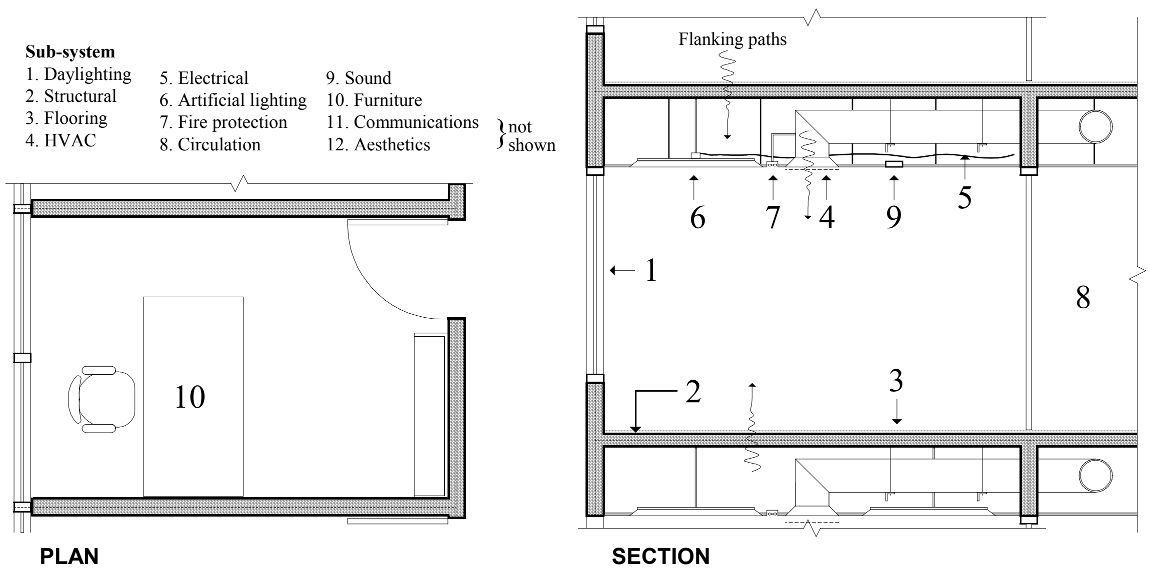


FIG. 10. Configuration of a typical office space used in the example.

In our example, it is safe to assume that the function of the office building is to provide a safe, habitable, and sustainable environment for its occupants. This high level function can be decomposed into various lower level functions. For the sake of simplicity and to stay within the limit of this paper we will only consider three most important performance aspects of the suspended ceiling – acoustics, lighting, and aesthetics.

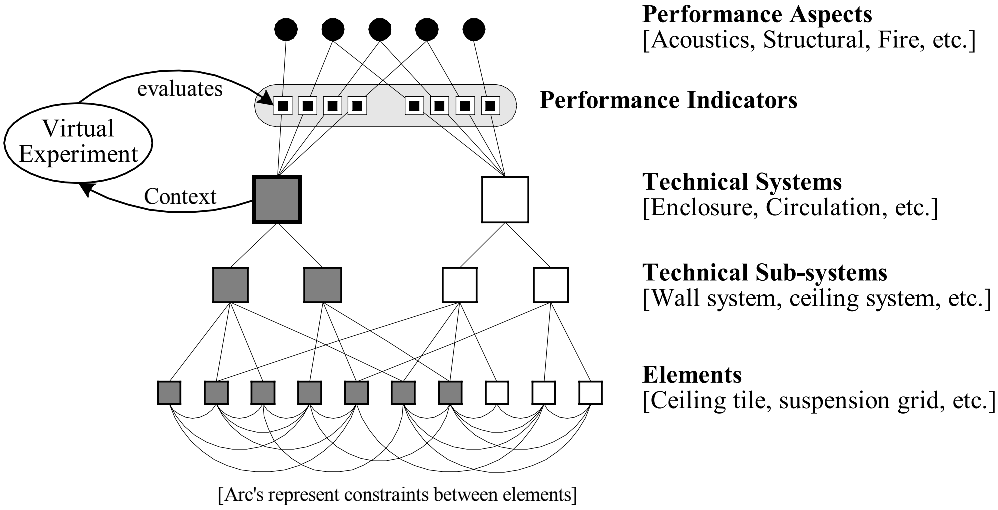


FIG. 11. Mapping between the functional system approach and performance concept.

At the building systems level, a suspended ceiling is part of an enclosure system and has a relationship with various sub-systems. It is composed of a number of elements, and element have constraint relationships with elements of related sub-systems and other elements of the suspended ceiling. For example, the height of the suspension grid must be equal to or greater than the maximum height of the HVAC duct.

FIG. *11* illustrates this decomposition of the space in to a mapping between the building functions and the building systems for our example.

Table 1, is an alternate representation of Fig. 11. The matrix in Table 1 shows the Function-System-Element relationships of a suspended ceiling. The Functional systems are represented as rows. The Performance Aspects and Elements that make up the system are represented as columns. An ‘x’ in the Element cell indicates the system in which the element plays a role. A “☑” in the Performance Aspect indicates performance indicators that are required to determine how well that system fulfils the performance requirement of the building function it is part of.

From the matrix we can infer that the selection of ceiling panels is determined by their role in four building systems – lighting, structural, fire protection, and room acoustics. Each of these building systems plays a role in fulfilling one or more performance aspects. And, that in order to evaluate indoor light quality, for example, one must develop performance indicators for each of the systems that have a role in fulfilling the building function (lighting, structural, flooring, furniture, etc.). For each of these systems it is necessary to have information regarding the elements that are part of the system. Table 1 is by no means a comprehensive matrix and is provided as an illustration to demonstrate the process. At the same time it must be noted that product searches are never based on exhaustive comparisons. Rather, first selection may be based on the dominant requirements with deferred checks of other performance aspects.

Table 1. Function – System –Element relationship matrix.

	PERFORMANCE ASPECT			**ELEMENTS**								
SYSTEM	Acoustical	Indoor light quality	Aesthetics	Ceiling panels	Suspension grid	Suspension rods	Retention clips	Light fixtures	HVAC vents	Sprinklers	Electrical points	Raceways
Lighting		☑	☑	x	x			x			x	
Structural	☑	☑	☑	x	x	x	x	x	x	x		x
Flooring	☑	☑	☑									
HVAC	☑		☑		x				x			
Electrical	☑		☑					x			x	
Fire protection			☑	x	x	x				x	x	
Circulation	☑											
Room acoustics	☑			x					x		x	
Furniture	☑	☑	☑									
Communications			☑								x	x

To demonstrate proof of concept we are implementing a prototype that addresses the requirements of Service 2, described in section 3.

5.1 Prototype Implementation

The prototype is implemented as a web based service. The user is presented with an Element & Performance Indicator Selector screen, Fig. 12. On the right hand portion of the screen are all the elements that belong to the suspended ceiling in our example. When a user selects an element by clicking on the check box the corresponding PI's appear under Performance-aspect of the functional system. The user can then select the PI's it is interested in using to evaluate the performance of the element. The user then clicks the "submit" button to instantiate a query in bcXML format for the selected elements.

The query engine then queries the manufacturer databases for elements that meet the functional requirements specified in the query. Only those elements that meet the required criteria are returned and stored in the candidate product database. After the search is completed the user can instantiate virtual experiments associated with the selected PI's.

While virtual experiments can range from simple equations to full blown simulations we believe that full-blown simulations are contrary to our purpose of providing simple executable experiments that do not require expert input. However, it must be noted that the type of product that is being tested will determine the complexity of the virtual experiment. Currently we are using simple equations and simulations in MATLab to create our virtual experiments. A web-based form for calculating Reverberation Time is shown in Fig. 13.

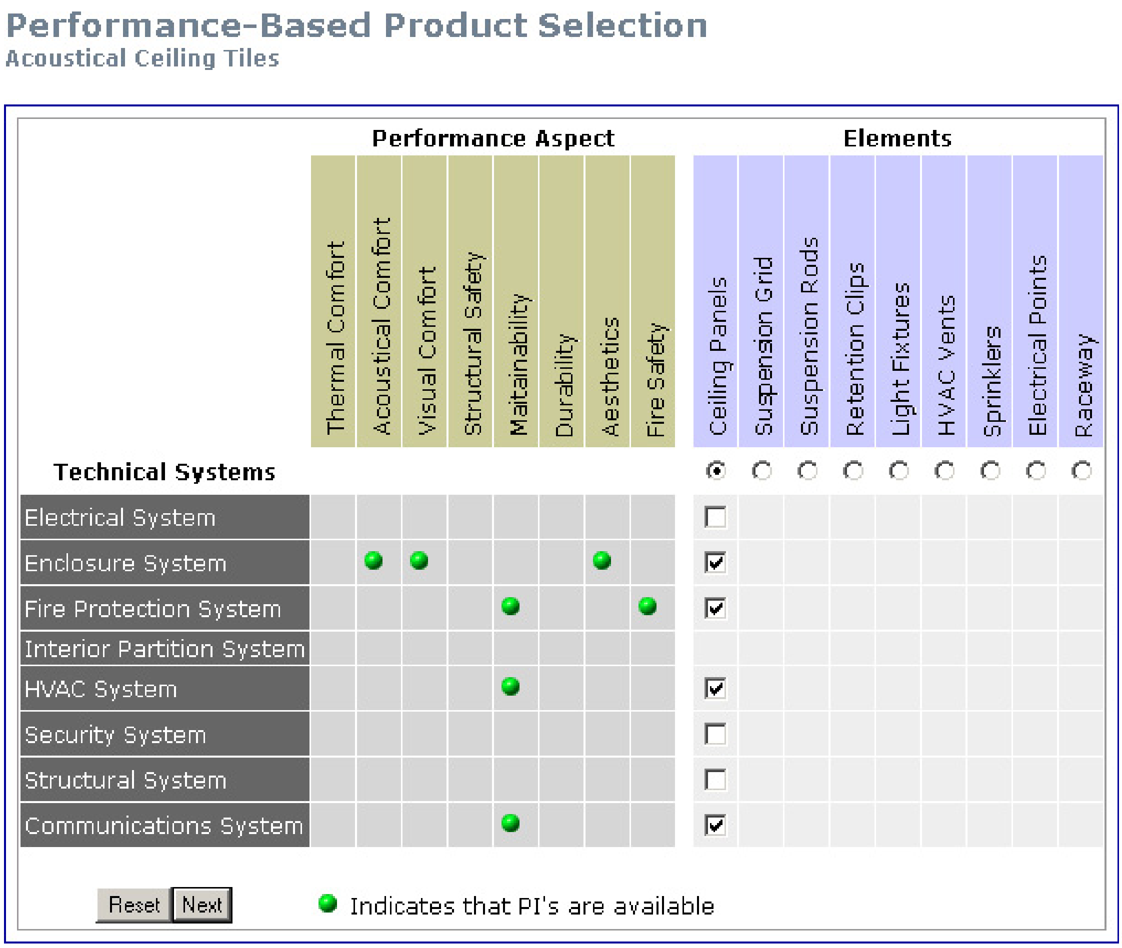


FIG. 12. Screen-shot of the Element & Performance Indicator Selector.

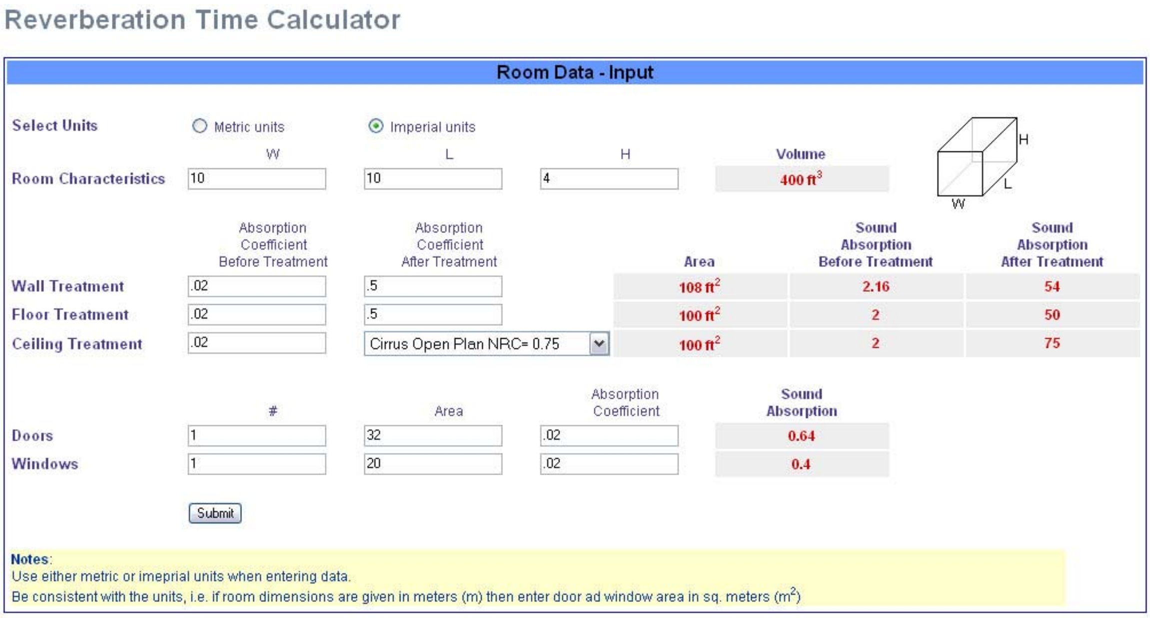
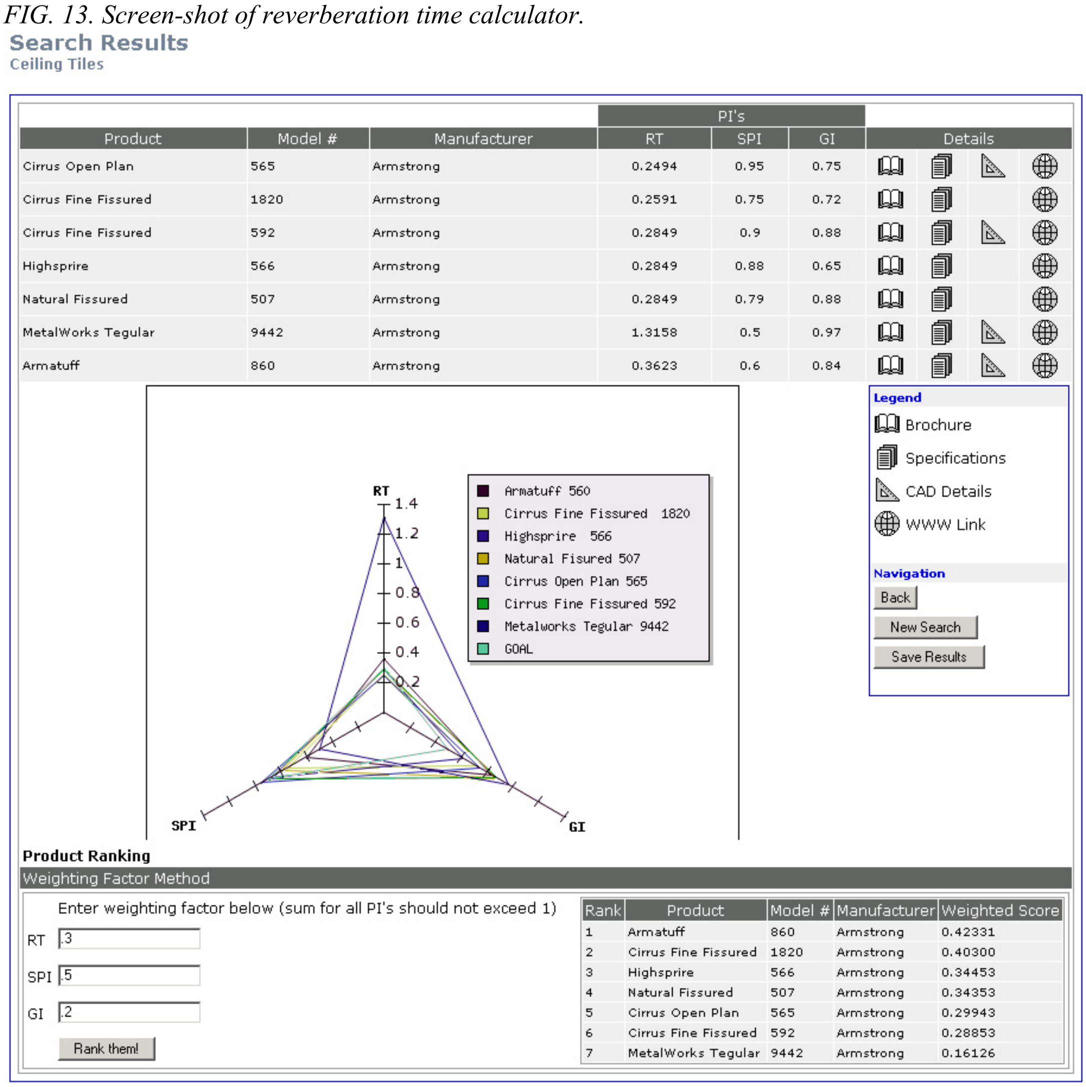


FIG. 13. Screen-shot of reverberation time calculator.



Product	Model #	Manufacturer	RT	SPI	GI
Cirrus Open Plan	565	Armstrong	0.2494	0.95	0.75
Cirrus Fine Fissured	1820	Armstrong	0.2591	0.75	0.72
Cirrus Fine Fissured	592	Armstrong	0.2849	0.9	0.88
Highsprire	566	Armstrong	0.2849	0.88	0.65
Natural Fissured	507	Armstrong	0.2849	0.79	0.88
MetalWorks Tegular	9442	Armstrong	1.3158	0.5	0.97
Armatuff	860	Armstrong	0.3623	0.6	0.84

Rank	Product	Model #	Manufacturer	Weighted Score
1	Armatuff	860	Armstrong	0.42331
2	Cirrus Fine Fissured	1820	Armstrong	0.40300
3	Highsprire	566	Armstrong	0.34453
4	Natural Fissured	507	Armstrong	0.34353
5	Cirrus Open Plan	565	Armstrong	0.29943
6	Cirrus Fine Fissured	592	Armstrong	0.28853
7	MetalWorks Tegular	9442	Armstrong	0.16126

FIG. 14. Screen-shot of search results page.

Once the system has computed all the PI's for the selected element the user is presented with a results page, Fig. 14. The top portion of the page provides details of the all the found elements with values of the PI's, links to available details such as product brochures, specifications, CAD drawings, and the manufacturers web site. The Radar chart shows the relative performance of each product. The user can use the navigation buttons to go back and refine the search, conduct a new search, and save the current search for future use.

At the bottom of the results screen is a ranking of the products found in the search results. A user determined weighting factor for each PI is used to rank the products. The results of the ranking and the weighted score of each product are shown on the right. The user can assign different weighting factors to conduct a sensitivity analysis for each product and PI's .

The next section, discusses the business benefits of using a performance-based approach to product selection. The performance-based approach is introduced as a value added service that could be provided by product information brokers.

6. BUSINESS VALUE

Most of building product information in the US comes from product information brokers. Though most manufacturers are now beginning to maintain their own product catalogues, product brokers offer the advantage of having product information from several manufacturers, which permits users to compare product offerings from multiple manufacturers from a single source. The performance-based approach offers a new value added service that product information brokers can provide. A product broker must have three basic components in order to support true performance based selections: (1) a gateway to select products from conventional e-Catalogues, (2) a suite of context sensitive filters (based on design context and constraints) to reduce the set of candidate products, and (3) a set of web hosted virtual experiments to evaluate candidate products.

The operation of the three components requires new types of interactions between the user and the information broker. First, the traditional search process will have to be abandoned, and must be replaced by a more robust process in which a designer can instantiate virtual experiments either directly from a CAD file or via a special interface. Second, the designer must be able to initiate new product searches based on functional product types. Third, these search results must be downloadable into the current CAD model. Other interfaces, such as custom configurations, automatic download of specifications will provide additional benefits. Table 2 is a value creation grid that lists the potential benefits of using this performance-based approach.

Table 2. Performance-based e-Catalogue value grid. Adapted from (Riggins, 1999).

Five dimensions of Commerce	Value Creation		
	EFFICIENCY	EFFECTIVENESS	STRATEGIC
TIME	Accelerate user task to find the "right" product for the design problem	Provide reliable, continuous, and up-to-date product information for decision making, project tracking	Effectively provide 24x7 customer service to users
DISTANCE	Eliminate long feedback loops by providing on-line product customization and product design	Present single gateway access to catalogues from multiple manufacturers	Global presence to allow design teams to interact with same product information
RELATIONSHIPS	Alter role of information brokers, new mediators	Provide customized service to users based on their preference	Create loyal customer base by providing value added services
INTERACTION	Interact directly with customer to learn about product preferences, choices, method of selection	Users can extract level of information relevant to their needs	Communicate with users on-line & through discussion forums to post product feedback, etc.
PRODUCT	Mass customization, automate time-consuming tasks	Assess product performance, product comparison tools, consistency in design details	Bundle information, products and services

7. CONCLUSIONS

With the advent of e-catalogues and the possibility to search for a product type across many of these catalogues the number of product hits will greatly increase. It is to be expected that the added value of the Internet will decrease if the search process cannot be supported by a user driven product ranking. We have introduced the basis for an implementation of such a ranking as a broker maintained service, based on quantifiable performance aspects of the candidate products.

The biggest challenge to scale the service up to cover a industry strength is the realization of a sufficiently large set of 'virtual experiments'. Each virtual experiment is defined as a simplified schematization of the real design case, yet accurate enough to provide a similar ranking of the candidate products as would have been found through full simulation in the real design case at hand. The next phase of the research concentrates on this aspect and will develop a strategy to define in each case, the simplest virtual experiment that meets that requirement.

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