Agenda 21: Information and Documentation – a Research Agenda

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Executive Summary:

The building industry is seen to be recalcitrant in terms of improving its efficiency and adopting innovative ways of working; there are explanations for this, placing responsibility on the structure of the industry and on its use of information for decision-making. Re-engineering, systematic procurement and performance-based building (PBB) are recent initiatives that impact on the use of information, i.e. on the 'information problem'.

Little work has been done on this 'information problem' – or more exactly, on the *problem about information on information* in the building sector. This suggests that research into this problem and its consequences is urgently needed, since information – in its two forms: general and project-specific – is an essential ingredient of all decision-making and of all knowledge enrichment.

The building industry is highly fragmented and its participants work in contexts that are unfavorable to good communication and, above all, unfriendly to the systematic acquisition of information, even if it is recognized as necessary to support the many decisions that must be made.

A conceptual model of the nature of information flows in the building process show what kinds of information are required at various phases of that process, within the context set by the chosen procurement strategies. However, it is necessary to understand the other changes that are afoot and recognize that they have repercussions on the nature and use of information, in order to see (a) in what ways they affect what information is needed and how it can be handled and, conversely, (b) whether the availability and use of well-adapted information might not in fact *facilitate* these changes.

Research into information should therefore be linked to the three complementary areas (re-engineering, procurement and PBB) in the form of a coordinated program of research projects, *starting with* (but not limited to) the two-way impact of information on PBB and *vice versa*. This program of work should build on the scarce (but valuable) work that is being done in various centers or groups scattered worldwide.

A number of research questions are proposed, together with possible research hypotheses. Research proposals have to be solicited and should be coordinated internationally to optimize the use of research resources which are rare in this domain.

This research program *excludes* studies of performance-based building as such and it is *not* about information technology *per se*.

Funding for the program is not discussed, but obviously has to be a matter of concern if the best resources are to be mobilized *and* effectively coordinated.

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Acknowledgements

I acknowledge with thanks the guidance provided us by members of CNBR (Collaborative Network for Building Research) in response to our call for "information about information" in the building and construction sector. Documents that they provided or referenced have been included in the paper and mentioned in the reference list at the end.

I also acknowledge the help we received from Mrs. My Loan Duong, Reference librarian at the School of Library and Information Science (Université de Montréal) who conducted a keyword search for us.

I note that some members of the PeBBu Domain 9 team provided information in response to the survey – mentioned in the paper - that was conducted some time ago for Domain 9 of the PeBBu project; we thank the few who focused their responses on what is, for us, the real problem, namely: information about information.

I also thank those who provided comments to the Agenda; their comments are mentioned in Appendix B.

The work on this Agenda would not have been possible without a grant from the Government of Quebec; I am most grateful for their support and encouragement.

Chapter 1. Introduction

Two true stories

Once upon a time, a senior University administrator was discussing building science with a senior researcher in a public research agency. Suddenly the researcher interrupted the (presumably) serious conversation to interject: "Architects never tell lies … " and after a pause charged with conflicting emotions, continued: "because they don't know what the truth is".

On a separate occasion, a professor of architecture met one of his ex-architecture students – now a computer specialist who had climbed to the top of the technical echelons of a major cable and video company. After an exchange of amiabilities, the professor asked: "I've always been curious to know why you studied architecture – since all your career has been deeply involved with computers". The reply was immediate – as if the question was really dumb: "Because it is the only education which teaches people to look at the whole of a problem before studying the parts".

These two stories complement each other. Beyond the irony of the first, lies the problem of knowing (or rather: not-knowing): how can the architect (or the engineer or the city planner …) possess all the information that is properly required to make professionally correct decisions?

Indeed, Leslie and McKay (1995) write:

> The importance of up-to-date information cannot be in doubt but practitioners constrained by lack of time, money and human resources and perhaps unaware of their knowledge gaps, tend to rely on old familiar material for solutions, Rarely, if at all, would a project be delayed while a search is undertaken for additional, but unknown, information. In other words, under current conditions, better information is sought only where there is a pressing need for it.
>
> Project procedures, contractual arrangements and even fee structures can act to discourage a practitioner from seeking new and possibly better solutions (page 23).

In the second case, the professor was tempted to comment (but refrained out of politeness): "Architects dare to look at whole problems because they know they can get away without ever knowing everything about all the parts" – which is the basis upon which the discussions about design methods (and its information needs) are founded.

Which is why we submit this report to CIB

CIB – in concert with leaders of the building and construction sectors[1] worldwide – is concerned about improving the performance of building design and production activities. In this context, under the umbrella title of Agenda 21, areas requiring study have been described and promoted to the stage of coordinated research programs. Sustainable construction, performance-based building and re-engineering construction ("revaluing construction") have taken lead positions in this collective initiative.

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1 Hereafter, the terms "building" and "building ~" are used to cover both building and construction.

However, an essential complementary program of activity has been neglected, we feel. In an environment of innovation, it is high time to study *information* as an essential ingredient of the production of buildings. Here, we refer to the need to understand how the building design and production process works, *viewed in terms of the information needed for the many decisions it involves*.

There is probably no disagreement – in principle – with the objective of really understanding the role of information in the building process[2]; what is not realized is the absence of research in this area, as we will show. We have immediately to make the distinction between the process of developing, acquiring, preserving, utilizing and disseminating information (Abecker *et al*., 1998) on the one hand, and information technology[3] on the other – while recognizing that there is (or should be) an impact from the latter on the former.

Information is not a trivial matter. Not only does it impact on the quality of buildings and the performance of the building process – as will be shown – but information management also represents a considerable cost item – as much as 25 % of total revenue (Lindfors, 2003).

The **objective** of this report, therefore, is to lay the foundations for a concerted effort to understand and improve the use of information for better decision-making in building and thence for quicker adoption of innovations.

Where are we coming from?

Lorna Tardif (1998) reminds us:

> There are many types of *information*; for example, the color of your eyes (which may be interesting, but is not relevant). Then there is relevant information, such as the quantity of concrete poured on May 22, 1997 on level 3, area C of project 'X' (which is objective information). Also, there is other relevant information, for example the expression on the face of the inspector when examining the concrete (which, while relevant, is not objective).
>
> We must remember that a document is *not information*; a document is only a means of *capturing information*.
>
> It is significant to note that in an ordinary project, we have:
>
> - plans for procuring materials,
> - plans for the production of shop drawings,
> - plans for estimating prices,
> - management plans of several sorts …
>
> But we have *no* plans for the management of information!
>
> As a result, there is an excessive use of letters and memos of all sorts – which are usually difficult to trace; there is an excessive duplication of information, and a

2 We emphasize that we use the term "building process" to include design, manufacture, use, management and removal as well as on-site fabrication and assembly of buildings and works.

3 "IT has been seen as a driver for the development of many construction organizations and operational processes" (Aouad *et al*., 1999). This has, in many cases, led to a backlash against information issues in general, largely from an over-confidence in the technologies themselves rather than as enablers of major improvements (Lindfors, 2003).

correspondingly excessive duplication of documents. There is neither quality assessment nor quality control of the information that *is* captured, and the storage of all the documents is inefficient, making their retrieval difficult if not nearly impossible (page 49).

The information context

Many researchers and practitioners are searching for ways to improve the value for money invested in building and construction, that is to say, to improve the quality of buildings and infrastructures being provided to Society for the resources being consumed now - and in the future. The search takes on different forms and is given different names: re-engineering, the performance approach, strategic procurement, sustainable development, …, all of which imply working to improve the *processes* and *procedures* by which buildings are initiated, designed, produced and used.

Through all these initiatives, there is a common thread: *information*. There is the information needed to study these changes and their implementation, and there is the information generated for the new forms of practice. Underlying these initiatives and their information needs, there is the information[4] that is the basis for the decision-making that supports *all* building processes and procedures – traditional or novel. Without information, the decision-making would be impoverished and building work would grind to a halt.

The implication is that the building design and production process can be described in terms of its decisions (see Figure 1, next page). The underlying hypothesis is that better decisions are made when better information is used for making them, suggesting that process oriented information systems will positively impact on the performance of project groups (Lindfors, 2003). Unfortunately, there is also evidence that time spent searching for information is not considered to be time well spent.

It is well known that the information used for these decisions falls into two classes:

- General information – the information that is *not* generated for a particular project but which is most often the product of a research institution, a codes body or a commercial firm:
  - *Information coming from a building research institution* usually addresses problems that are of current concern in a given region over a given period; to be useful, it must find its way into practice – i.e. it must be[5] disseminated and stocked so that it can be taken up (voluntarily) when needed.

    It goes without saying that it should be comprehensible for its users, that is to say, written in a language that they are at ease with (Eksteen, 2001), and presented convivially (e.g. with appropriate kinds of illustrations). Indeed, Eksteen (2001) writes: "There is a need to develop mechanisms for integrating higher level system purposes with affect tracking, so as to establish what forms of display and other system behavior are optimal" (page 25).

4 In this document, the term "information" is used, unless the context implies differently, to include (i) the actual information being communicated and also (ii) the supporting documents and document handling used to collect, stock and disseminate it. The document can, of course, be electronic.

5 "must be" if one understands that research which is *not* applied is devoid of economic sense (Corsten and Junginger-Dittel, 1986).

- *Information generated by a codes body* – because of its obligatory status – is necessarily disseminated and used; it has to be made readily available and it has to be susceptible to uniform interpretation.
- *Information produced by a commercial entity* (essentially product information) is characterized by being actively, indeed aggressively, disseminated; its content is shaped by the business needs of its editors.

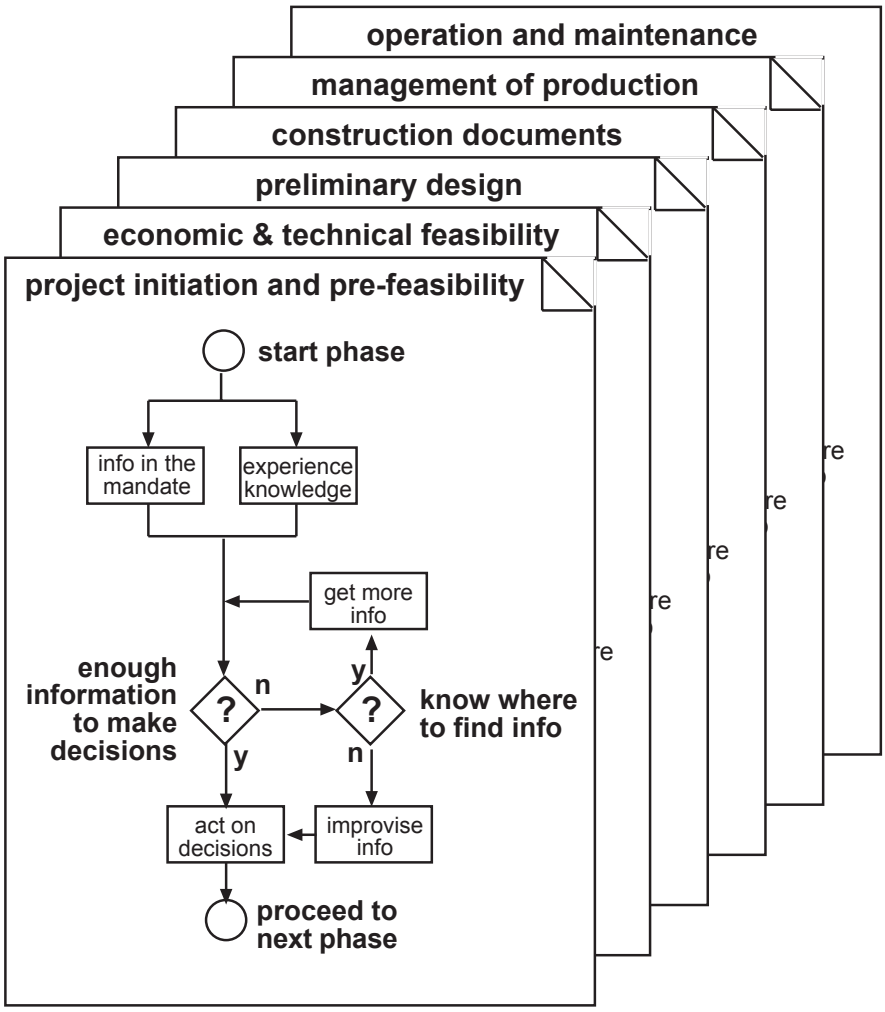

Figure 1. The phases of a building project viewed in terms of the decisions to be made and the access to the information required to make them. What happens when this information is not retrieved – possibly because it was not available or was not easy to find? "Improvisation" i.e. reference to experience drawn from the past (which may or may not be directly applicable).

The essential feature of general information lies in the fact that there is usually a time lapse between its production and its use, requiring warehousing it and suggesting related problems of indexing and retrieval.

- Project-specific information – i.e. the information that *is* generated for a particular project, which flows between the participants, receiving additions and undergoing transformations as the project progresses.

  Project-specific information (about designs and specifications) may or may not be packaged in ways that suit the receivers; indeed, its presentation is governed by traditions that prevail in a given locality and it is still commonly accepted today that skill is required for the interpretation of instructions (UN-ECE, 1958). This situation suggests in turn that when there is any change from traditional practices (e.g. when there is innovation), the traditional approach to dealing with information may no longer apply. The information related to innovation will probably upset the reliance on this "interpretation skill", potentially leading to acute communication problems and putting a brake on innovation itself - unless the information is systematically designed in parallel with the innovation it describes.

The building industry context

As we have suggested, there is, currently, a certain "impatience" with the building industry, worldwide. This impatience is proclaimed in various public sector reports, which assert that - through a better organization of the building process - savings can be achieved, project durations shortened and quality improved. Private sector clients of the industry add their voices to this call for improved performance.

Innovation, or rather the lack of it, is seen as the major brake to the improvements that are called for. The structure of the industry and the habitual processes by which projects are procured, designed, constructed and maintained, and their component parts specified and manufactured, all seem to explain, if not justify, this apparent reluctance to innovate. The explanations include:

- the fact that the building industry is composed of a large number of different (and generally small or very small) firms and enterprises, falling into different categories with different codes of conduct; this fragmented and heterogeneous industry is referred to as a "multi-industry" (Davidson, 1988);
- the fact that building projects are entrusted to groups of participants who are brought together from within this multi-industry - through the building owners' procurement strategies - for the duration of the project; these short-lived heterogeneous groups are called "temporary multi-organizations" (Davidson, 1988);
- the fact (already mentioned) that any effort regarding information (retrieving and reading it) is currently *not* regarded as a productive use of one's time.

Katsanis *et al*. (1997, page 324) point out in this connection that:

> Network organizations are clusters of firms interconnected together by contractual or informal communication and exchange links; the firms work jointly toward common external objectives, such as the production or delivery of products or services, within an explicitly designed scope, budget and time frame, Once the life cycle of such endeavor comes to an end, the particular network organization is disbanded, while its former constituent firms are likely to pursue new alliances and join other networks in moves that are consistent with each firm's own internal objectives.

> In this description of network organizations, *external* objectives refer to the shared objectives towards which all firms in a network operate. Such objectives are project-specific, and a firm espouses these as a result of its commitment to the network's collective reputation and well-being. The *internal* objectives, on the other hand, are the firm's own long-term objectives expressed in performance measures, such as return on investment, stability in the market place, etc.
>
> In the current business environment of network organizations, where boundaries are thin and transparent (Bahrami, 1992), a congruence of internal and external objectives not only becomes imperative, but is often dictated by the very operation of the network and the nature of the transactions that the technology and the market support (Snow *et al*., 1992; Eccles and Crane, 1987),

Note in passing that this mode of operating is not necessarily all negative; members of the building industry have developed a high level of skill at working within this project-by-project environment – a skill, incidentally, that is now being copied in other industries as they move away from rigid bureaucratic structures and adopt matrix-type project-related management strategies to cope with an increasingly dynamic environment (Groàk, 1992).

Within the building "multi-industry", which we have referred to, the various participants can be described in terms of their "information appetite", namely the amount of information they require in their daily professional activities.

For example, architects are required to build into their projects[6] a vast amount of information: social, economic and cultural at the start of their activities; technical and practice-oriented later on. On the other hand, the specialty trades, again for example, require focused information, which they bring to bear on the instructions included in their contracts – instructions they have to be able to interpret and act upon. Wong *et al*. (2003) – in the context of a study of safety issues – comment that

> The construction industry has its unique nature that all construction projects are carried out under almost all sorts of weather conditions and stringent program in terms of time and completion. Moreover, the high mobility and dispersal of workforce over wide areas of construction sites, and generally low level of education of construction workers are the sources of communication difficulties.

However, as Love and Irani (2003) state:

> In construction projects, activities are typically divided into functional areas, which are performed by different disciplines (e.g. architects, engineers, and contractors) and that therefore operate independently. Invariably, each discipline makes decisions without considering its impact on others […]. Moreover, these functional disciplines often develop their own objectives, goals, and value systems. As a result, each discipline has become dedicated to the optimization of its own function with little regard to, or understanding of, its effects on the performance of the project with which they are involved. In fact, the interfaces that exist between functional disciplines have become a potential barrier for effective and efficient

6 When we write: "build in information", we refer to the fact that the information that architects (in this example) use to make the necessary decisions in a timely manner is not "visible" in the final product, the building. If it is required afterwards (in the context of a historical analysis, for example, or a case in court), it has to be *decoded* from the building itself. This is in contrast with research, where the final product, the report, *is* the information.

> communication and coordination of projects […]. When a breakdown in communication is identified, the source of the problem can typically be traced back along the supply chain and it often becomes evident that there were 'informational flow mishaps' in the process. This is linked to information sharing and channeling (page 649).

Gann (2003) echoes this concern, commenting that while design and construction activities are intended to provide collective problem solving, there is very little indication that the industry succeeds in creating and disseminating new, context-specific knowledge – in terms of communicating across professional and disciplinary boundaries.

What is the source of the difficulty? Where should this information come from and how should the rules for its optimum exchange be established?

In the case of the architects, the information that they use for their projects comes from their experience (i.e. their tacit and explicit knowledge[7]), from their commission (the brief), and from contextual indications (e.g. the projects' location, site etc.). Only rarely does it come from sources outside their office. Indeed, it has been found (Bardin and Blachère, 1992; BRANZ, 1984; MacKinder, 1982) that in the absence of the pertinent knowledge, information is sought as follows:

- from colleagues 'at the next drawing table',
- from the senior draughtsman 'on the other side of the office',
- from the 'job captain' and
- from the most convenient manufacturer.

It is very unusual that the search for information moves further; a research institute, a reference base or an 's.v.p.' service is rarely consulted, despite their apparent relevance. Similar findings apply to engineers, with the one difference that they appear to prefer asking colleagues *outside* their office rather than asking around in-house (Bardin and Blachère, 1992).

Regarding the information provided by a manufacturer, Burry *et al*. (2001) write that:

> Designers often rely heavily on product literature for construction details and specifications. These typically promote a limited range of materials and their extension to composite systems and context related decision-making is not necessarily supported. This information source has the advantage of immediate product availability, dimensional and performance limitations and cost implication as a reliable and typically free service to the designer. This may effectively limit experimentation and innovation by building designers, however, and transfer construction industry research and development away from building design professionals towards product designers.

Wherever this information comes from, Leslie and McKay (1995) point to the risks associated with information acquired through the dominant "ask-as-you-go" approach. Reliance on someone's personal knowledge and experience as sources of

7 An existential problem emerges here; while it is true that an architect, for example, acquires knowledge and experience related to a specific project and its particularities (determined notably by the identity of the other project participants), it is unlikely that this experience can be applied easily to another project with is different particularities (different mandate, other project participants, etc.).

information is risky. The information may not be current, its communication can engender misunderstandings and: "the person with the knowledge must be there at the time of deciding, be attentive and have the necessary powers of recall".

Chapter 2. Information flow in the building process

It is possible to focus on understanding (and describing) the building process by looking at the effort invested, and the time spent in supporting the "gateway decisions" – those decisions that enable a project to move forward to a subsequent phase – and to see what are the consequences of having to search for the *information* needed to support these decisions (Figure 2).

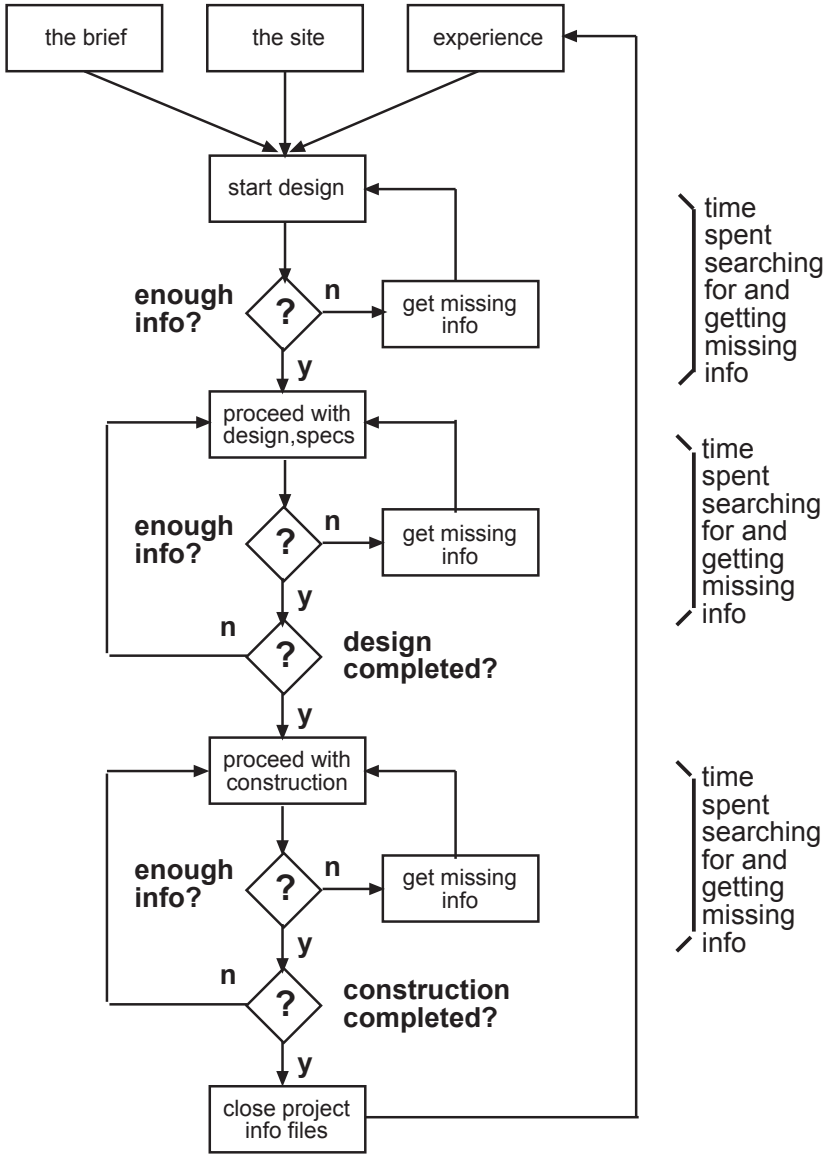

Figure 2. Getting missing information can take time.

Information whereabouts may not be known, its form and content (including the language used) not suitable, and the source unwilling to release it.

In this Figure, the feedback link from "close project info files" to "experience" is somewhat misleading, since only a small part of the acquired knowledge will be pertinent for the "next" project – unless the concerned participants are highly specialized and offer their service in focused niches. (Source: adapted from Lockley *et al*., 1987).

As has already been explained, "information"[8] falls into one of two main types: *general* and *project-specific*, where

- "general information" refers to information that *is not* prepared with any specific project in view, such as
  - research reports,
  - practice notes,
  - codes and standards,
  - trade catalogues;
- "project-specific information" refers to information that *is* prepared with a specific project in view, such as
  - project brief,
  - project design drawings,
  - project technical drawings and specifications,
  - project-related contract documents and change orders.

To obtain the *general information*, it is necessary for the project participant who needs it, to make an effort to enquire outside the confines of the project team, acquire the information and adapt it in response to a question of immediate and practical concern. As we have pointed out, research shows that practitioners are reluctant to invest time and effort in accessing the information they need to make informed decisions (Bardin and Blachère, 1992; Bardin *et al*., 1993, MacKinder, 1982) and reading research reports is not considered a good investment of practitioners' time: "Research is heavy jargon … after the first page we start falling asleep" (King, 1984). It is worth noting – as Bardin and Blachère (1992) and Bardin *et al*. (1993) point out – that research institutions do not regard putting out vulgarized information as a worthy use of time. Davidson (1995) quoting Brillouin (1959) writes:

> *An item of information only becomes intelligence if it reaches the decision maker who can use it on time and in the desired form*. Yet information coming from research does not reach practice (our translation; italics in the original).

The *project-specific information* is passed from participant to participant within the project team as the team grows in complexity, new members join and others drop out when their task is completed. Within the growing volume of project-specific information, questions are asked up-stream and replies given down-stream. The flow of information is asymmetrical within the building project team; having information is a source of power and having difficulty in accessing it easily leads to conflicts, which are reflected in reduced productivity (Mohsini and Davidson, 1986). Indeed, Mohsini and Davidson (1991) have shown that of the three main sources of conflict:

- consensus about domains of intervention,
- availability and access to information and
- task interdependence,

the second source of conflict ("availability and access to information") is negatively

8 The term "information" includes, as elsewhere in this report, the documents serving to support and transmit it.

correlated with most of the conflicts observed – i.e. less availability and access leads to more conflict. Quite clearly, then, there is a direct link between the easy availability of adequate information and the improved performance of the building process.

It goes without saying that the two types of information – general and project-specific - have to be accessed when needed for decision-making, within the economic realities of building projects. They have to be accessed quickly and completely – otherwise they may not be accessed at all. Not having the proper information is often a source of rework and/or of delays (see Figure 2, page 9).

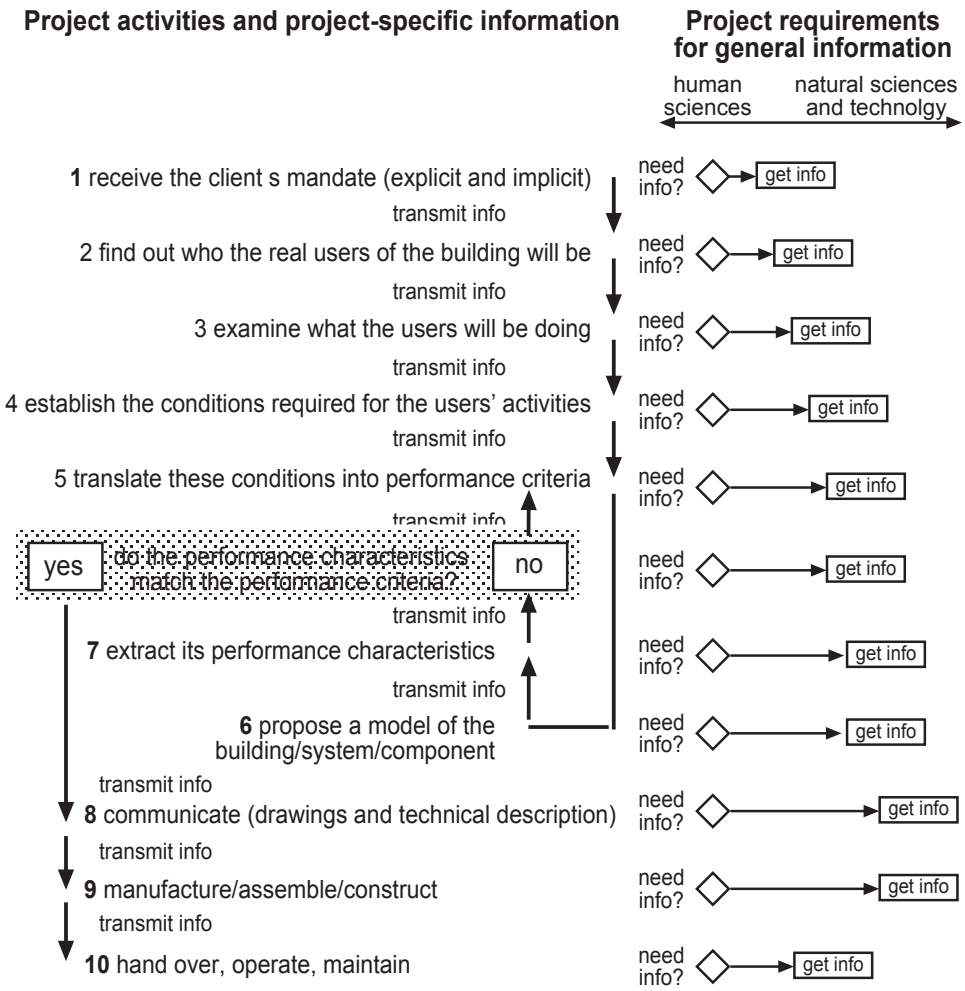

Figure 3. General conceptual model of the stages of the designing and building process, and the acquisition of additional information.

Whatever the procurement strategy, all projects implicate the steps 1 to 10. Between steps 5 and 6 is the "creative leap" when a "satisficing" (sic) solution (Simon, 1979) to the performance requirements is proposed. To proceed from step 7 to step 8 is only possible when the performance characteristics provided match the performance criteria asked for.

In general terms, that is to say, without regard to the procurement-driven strategic spread of responsibilities, the decisions in the project delivery process can be modeled as shown in Figure 3, previous page; when information is needed, the concerned participant is expected to make an effort to obtain it. Figure 4 gives further indications as to the kind of information likely to be needed at each step of the building design-and-produce process.

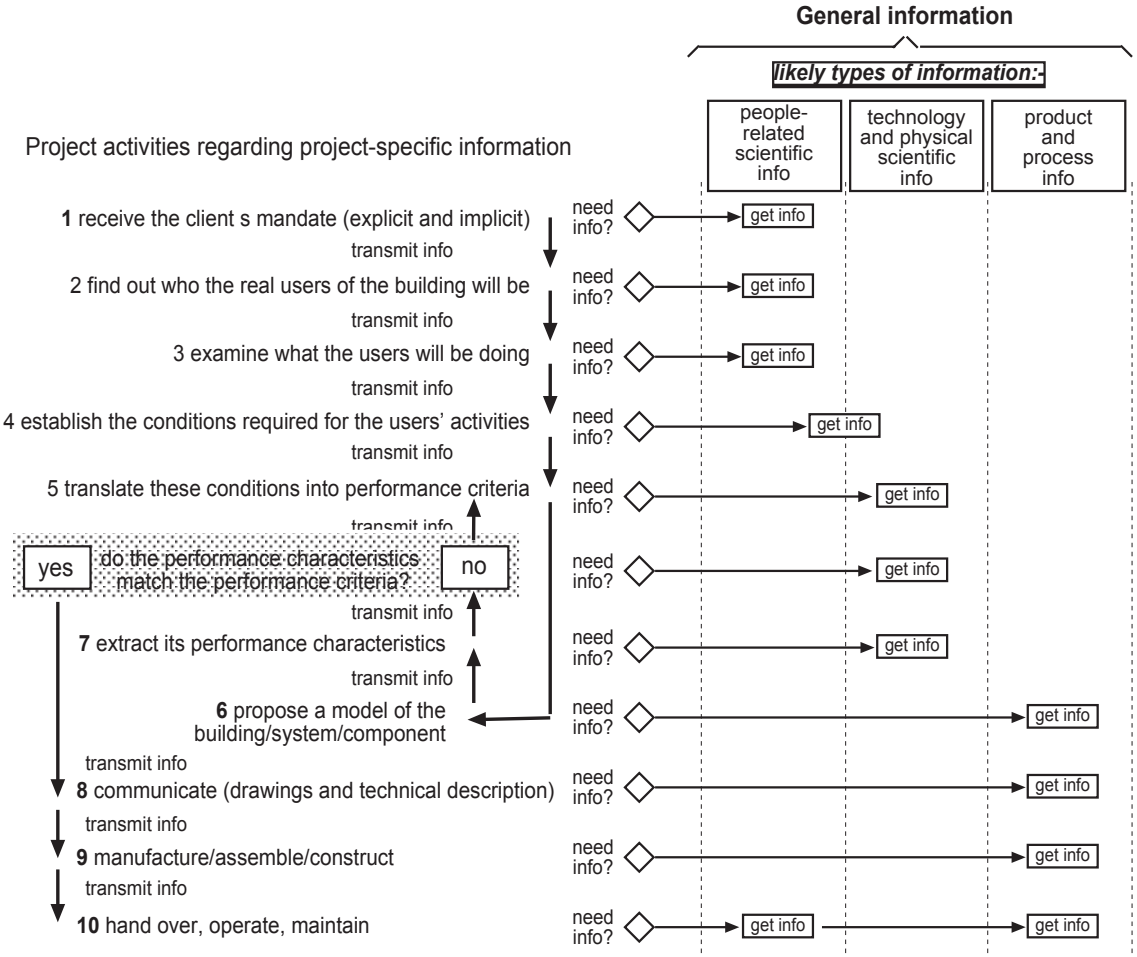

Figure 4. Conceptual model: depending on the step in the design-and-produce process, information will be retrieved from different sources with different content.

For example, the required information will probably be found as follows: in steps 1, 2 and 3, from the human and behavioral sciences; in step 4, from the physiological and physical sciences; in steps 5 and 7, from technology and the physical sciences; in steps 6, 8 and 9: from product and process sources.

For the evaluation of the match between performance characteristic and performance criteria (between steps 7 and 8), the information will be obtained from technology and the physical sciences, hopefully in a language adapted to extracting performance-related information.

We suggest that the information required to support the successive decisions, shifts progressively from the human sciences towards the natural sciences and technology as the process advances. The implication is that the information has not only to be available in a form that enables it to be used for *prediction* – i.e. to anticipate the user-related consequences of the design decisions being made – but also available in a form best suited to the needs of the practitioner involved at that moment.

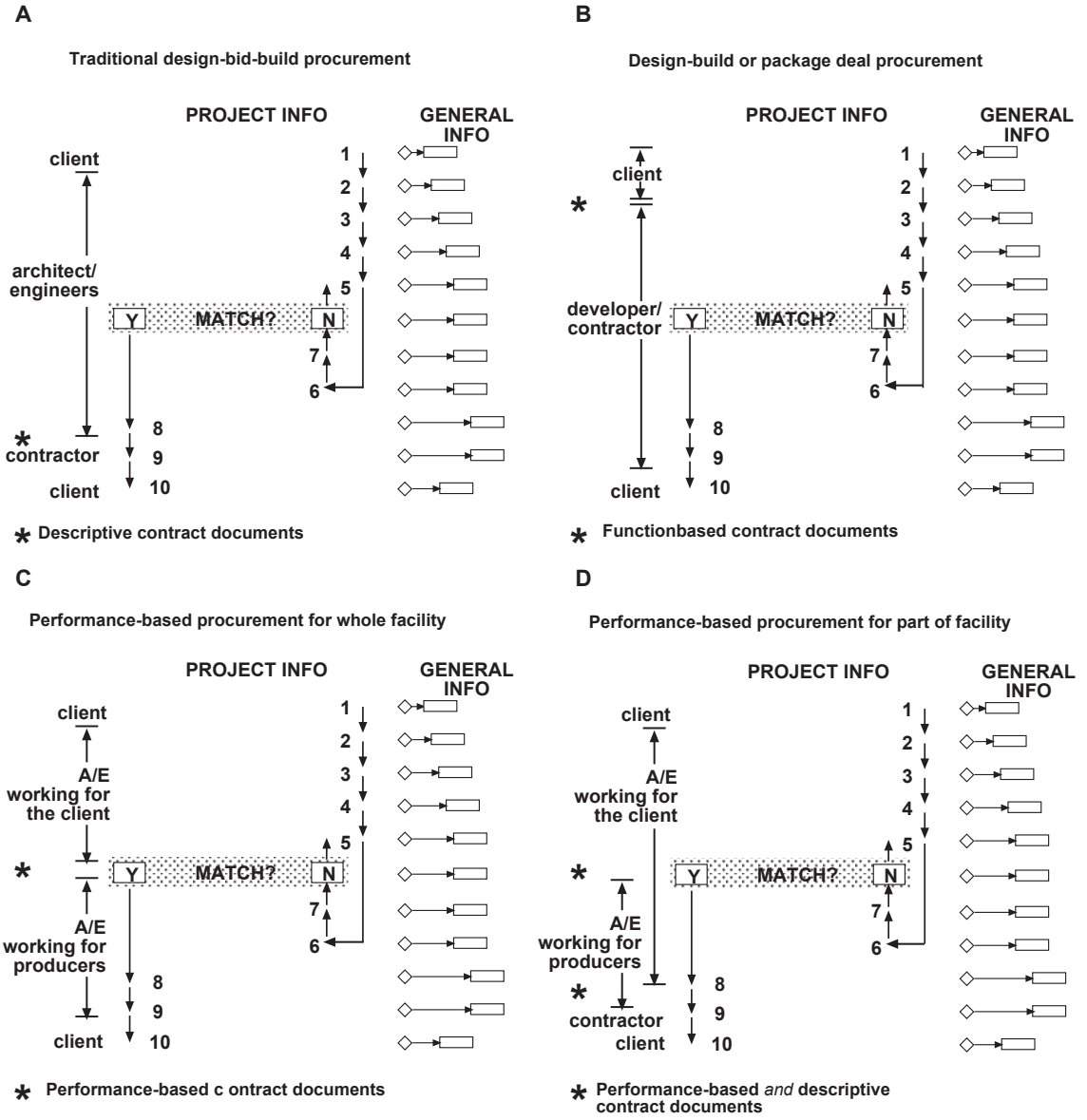

Figure 5. Spread of responsibilities between participants under various procurement options.

In option **A**, the performance thinking (if any) will be internal to the A/E team; in option **B**, it will be internal to the developer/contractor; in options **C** and **D**, it will be explicitly reflected in the performance-based contract documents. The asterisks show where there is a contract enabling the project to move forward to the next major phase; the existence of and the need for the contracts correspond to bottlenecks in the flow of information, where formal methods of communication replace the informal ones; the kinds of contract documents are also

indicated.

The two types of information we have described differ not only in their content, but also because of the *access* route required to obtain them. Access to general information requires searching outside the bounds of the project team, which in turn implies having the skills to know how to obtain it and how to interpret it [9].

Access to project-specific information on the other hand, will vary, depending on the participants' roles and on the possible impact of re-engineering and of procurement strategies on the definition of these roles (and of the ensuing relationships), and on the impact of innovations such as PBB.

What kinds of information?

In describing our model, we have hinted at the notion that the kinds of information required to meet the needs of the various steps of the process of designing and producing buildings changes systematically. This is presented in Figure 4, page 12.

Some of the project-specific information may be found within the expertise and knowledge (explicit or tacit) of the concerned offices and firms, while other has to be searched for from outside, from the realm of general information (remember the findings quoted above concerning the will to search for information - or not to bother). The providers of general information should anticipate who is most likely to use the information they put out and to anticipate what he or she will be doing when using that information, that is to say: bringing into their store of project-specific information.

Therefore the question: "what kinds of information" suggests that not only the *content* of the information has to be pertinent for the decision tasks at hand, but also that the *presentation* has to be suitable i.e. convivial for the intended decision-maker (Eksteen, 2001).

Information and innovation

As we mentioned in the Introduction, this report addresses the question of information in the context of CIB's coordinated initiatives for improving the building process: primarily re-engineering and performance-based building, to which we add: procurement strategy.

The subject is therefore set against the backdrop of **re-engineering**[10] the building process. New roles and thus new links between project participants necessarily impact (i) on project-specific information (its movement and its content, for whom and when) and (ii) on the kind of general information that is pertinent for them. Research in re-engineering cannot be isolated from studies of its impact on information - and vice versa.

Choice of **procurement strategy** is also likely to be a significant factor in determining the relevance of, and means of access to certain types of information, since it too affects participants' roles and responsibilities. Again, this suggests the

9 Information from research sources needs "refinement" before use by practitioners. Imagine driving across Alberta and seeing that the gasoline gauge is low; you spot some oil wells beside the road, draw over and fill the gas tank with the black liquid being pumped out. Turn the ignition key – and nothing will happen. Why? Because the product was not refined to suit your needs! The analogy with information dissemination is obvious. (Jean Michel, personal communication to W57, Paris).

10 Re-engineering the construction process is now called "Revaluing construction"

scope for a programmed interface between research into information and research into procurement.

Performance-based building (PBB) radically affects the spread of responsibilities for decision-making in almost all phases of the processes, even if this may be less obvious than for re-engineering and for strategic procurement. Adopting PBB affects the kinds of information the participants require, as it has to be matched to their now-modified roles; conversely the availability of appropriate information impacts on their ability to operate within a PBB environment. Indeed, the need for research on this subject stretches beyond or, more precisely, *precedes* the introduction of PBB.

In other words, within the broader context of the changes to the building process currently being explored[11] by CIB and others, information, we suggest, is a mediator whose importance is scarcely recognized today.

Let us take a close-up information-oriented view of re-engineering, procurement and PBB.

Re-engineering and information

The structure of the industry which we described above, supports suggestions that, for example, re-engineering the building process may hold the key to opening the door for the major improvements that are wished for.

To succeed, the re-engineering is, or should properly be, accompanied (i) by appropriate and systematic approaches to the movement of information between the project participants with their newly defined roles, and (ii) by repackaging the information to suit these re-engineered roles.

It should be pointed out that forecasting trends in the organization of the building process (whether re-engineered or not) is not the subject of easy agreement. For example, one view proposes the emergence of *integration*, particularly of the enterprises implicated in the concomitant demand for increasingly large projects (Bakens, 1997). A contrasting view is proposed by Katsanis and Davidson (2001) who predict hyper-specialization accompanied by hyper-fragmentation. Whichever view turns out to be correct in a given context, they both presuppose new requirements regarding the movement and use of information – within firms (in the integration scenario) or between firms (in the fragmentation scenario).

For example, the integrated (and presumably larger) firms will possess information processing capabilities (such as an in-house technology watch service – see Figure 6, page 21). This service should be able to manage the information / knowledge streams expressly for the staff of the integrated firm, with their known specialties. The hyper-specialized, probably small, firms have an in-depth knowledge of their specific domains (the commercial basis for the success of their operations) and are likely to be able to manage their focused information requirements (provided such information exists, i.e. has been produced by the research institutions) - notwithstanding their

11 Sustainable development is another change, which impacts on the building processes in a more subtle way; it affects every participant without necessarily affecting their roles or the organizational structures within which they work. Nonetheless, a proper approach to sustainability presumes ready access to complete information on sustainability issues packaged in a way that is matched to its users.

smaller size, since the focused information is the key to their survival in the market-place.

In either scenario, the re-engineered building process still implicates a significant number of participants; consequently, it is hardly necessary to stress the need to "re-engineer" the provision and handling of information for and by them - in parallel.

Procurement and information

In the economic contexts that prevail world-wide – characterized by increasing project complexity and speed in the industrialized countries, and by inadequate resources to meet pressing needs in the developing countries – traditional contracting strategies are found to be inadequate. Instead of design-bid-build, contemporary procurement routes involve novel organizational designs with novel sharing of responsibilities, opportunities and risks.

Procurement options now available fall into three broad classes: separate and cooperative, integrated, and management oriented (Masterman, 2002). To these three classes, a fourth option is sometimes added, "integrated design, construction and operation" (Lennard and Mohsini, 1998).

Procurement, in many ways, matches re-engineering, except that the emphasis shifts from a view of trends in the industry as a whole (re-engineering) to concerns for the reorganization of individual projects or programs of projects (procurement) governed by the clients' priorities.

At the project, or program-of-projects level, procurement-induced changes of roles and modified responsibilities for decision-making call for significantly changed access to information resources, affecting content and form.

Performance-based building and information

In parallel with a concern for re-engineering and for procurement studies, another view of the same "productivity" problem in building suggests that performance-based building is a way to work around the current roadblocks. Without necessarily analyzing the impact of up-front procurement strategies on the spread of tasks between design, manufacture and construction (i.e. of re-engineering and of procurement), it is readily assumed that the language of performance, describing the ends and not the means, is best on the demand side, and that describing the means that meet these ends is best on the supply side.

Figure 5 (page 13) shows the impact of procurement strategies on the spread of responsibilities for collecting information to support the design-production process. The boundaries between the various blocks of responsibilities are reflected in the location of the contracts (the asterisks in the figure) that act as milestones marking out the steps in the process.

It should immediately be pointed out that the concept of the "use of information in the PBB context", as mentioned above, actually covers a two-way situation where:

- the PBB approach requires new *types* of information (both ‘project-specific’ and ‘general’ – see more below), and new ways of retrieving and presenting it, that is to say: of *handling* the information;
- the new ways of handling information will in turn impact on the way the PBB approach is adopted, how rapidly and how comprehensively.

Information and PBB

So far, we have placed equal emphasis on the three current changes being promoted within (or on behalf of) the building industry: re-engineering, procurement and PBB. We now turn our attention specifically to PBB - as a potential *catalyst* for a long overdue interest in the movement of information within the building industry. However, it must immediately be pointed out that the changes induced by PBB are probably more complex (and less easily identified) than the organization-specific changes that follow from re-engineering or from procurement strategies.

Specifically regarding the structure of the industry (within which performance-based building is to be implanted and within which information necessarily must flow), it is fragmented, as mentioned above, and it is largely made up of small and medium enterprises (SMEs) – indeed many of them are "micro-enterprises" - who possess particular skills and occupy narrow niches in the industry.

Within this industry, CIB recognizes that performance-based building is worth promoting; it is seen (a) as a way to open the door for innovation by those who are most able to undertake it (assuming that they will seize the ensuing opportunities – which is not always evident), and (b) as a much needed stimulant for tackling the "obsolete" divisions of responsibilities among the many participants in the processes of producing a building[12].

PBB can be caricatured by the catch phrase: “The ends justify the means”. In other words:

- the buyers (in the case of buildings: the clients or their professional advisers) state clearly what is wanted – but only in terms of the required qualities: the performance *criteria* derive from the functional requirements (step 5, Figure 4),
- the vendors (in the case of buildings: suppliers or contractors) show what they can best provide – describing it in terms its performance *characteristics*, based on their production processes and on their capacity to innovate (steps 6 and 7, Figure 4).

The performance approach implies, therefore, matching the *criteria* (what is being asked for) with the *characteristics* (what is being proposed) and checking that the characteristics are equal to or better than the criteria. This is a difficult decision process that (i) requires appropriate information and (ii) has to be carefully allocated to some responsible participant.

- Regarding the "appropriate information":
  - those who are responsible for establishing the performance criteria have to do so in terms of the functional requirements - without knowing what building techniques will be adopted. When the criteria are spelt out *in detail* (e.g. in performance specifications), the specifier faces the dilemma of (i) not knowing what the solution will be, while (ii) recognizing that there will be complex interactions between parts of the proposed solution which might not have been anticipated in the specification. There is a kind of chronological *information gap* between what is known (the performance *criteria*) and what has yet to be decided by others (the performance *characteristics*).

12 Notably in the traditional approach, called "separate and cooperative" (Masterman, 2002).

- those who are responsible for proposing a solution whose performances are equal to or better than the criteria required of them have to access information (or produce test results or experts' judgments) to "prove their point". There is an *information translation* problem as one works back from the physical properties of the intended building to its performance *characteristics.*

- Regarding the responsible persons:
  - their roles depend entirely on the applicable procurement strategy as do their allegiances, in other words on the chosen procurement path (see Figure 5, page 13). For example, in an extreme case, with design-build contracting: "the role of the design-builder has to be clarified, particularly regarding the design-builder's architects, which is unique. The architects are provided by the design-builder as professionals and as such they have a slightly different responsibility than the other 'commercial' members of the team. As professionals, *by definition*, they are saying to the users and the community 'we will protect you no matter who is paying our fees' " (Wundrum, 1998; italics in the original),

What has *not* yet been mentioned here is: who are the key participants entrusted with matching the performance criteria with the performance characteristics? What are their contractual positions as determined by the adopted procurement strategy? What relationship do they have with the other participants who hold (or withhold, e.g. for short-term commercial reasons) the needed information? And, above all, what are the kinds of and sources of, the information that is required for proper decision making - at any of the ten stages shown in Figure 3, page 11.

Chapter 3. The information problem: the need for research

In this way of looking at the building process and the emerging trends, *information* appears as a key ingredient, particularly in any attempt to change the building industry, its capability to innovate and its hoped-for adoption of the performance approach. The absence of an understanding of the key role of information translates into a *problem of information about information*.

We base our concern for research into "information" (its generation, its warehousing, its movement, its retrieval and its use) on the concomitant need for re-engineering the building process, for systematic procurement *and* for adopting the performance approach - together. But we have also briefly shown that information lies at the center of any improvements in the building process – whether driven by re-engineering, by systematic procurement or by the performance approach.

We stress – as mentioned above - *the two-way influence of the changing approaches to the organization of the building process on information, and conversely the impact of novel approaches to information on improving the building process*.

In doing so, we hope to show that information is – or more realistically - *ought to be* the kernel of research in this search for improved building through quicker and better innovation – both organizational innovation *and* technical innovation.

In short, we suggest that there is an "information problem" to be solved before there can be significant innovation. We also suggest that performance-based building can well be taken as the starting point for research into information and communication in the context of knowledge-intensive building processes – but it is only the starting point.

This *problem of information about information*, broadly requires (a) an understanding of the movement of information between participants: researchers, professional practitioners, enterprises, controlling authorities, etc., and (b) an understanding of the nature of the information, its content and its most likely sources (see Figure 3, page 11).

This *problem of information about information* is largely unsolved; it has been left to be examined by specialist librarians (in the scientific arena) or by marketing consultants (in the product arena). These people possibly have partisan viewpoints that may prevent them from integrating their work into a broad understanding of the stakes in today's changing building scene.

Antecedents within CIB

We conducted a survey of all the sites of all the full members of CIB to see whether there were indications as to research already being done regarding the 'information problem' as we describe it in this document.

An annotated list of what we found is included in Appendix A. In brief:

- many members provide information to their 'clients' through an information *service* – the nature of these *clients* depending on the organizational structure and position of the research institutes in question;
- several members provide that information through an information *system* – but without explaining how the system was designed (i.e. what research was

conducted in the first place upon which the design was based) and how it operates;

- a very limited number of members indicate that they are carrying out research into what we call "information about information" and appear to have published on this subject.

Within the ambit of the PeBBu project, the Domain 9 ("Information and documentation") team was charged with finding out what, if anything, was being done internationally about the *specific requirements regarding information in a performance-based building context*, hopefully with the purpose of networking the involved researchers.

This task was undertaken through workshops and a cluster of international surveys. The findings were essentially negative; in other words, with the exception of two of the reporting countries (Denmark and New Zealand), nothing much was reported as being done to address the opportunities and the challenges presented by the emerging adoption of performance-based building – *specifically from the "information" point of view*. It is important to distinguish here between work on performance-based building *per se* (which was mentioned in the responses to the surveys even if that was not what was being asked for) and the specific subject of information related to performance-based building: its content, processing, use etc., which is the concern here and which was not described in most of the few survey responses.

Thus, there appears, from the surveys, to be an almost total unawareness of the importance of information in the PBB context (what it is, where it comes from, how it is distributed and how it is presented and used). Instead, some rather diffuse claims were found regarding information *about* PBB. Moreover, nothing was found on the web sites of major building research institutes about information *for,* or *as an integral part of* PBB.

These findings are based on surveys which were conducted: (a) by some of the original members of the PeBBu Domain 9 team, (b) by an Internet search of all the CIB full members' sites and (c) a general keyword search on the Internet.

In parallel, research is being undertaken regarding the transfer of information to small and medium enterprises in the building sector, both in Commission W102 and Task Group TG47, and was the theme of the congress organized by the Belgian Building Research Institute (BBRI) in 2000 (see, for example, Davidson, 2000). Though this work is not specifically related to the PBB information problem, its findings can certainly pave the way for better understanding information-related processes (see Figure 6, next page).

Information, innovation and technology watch

The major high-tech industries value information for innovation, and invest significantly in in-house technology watch services, with trained personnel including documentalists, analysts and gatekeepers in touch both with the firm's strategic decision-makers and the classical sources of strategic information (patents, research publications, economic analyses etc.). Small and medium enterprises cannot often afford this kind of service; they rely on ad-hoc methods for gleaning information,

typically through trade or professional associations' congresses or through continuing education courses (Bardin and Blachère, 1992; Bardin *et al*., 1993). Sometimes,

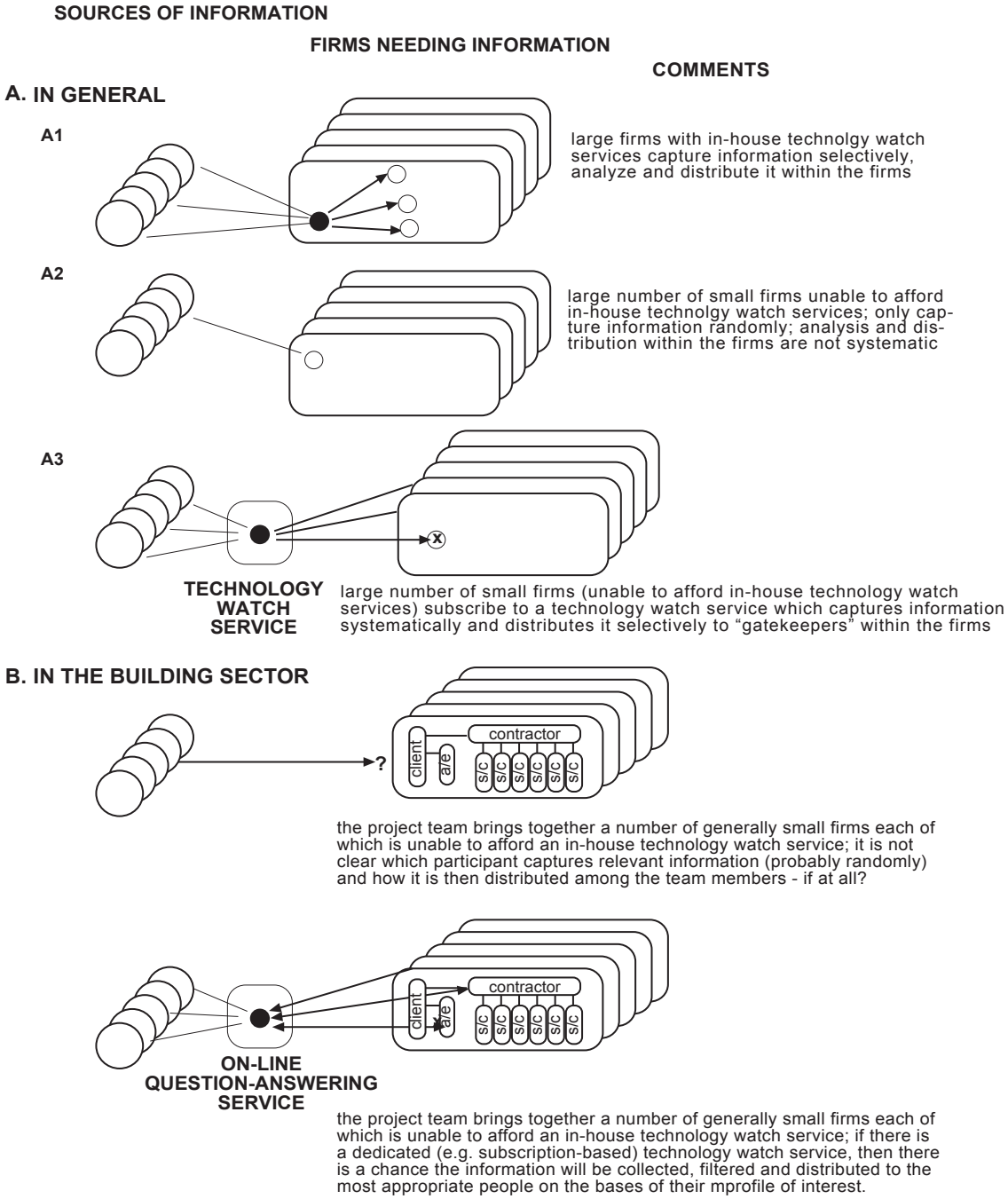

Figure 6. The transfer of innovation-related information from research to practice.

A. In general; **A1** large firms, **A2**, SMEs, **A3** SMEs helped by a technology watch organization; **B.** in the building sector; getting information to, and into, the project team.

Note that in situation **B.**, the inherent difficulty is compounded by the fact that the project team is short-lived and, if there is an identified leader (such as a project manager), his/her

mandate is limited to the duration of the particular project.

technology watch services act as essential go-betweens[13], enabling the participating firms to be kept informed.

Transposing this *technology watch service* approach to the building sector is tempting. However, there are a number of related questions that immediately arise: what interdisciplinary technology watch services exist? If they did exist, and if they provided information to the project teams, how would the information they provide be distributed within the project team?

Manley (2003), commenting that most innovations in the road- and bridge-building sectors that her team studied, note that most innovations that were reported concerned the business practices domain. Their findings confirmed those of the OECD (1996), emphasizing the relationship between involvement in knowledge networks and innovation performance. Manley adds:

> The importance of paying more than lip service to knowledge sharing and collaboration cannot be stressed enough. Pro-active and sustained measures are required. The focus of such activities ought to be the *flow* of communication, rather than the *content*. Organizations, especially large ones, can usefully appoint a Knowledge Coordinator, to care-take and promote such flows (page 55, italics in the original).

But, as we have said, the broad-scope challenge is to help the small enterprises!

For innovations like PBB, this is a major problem, and is directly linked to understanding the organization of the building process – an aspect that has to be "designed" into any sustainable research initiative.

Work of Commission W102: Information and Knowledge Management in Building

W102 has been working in the area of information about information since its establishment in 1999[14]. Reports of the meetings of W102 can be found at

www.grif.umontreal.ca/pages/W12homepage.html

The Commission – as its name and mission imply – has brought together a number of papers on the subject of *information about information*, accompanied by in-depth discussions.

Also, an on-line publication: "Information in the Building Industry" edited by Prof. Colin H. Davidson (1st edition: May 1998), is available at

www.grif.umontreal.ca/pages/publications.HTM

it includes the following papers that are relevant to the subject of this report:

- Davidson, Colin H., "The Information Problem in Building – Causes and Effects",
- Nurnberger, Elke, "Arconis – a System for Answering Questions",

13 Examples include the Building Centers. In Canada, the National Research Council has Industry research and practice (IRAP) officers strategically located in key Faculties or trade associations.

14 W102 'inherited' expertise from W57 in 1999, which in turn had built on early work of W52.

- Wissman, Wilhelm, "Practicalities of the Transfer of Information from Research to Practice".

Chapter 4. A Research Agenda

The objective of this proposal for a "Research Agenda" is (i) to present the scope for a program of research in the field of *information* in the building sector, using performance-based building (PBB) as the main catalyst, and (ii) to show its importance for improving the efficiency of building production.

As a consequence of the *problem of information about information*, its ramifications into the areas of building process re-engineering and of technology transfer, and as a consequence of the lack of antecedents described above, a *program* of research is called for. This program comprises a set of related exploratory research activities leading to fully-fledged cooperative research projects addressing this relatively unexplored domain.

It is possible to envisage that research into re-engineering construction, procurement strategies and PBB can (and indeed probably should) include focused sub-projects oriented to the information aspects of these main research fields. Obviously, any new initiatives such as in this proposal should be strongly coordinated with such work (Figure 7).

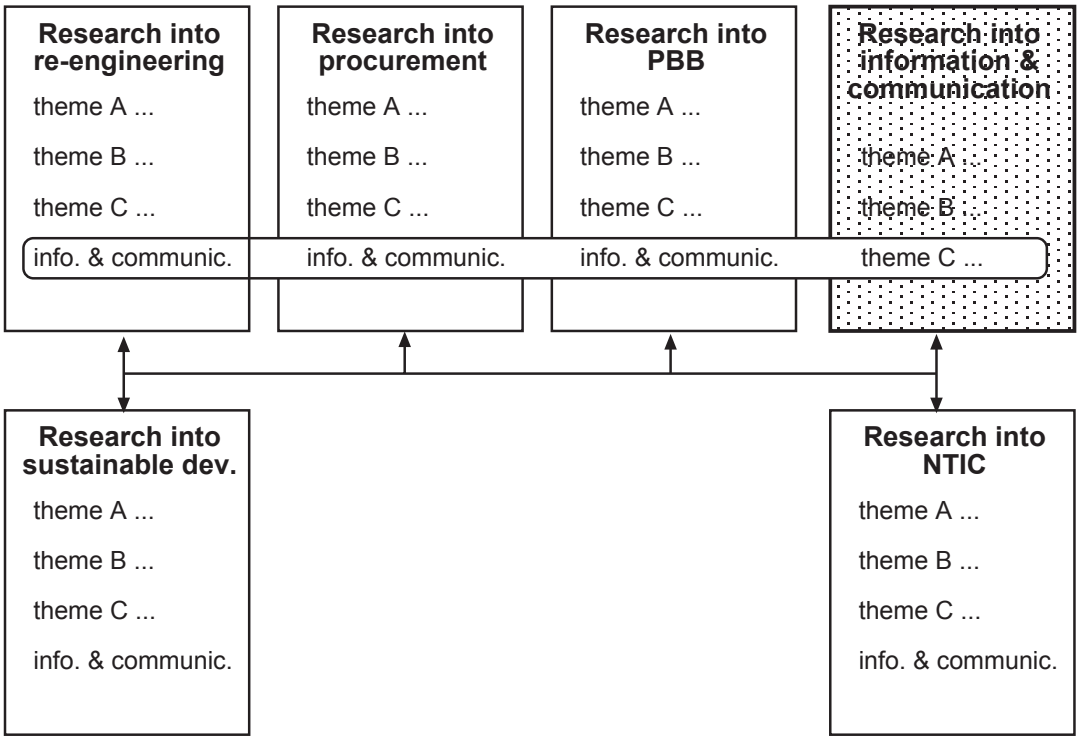

Figure 7. Research into information and communication in the building industry.

There is a need for strong links between the program of research into information and communication and the information and communication aspects of current or potential research in the fields of re-engineering, procurement and PBB; a link with work on NTIC (e.g. with W078) and a weaker link with work on sustainable development are pertinent.

The notion of a *program* of research is used to suggest that research bodies that feel inclined to participate should be able to select particular aspects of the broad domain that interest them - in a coordinated way.

To stress this point, the research domain (as has been mentioned) actually embraces three related and interlocking subjects:

- re-engineering and its impact on information and technology transfer – and *vice versa*,
- procurement strategies and information and technology transfer within the building sector,
- performance-based building and its information requirements - and *vice versa*.

It is suggested that it is appropriate to link the program proposed here to the study of PBB, at least as a starting point, though it cannot be isolated from a proper understanding of the other two.

Research questions

The research questions concerning information in the PBB context can include:

- What kinds of information are required for performance-related building design, manufacture and construction, including process management and control, and building maintenance and use?
- Where can this information be found?
- How is it (or could it be) taken up and used by professionals and enterprises who, for various reasons, choose (or are obliged) to work with the performance approach?
- How is performance-related information adapted for use at the various stages of project development (from briefing and design through to maintenance and use), and who assumes this responsibility?

These questions immediately raise corresponding questions that are relevant for the re-engineering and procurement strategies, mentioned above:

- How does re-engineering affect the flow of information within a re-engineered building industry? How does this modified flow of information affect the scope for innovation? Etc.
- How is information flow affected by various novel procurement strategies (using the traditional design-bid-build situation as a negative control)? Does consideration of information flow have a proper place in the contractual regime stemming from such and such a procurement strategy? How is the scope for project-level innovation affected by the ensuing information patterns? Etc.

Other questions include:

- Are there any successful examples or models of technology transfer services (within building sector enterprises or stand-alone services serving certain categories of firms) and how do they fit into a changing building industry?
- Do contemporary models of a re-engineered building industry take into account the impact on the flows of information within the sector?

- Can understanding the needs regarding the flow of information have a positive impact on attempts to re-engineer the building process?
- In this regard, what is the relationship between re-engineering, procurement strategies, roles of participants and information needs?
- Specifically with reference to technology transfer, what strategies seem most promising in terms of successful up-take of innovations?

Two points must immediately be stressed once again:

- *Information flow* refers to the movement of information from research to innovative practice (seen as an "irrigation" where the sources – the research institutes - and the captors – the professionals and businesses - both have a significant role to play) (see Bardin and Blachère, 1992; Bardin *et al.*, 1993).
- *Information flow* also refers to the exchange of information between the parties to the building process for a given project – whatever the procurement strategy might be.

Some research hypotheses in the PBB context

These research questions suggest a number of research hypotheses. For example, a broad hypothesis relating to performance-based building might take the following form:

> **A broad change *from* the traditional way of describing buildings and their parts (e.g. descriptive drawings and descriptive specifications) *to* descriptions based on performance (e.g. performance specifications possibly accompanied by 'footprint' drawings) has a two-way impact on information, communication and documentation.**

More specific hypotheses could then be:

1. Performance-based building requires that new kinds of information be made available for decision-makers, whether they be concerned with project initiation, with project design, with project manufacture, assembly and construction, with project management, with project control or with facilities management. (This hypothesis concerns the content of information).
2. The demands placed on decision-makers by performance-based building require that the needed information be made available to them in new ways and in new 'bundles'. (This hypothesis concerns the vehicles used for distributing the information).
3. Performance-based building is closely related to procurement strategies, thus impacting on the roles of the project participants and their required information. (This hypothesis knits the information *content* and the information *vehicles* into the processes of project initiation and implementation).

Exclusions:

- The program of research is ***not*** about the performance approach *per se*.
- The program of research is ***not*** about information technology (IT) *per se*, even though it is obvious that the rapid evolution of IT and its progressive take-up

within the building sector has an impact on the availability, presentation and use of information by project participants.

In this regard, we agree with Leslie and McKay (1995) who write:

> Computing is a tool and, like all tools, we need to think how it is best used. But computing is causing fundamental changes in the way we see and do things. To optimize its performance, the industry must review operating and business procedures to ensure they continue to be relevant (page 12).

Program organization

As mentioned previously, the extent of the research domain concerning, initially, information in the PBB context – if only because of its ramifications regarding technology transfer and re-engineering – strongly suggests that a *program* comprising a coordinated set of research projects is required. The full set of research projects comprising the program can be designed more fully, using the elements proposed in this Agenda, and suitably completed by a call-for-proposals; this process will yield further ideas about individual projects that can systemically constitute the program.

The coordination activities (including the call-for-proposals) can best be handled by the CIB, acting in a centralizing role.

Once this phase is completed, the allocation of the constituent projects can proceed. Some of these (that is to say, the suggestions made in response to the call-for-proposals) will be "owned" by the organizations that proposed them (though it is quite possible that even by making their suggestion they did not imply that they wished to conduct the ensuing research); in other words, they should have "first refusal".

As for the other projects (identified through the call-for-proposals or by brainstorming and similar techniques), a follow-up invitation can identify volunteer research organizations (or individual researchers) willing to tackle them.

Finally, if certain sub-domains that are central for the coherence of the program are not adopted, then specific measures (and inducements) will be necessary to find a resource that is ready to undertake the work in question.

Program and project funding

Note that no mention of the financing of the effort in setting up and coordinating the research program nor of the individual projects is made here; this lies outside the scope of this stage in preparing the Agenda – though it is obviously a matter of prime concern.

Timing and deliverables

The underlying postulate in this Agenda is that the *problem of information about information* in the building sector is hampering the hoped-for development of the industry and its improved performance. *It is therefore **urgent***.

More specifically, proposals to re-engineer the building industry and to improve its project-by-project way of working through strategic procurement studies must be accompanied by research into information and communication. Similarly, and at a focused level, introduction of PBB properly calls for studies about the availability of, and the use of appropriate information.

The reality of research financing being what it is, suggests that when the budgets for the next monetary period are established, the interested institutions (research centers and universities, in all probability), should allocate effort to finding funds for work in this area. The steps are indicated in Figure 8.

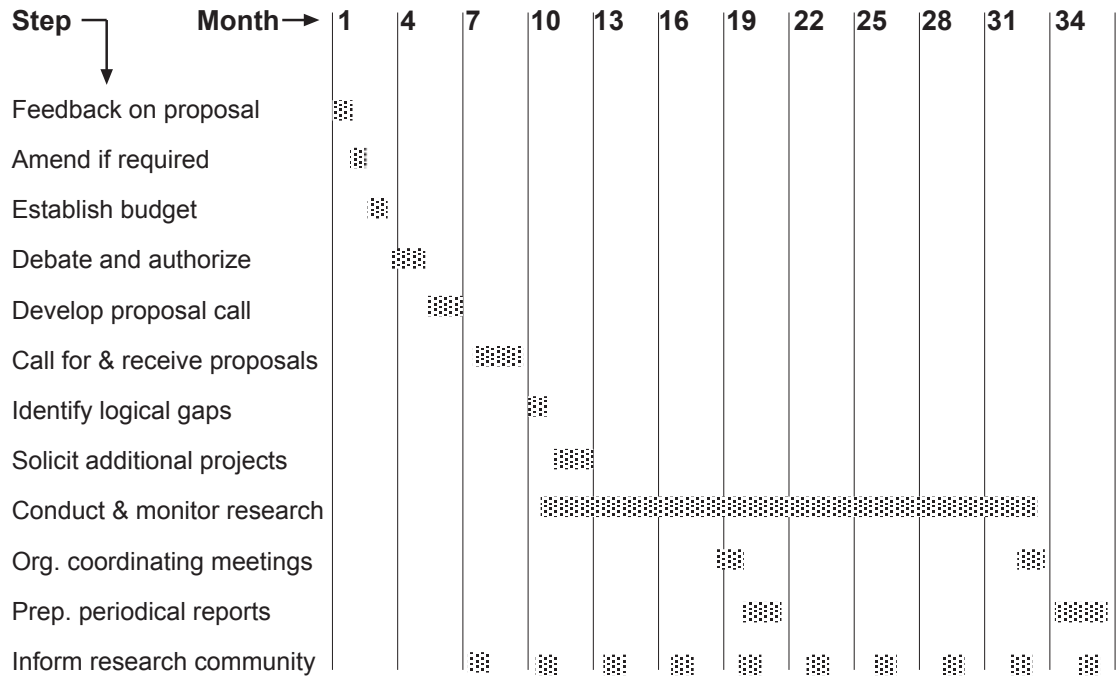

Figure 8. Tentative schedule of tasks over an initial 3-year period.

Chapter 5. Conclusions

We have shown that information – its creation, distribution, storage, retrieval and use – is essential for the efficient working of the building initiation, design and production process. Indeed, it is so central that we can suggest that hitherto it has been "taken for granted", only being the subject of focused attention when information *technology* is being studied.

We have also shown that information – or, to be more exact, ease in its retrieval and conviviality in its use – contributes to improved productivity. Furthermore, we show that innovations, to penetrate into practice, make special calls for information through technology watch.

It is for all these reasons that we propose to CIB the timeliness of launching a research program on *information about information* in the building process. This is seen as a companion to the other Agenda 21 projects and, like them, calls for international cooperation between all interested CIB members.

There are many advantages to be gained from launching a program of this sort:

- individual participant institutes or researchers will enhance the *use* of the information they produce as part of their normal research activities, by fitting it better into generally accepted information-related procedures,
- practitioners will find that obtaining the information they need is efficient and can no longer be called "time wasted",
- CIB will have the satisfaction of knowing that it has created the infrastructure for ensuring the success of the other Agenda 21 projects.

References

Abecker, A., A. Bernardi, K. Hinkelmann, E. Kuhn and M. Sintek. (1998). "Towards a Technology for Organizational Memories", *IEEE Intelligent Systems*, **13** (3), pp. 40-48.

Aouad, G., M. Kagioglou, R. Cooper, J. Hinks and M. Sexton. (1999). "Technology Management of IT in Construction: a Driver or an Enabler", *Journal of Logistics Information Management*, **12** (5), pp. 130-137.

Bahrami, Homa. (1992). "Emerging Flexible Organization: Perspective from Silicon Valley", *California Management Review*, **34**, pp. 33-52.

Bakens, Wim. (ed.). (1997). *Future Organization of the Building Process*, Rotterdam, International Council for Research and Innovation in Building and Construction - CIB.

Bardin, Sylvie, and Gérard Blachère (Collab. Colin Davidson). (1992). *Amélioration de l'efficacité de la diffusion des resultants de la recherche en bâtiment*, Paris, Auxirbat, 344 pp.

Bardin, Sylvie, Gérard Blachère and C.H.Davidson.(1993). "Are Research Results Used in Practice?. *Building Research and Information*, **21** (6), pp. 347-354.

BRANZ (Building Research Association of New Zealand). (1984). *Abbreviated Report of Information Dissemination Strategies*, Porirua (N.Z.), BRANZ.

Brillouin, L. (1959). *La science et la théorie de l'information*, Paris, Masson, 302 pp.

Burry, Mary, James Coulson, Julieanna Preston and Earl Rutherford. (2001). "Computer-aided Design Decision Support: Interfacing Knowledge and Information", *Automation in Construction*, **10**, pp. 203-215.

Corsten, H., and K.-O. Junginger-Dittel. (1986). "La politique d'utilisation des resultats de la recherché en tant qu'élément d'une communauté européenne de la technologie", *in Utilisation des resultants de la recherché et du développement publics*, Luxemburg, Commission des communautés européennes, Direction générale Télécommunications, industries de l'information et innovation.

Davidson, Colin H. (1995). "Documentalistes, où vous placez-vous? Entre la recherché et la pratique !" *Documentaliste – Sciences de l'Information*, **32** (4-5), pp.199-204.

Davidson, Colin H. (1988)."Building Team" *in* Wilkes, Joseph A., and Robert T. Packard (eds.), *Encyclopedia of Architecture: Design, Engineering and Construction*, New York, John Wiley and Sons, Inc.

Davidson, Colin H. (2000). "Technology Watch in the Construction Sector: Why and How?", *in* De Pauw, Carlo (ed.). *Technology Watch and Innovation in the Construction Industry*, Brussels, Belgian Building Research Institute, pp. 289-296.

Eccles, Robert G., and Dwight B. Crane. (1987). "Managing through Networks in Investment Banking", *California Management Review*, **30** (1), pp. 176-195

Eksteen, Johan. (2001). *Affective Computing – Designing Information Systems for Real Users*, Pretoria, CSIR *i*comtek Monograph Series No. 2, 33 pp. www.csir.co.za/plsql/ptl0002/PTL0002_PGE015_PRODUCT?PRODUCT_NO=7130488

Gann, David. (2003). "Trading Places – Sharing Knowledge about Environmental Building Techniques" *in*: Cole, R.J., and R. Lorch (Eds.) *Building, Culture and Environment: Informing Global and Local Practices*, Oxford, Blackwell.

Groàk, Steven. (1992). *The Idea of Building – Thought and Action in the Design and Production of Buildings*, London, E.&F.N.Spon.

Katsanis, Constantine J., and Colin H. Davidson. (2001). "Horizon 2020: Building Procurement and Industry Fragmentation, a North American Scenario" *in* Taylor, Prof. R. (Ed.). *North Meets South – Developing ideas*, Durban, University of Natal, pp. 251-260.

Katsanis, Constantine J., Dennis J. Cahill and Colin H. Davidson. (1997), "Networks and the Learning Organization", *in* Davidson, Prof. Colin H., and Dr. Tarek Abdel Meguid (eds.). *Procurement – a Key to Innovation / La maîtrise d'ouvrage – clé de l'innovation*, Montreal, IF Research Corporation, pp. 323-332.

King, J. (1984). "Research in Practice: Generation, Use and Communication" *in* Snyder, J. (ed.). *Architectural Research*, New York, Van Nostrand Reinhold.

Lennard, Dennis, and Rachid Mohsini. (1998). "[Recommendation from] the Organizational Workshop" *in* Davidson, Prof. Colin H., and Dr. Tarek Abdel Meguid (eds.). *Procurement – a Key to Innovation / La maîtrise d'ouvrage – clé de l'innovation*, Montreal, IF Research Corporation, pp. 323-332.

Leslie, H.G., and D.G. McKay. (1995). *Managing Information to Support Project-Decision Making in the Building and Construction Industry*, Melbourne, CSIRO, 80 pp.

Lindfors, Christian. G. (2003). *Process Oriented Information Management in Construction – Information Systems Supporting the Work Processes of Project Managers and Project Groups*, Doctoral Thesis, Stockholm, Royal Institute of Technology, 250 pp., ISBN 91-7283-593-1
http://www.lib.kth.se/Fulltext/Lindfors031114.pdf

Lockley, S.R., T.J. Wiltshire and S.J.M. Dudek. (1987). "Information Transfer and Knowledge Based Systems in Architectural Desing (sic)", *in ARECDAO, 1st International Symposium of Computer Aided Design in Architecture and Civil Engineering*, Barcelona, Institut de Tecnologia de la Construccio de Catalunya.

Love, Peter E.D., and Zahir Irani. (2003). "A Project Management Quality Cost Information System for the Construction Industry", *Information and Management*, **40**, 649-661.

MacKinder, Mary. (1982). *Design Decision Making in Architectural Practice*, York, The University of York, Institute of Advanced Architectural Science, Research Paper 19.

Manley, Dr. Karen. (2003). *Innovation in the Queensland Road and Bridge Industry*, Brisbane, Faculty of the Built Environment and Engineering, School of Construction Management and Property, 87 pp.

Masterman, Jack W.E. (2002). *An Introduction to Building Procurement Systems (2nd ed.),* New York and London, Spon Press, 239 pp. ISBN: 0-415246415

Mohsini, Rashid and Colin H. Davidson. (1986). "Procurement, Organizational Design and Building Team Performance: a Study of Inter-Firm Conflict" *in*: *Translating Research into Practice, CIB '86, Proceedings of the 10th Triennial Congress of the International Council for Building Research, Studies and Documentation, Volume 8*, Washington (DC), National Bureau of Standards.

Mohsini, Rashid, and Colin H. Davidson, (1991). "Building Procurement – Key to Improved Performance", *Building Research and Information*, **19** (2), pp 106-113.

OECD. (1996). *The Knowledge-Based Economy*. Paris, OECD.

Simon, H.A. (1979). *Models of Thought*. New Haven, Yale University Press.

Snow, Charles C., **R.E. Miles and H.J. Coleman, jr.** (1992). "Managing 21st Century Network Organizations", *Organizational Dynamics*, **20** (3), pp. 5-20.

Tardif, Lorna. (1998). "Procurement: Communicate – or Else … ". *in* Davidson, Prof. Colin H. (Ed.), *Procurement –the Way Forward / La maîtrise d'ouvrage de demain (CIB Publication 217)*, Montreal, IF Research Corporation, xvi + 94 pp. (ISBN: 0-9682215-1-3)

UN-ECE (1958). *Government Policies and the Cost of Building*, Geneva, the United Nations Economic Commission for Europe.

Wong, Francis, Albert P.C. Chan, Paul Fox, Kenny Tse and Esther Ly. (2003). "Communication of Safety-related Information in Construction", *Second International Conference on Construction in the 21st Century (CITC- II) "Sustainability and Innovation in Management and Technology", 10-12 December,* Hong Kong.

Wundrum, Edward C. (1998). "Design-Build – a Successful Procurement Option", *in* Davidson, Prof. Colin H., and Dr. Tarek Abdel Meguid (eds.). *Procurement – a Key to Innovation / La maîtrise d'ouvrage – clé de l'innovation*, Montreal, IF Research Corporation, pp. 323-332

Appendix A:

Annotated list of CIB full members' sites containing explicit references to information-related research.

Web address	*Annotations*
www.construction-innovation.info	Queensland experience with knowledge flows in the road industry
www.bbri.be	Research into information and communication technology
www.nrc.ca	Provides link to CISTI and thence to bibliography searchable by keywords
www.sbi.dk	Research into productivity and quality development in building: "… contributes to improved dissemination of knowledge to enhance its application in firms and on building sites"
www.vtt.fi/rte	Under 'Business and process management': research into enabling technologies and knowledge, business, process and product modeling, […] ICT in life-cycle management of the built environment
www.cstb.fr	Priority research theme: Application and use of new ICT – processing, modeling of project information, management of information flows for construction
www.itc.cnr.it	Under network information technology/use of NITC: research orientation: technical information in the construction sector
www.kict.re.kr	Information services division: "foremost information centers in KICT which collects and computerizes vast amount of documents and information directly or indirectly related to the construction industry or technology and it provides nation-wide services through an electronically wired computer network […}"
www.minvrom.nl/international/	Provides a list of information sources
www.branz.org.nz	"The Association's mission is creating New Zealand's building and construction knowledge base"
www.byggforsk.no	Publishes documents as part of knowledge transfer mission

www.lnec.pt	Mention of data systems and technologies, including "recent technologies for information processing in [… the] environment"
www.csir.co.za/bouwtek/index.html	Reference to monograph entitled "Affective computing – designing information systems for real users" which stresses the importance of considering emotions is very important in enhancing the design and development of information systems
www.scpm.salford.ac.uk/scpm/research.asp	Network on information standardization and exchanges in construction, including work on industry foundation classes
www.bfri.nist.gov	Internet Development, Computing and Network Resources includes thoughtful navigation schemes and new techniques for sharing information; publication titled "Information transfer in the XXIst century, also proposing the 'knowbot' to search many databases

Comment: this list does not include references to CIB associate or individual members' sites, which were not covered by this survey.

It should also be noted that we know of some full members who operate information systems or services, which are not mentioned on their sites.

Appendix B:

Comments received from CIB members who are active in, or interested by, the PeBBu project.

Nineteen people were sent the Agenda as above and solicited for review comments. Three replies were received (= 16%) and they are added to the document as originally distributed in the form of this Appendix B. The Authors' own comments on the comments follow.

Reviewer 1 found the Agenda to be "interesting reading" but she added that she did not wish to make any specific comments.

Reviewer 2 did not want to change anything to the document, which, he found to be addressing important issues. He added that in Domain 2, the "information problem" is seen to be related to the "[information] translation problem" [which is referred to in the Agenda as "appropriate information" (pages 17 and 18)].

Regarding the hypotheses, this reviewer sees hypothesis 1 (page 25) as the most important one (again, from the Domain 2 point of view). He also comments on hypotheses 2 and 3, pointing to the need for content – which may well be unavailable; he notes "Hypotheses 2 and 3 gain interest when the content is available. On the other hand a structure beforehand can help the organization of the content". He asks whether the ISO 9001 requirements might not be harnessed to solve the problem.

Reviewer 3 sees the need for information about information in the context of the Construction Products Directive, since it might help manufacturers meet the declaration of conformity required of them.

The problem of there being no mechanism for collecting, processing and making the product data available comes up; "many actors in the sector would benefit tremendously if such data were to be made available in an (internet platform based) database". This reviewer suggests that this particular practical issue might be addressed as well.

The Authors' comments on the comments.

We note that within the two-week period allocated for comments, three out of the nineteen people contacted replied. We thank them for their remarks, which we found encouraging and useful.

Regarding the third reviewer's comment about the availability of data, we feel that an attempt to centralize the handling of products data would be difficult to attain, but rather an approach based on standardizing the structure of, and modes of internet access to, product information would be more feasible.

Our final comment reiterates a theme that runs though our Agenda proposal, namely that "information is taken for granted".

As some readers may remember, Malaparte (in "The Skin") describing post-war Naples, mentions a Neapolitan who walked into a hollow on the slopes of Vesuvius with his dog; to the surprise of the onlookers (who paid to watch the 'experiment'), the dog passed out but the experimenter did not. The explanation was easy: volcanic CO_2 lay in the bottom of the hollow, to a greater depth than the dog but not the man.

Like the Neapolitan of Malaparte's story, we take air (alias: information) for granted; when it is in short supply or when we cannot access it sufficiently readily, then things are not as good as they might be; unlike the Neapolitan, it is not profitable for us to exploit this situation.

The Agenda invites CIB to take a leadership role (which we believe it is well placed to do) in completing its Agenda 21 proactive program with a strong initiative focused on the "problem of information about information" in the building and construction sector.