Some Integration requirements for Computer Integrated Building

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Abstract

Introduction of computer technology in the Building and Construction industries follows a bottom-up approach. Bottom up approaches always lead to (1) communication problems on higher levels - in this case recognized as 'islands of automation' - subsequent followed by, more recently, (2) a plea for *integration*.. Although the word ‘integration’ quickly became in vogue, it is not clear what it really means and what it is that we are supposed to integrate. Another interesting and pressing question is: 'How to integrate the different integration efforts?'

The paper discusses five hierarchical technical levels of integration. Each level will be elaborated in some detail. Also the relations between the levels will be brought into perspective. Non technical integration requirements[1] (e.g. social, organisational, or legal) will not be discussed.

1.INTRODUCTION

Webster's unabridged dictionary defines *to integrate* as: '..to make whole or complete by adding or bringing together parts '.'To make whole' means that the parts together can function as one whole (at least from a certain point of view). The parts of my body are integrated, because they can function as a whole. Even if my left arm would be paralysed, it would still be an integrated part of my blood circulation system and my bone system. So, integration means that - from a given point of view - parts of a system can function as a whole. In the case of Computer Integrated Building, the viewpoint is *computer* integration, e.g. integration of the different computer aids supporting the building and construction processes.

With this informal definition in mind we can try to understand the different integration needs of the Building and Construction industries.

Five levels of integration

The following five levels of integration have been distinguished:

1 integration of building and construction processes,
2 integration of technologies (e.g. design technologies, material technologies, construction technologies),
3 integration of CAxx tools,
4 integration of information (or knowledge),
5 integration of CASE tools.(Computer Aided Systems Engineering).

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1 Probably the most important bottle necks!

In the following the integration requirements of each level will be explored using a concept of the information systems theory, the so called information paradigm.

The information paradigm

The information paradigm states that each dynamic system can be regarded to contain two smaller systems: a Real System (RS) and an Information System (IS). The RS transforms either 'real things' like matter, or energy, or 'abstract things' like objectives, or conceptual designs[2]. The RS is controlled by the IS, that receives information from the RS (e.g. perceptions) and the environment (e.g. goals) and that gives information to the RS (e.g. decisions) and the environment (e.g. communications). To be able to control its RS, an IS contains a *representation* of the RS. The representation contained in the IS may be a real world representation, which is than called *isomorphic*, or a simplification of the real world, which is called *homomorphic*. In the Building and Construction industries representations are always homomorphic; because buildings are extremely complex each participant reduces the information required to perform his task as much as possible.

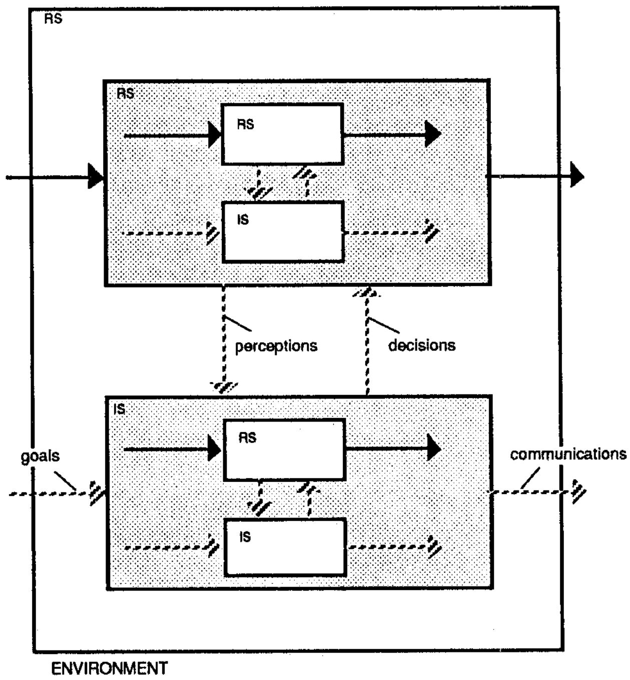

Figure 1 RS-IS paradigm

The RS-IS paradigm can be applied recursively, each RS and each IS can again be regarded to contain a lower order RS and IS.

Figure 1 shows an RS with one RS-IS combination, where both primary RS and IS again contain a lower order RS-IS combination. An interesting feature of this modelling approach is the possibility to model different levels of abstraction in one diagram, displaying for instance communications that overstep different levels.

It must be stressed that an IS is not necessarily computerized. ISes existed long before computers. In this paper however we are mainly interested in the consequences of the computerization of ISes.

2 The design *concept* rather than the drawings that display the concepts (the latter belong to the IS).

2. INTEGRATION OF BUILDING PROCESSES

Computer integration of Building and Construction processes means that, from the point of view of electronic information interchange, sub processes performed in building projects can function as a whole.

As an illustration, consider figure 2 (next page), where the sub processes are modelled by RS-IS combinations. The RS Perform Building Project contains one primary RS-IS combination: the RS Realize Building Project and the IS Control Building Project, each containing a number of lower order RS-IS combinations. The choices made in figure 2 are rather arbitrary. The point is that each small IS communicates with its RS and with one or more of the other ISes (see the dotted arrows). Currently most of these communications use paper as their medium. *The step from traditional building to Computer Integrated Building means that the ISes will be computer aided and the communications (dotted arrows) will be performed by computers.*

When studying figure 2 it becomes quite clear that currently integration on this level - by our definition - is not possible. Though most ISes use some computer aids (Construction Control still uses very little, no site automation systems, no construction robotics), there are hardly no communications performed by computers. Paper is still the main carrier of information. The reason is that the communications required are quite diverse and, as yet, no effort has even been started to formalize and agree a possible standardization of exchange formats. Only very few communications are covered by some standardization effort, e.g. the communications regarding orders and invoices made by the Supply Control are covered by the EDI-standard. And even that is only true on the physical level (the EDI-protocol) and not on the semantical level, because, in most cases, the contents of the EDI-messages have not been standardized. Of course there are some efforts going on to develop information interchange standards for other communications, e.g. STEP for the product data interchange and SGML for the exchange of documents, but also these efforts mainly concentrate on the physical aspects and not yet on the semantical aspects.

The step to CIB - on this level - requires that computerized information flows between ISes is possible in an *open* systems environment (e.g. without having to buy one particular type of computer aid). An important first step towards this goal is the development of a global reference architecture displaying the main RS-IS combinations of the Building and Construction industries, together with the most important IS-communications requiring standardized electronic information interchange. In this architecture current standardization efforts can be indicated, showing overlaps and white spots.

For the Building Industry as a whole it is important to require that the step from the current paper driven communications to CIB will:

1 not disturb the communications with other industries, e.g. like Mechanical and Electrical, because there exist many interrelations with these other industries,
2 not disturb the communications with Building and Construction companies outside our own country, or continent, and
3 be made possible in an evolutionary way, without too many unnecessary manual information transformations and without having to throw away investments in unsuccessful standardization efforts.

None of these requirements is easily fulfilled. Current information interchange standardization efforts are not integrated, so watch your STEP.

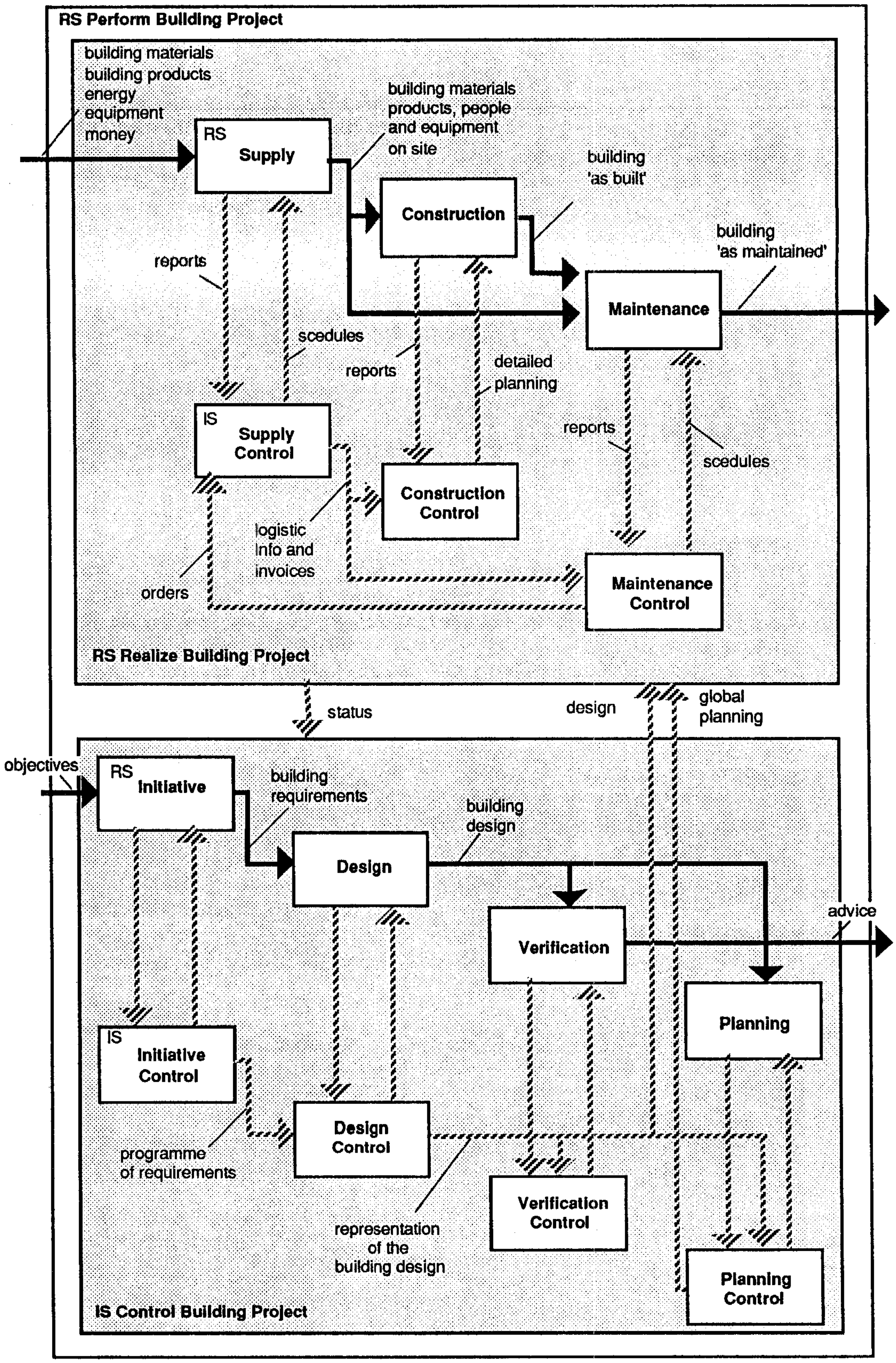

Figure 2 RS-IS paradigm applied to the Building and Construction industries.

3. INTEGRATION OF TECHNOLOGIES

As a next step consider the mechanisms required for the integration of the different technologies (e.g. design technology, planning technology, material technology, construction technology). Computer integration of technologies means that the information systems supporting the different technologies can function as a whole. That would for instance mean that construction knowledge, material knowledge, planning knowledge and maintenance knowledge can be used in the design stage, e.g. to improve Design for Construction, Design for Logistics and Design for Maintenance. At present these technologies are not integrated by our definition. Here we see 'islands of technology'.

In order to resolve this situation we first have to develop the required *knowledge transfer mechanisms,* that allow the different islands of technology to function as a whole. e.g. that allow design knowledge and planning knowledge to flow downstream to Construction Control and Maintenance Control and, the other way around, allow construction knowledge and maintenance knowledge to flow upstream.

As illustrated in figure 3, there are a number of different feedback and feed forward mechanisms required: zero level mechanisms are instantaneously used to control upstream or downstream RSes, one level feedback mechanisms control higher level RSes and two level feedback loops allow us to catch technological information in a re-usable form (see figure 3) and to re-use it.

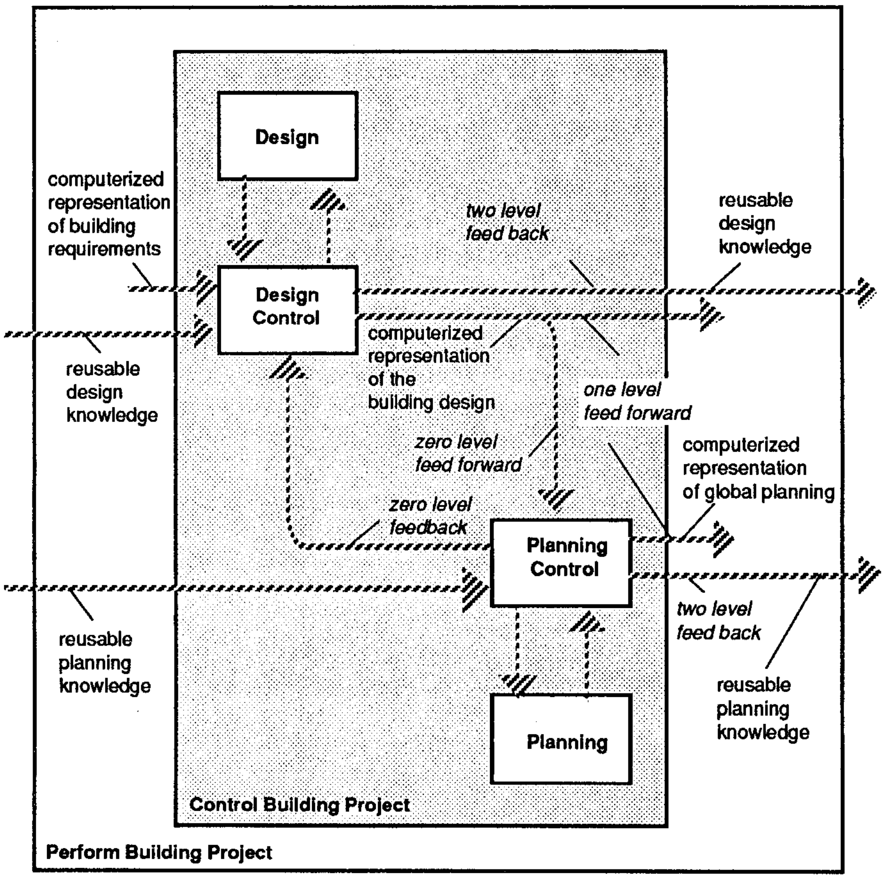

Figure 3 Simplified example of multi level knowledge transfer mechanism. Each type of feedback and feed forward has its own requirements, e.g. zero level communications may require procedural interfaces, one level communications may be satisfied with file interfaces and two level communications with database interfaces.

Implementation of the required knowledge transfer mechanisms will require research and development in a number of areas, like: coding and classification systems, neutral formats for knowledge representation and access, libraries with standard technical solutions, product modelling and project modelling.

4. INTEGRATION OF CAxx TOOLS

Integration of CAxx tools means that all the different CAxx tools (workstation, drawing systems, NC machines,..) can function as a whole. Though perhaps most CAxx tools can communicate something, it is a long way to integration by our definition. Currently we only see 'islands of automation'. The step to integration is not merely a matter of connecting computers, but also of agreeing about semantical contents. That requires integration of information.

5. INTEGRATION OF INFORMATION

Integration of information means that the information required in a building project can function as a whole, e.g like one (distributed) information base, or knowledge base. No such integration currently is possible. On this level we have 'islands of information, or knowledge' (e.g. design knowledge, construction knowledge, etc).

Integration of information[3] (or knowledge) requires the development of so called *product type models*. Product type models are models of the reality of classes of products (e.g. office buildings); they represent an integrated description of the information required during the product life cycle. As an extension of the idea of product type models it is also useful to consider the idea of *project type models*. A project type model is a model of a class of projects, e.g. office building projects. Project type models contain product type models, activity type models, resource type models and control type models in an integrated way [5, 6].

As discused in paragraph 2, many different parties are involved in the organisation and execution of Building and Construction projects. Traditionally each of these parties has its own specialized view on the project results, e.g. the product (bridge, building, road,..). Such a view is tailored towards the specific needs of each individual party. This holds both for the products, as for the building and construction processes and resources.

Starting with the product view, it is clear that designers have different views on their buildings, or bridges then electrical installation engineers, or subcontractors, for example. Because of the huge amount of information involved in a building project each party traditionally has reduced its view on this information as much as possible. This reflects for instance clearly in the specialized 2D idealized models used by most structural engineers. Because the introduction of Computer Aided techniques took place on an evolutionary basis, each party implemented his traditional view in his own CAxx system. The reality of the product involved was described in numerous drawings and other documents. A drawing of an object however is not a model of the object[4] and thus the process of deriving a specialised product view was not supported by computer aids. This is basically the reason for the current 'islands of automation', because view models are not very much suited for information exchange and a centralized 'neutral' product model (or project model) is not available. Figure 4 illustrates the current practice:

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3 Data and procedures

4 A model is an abstraction of the reality containing one or more characteristics of the reality in simplified form, e.g. a mock-up contains the simplified shape, or a FEA-model contains the simplified structural behaviour.

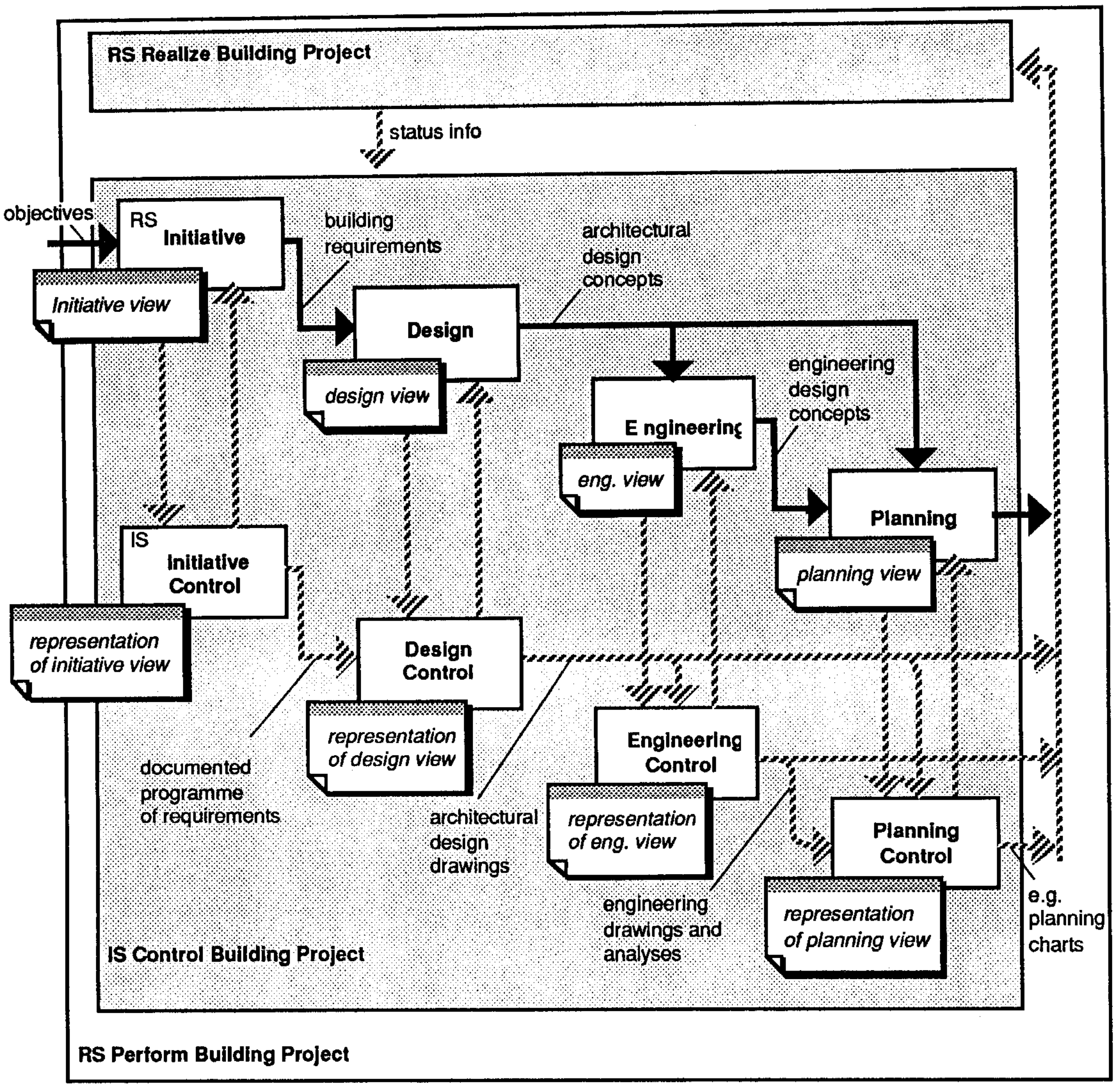

Figure 4 Each IS uses a homomorphic representation of its RS (abstracted to just satisfy the requirements). Output of the ISes refers to the local representations. Homomorphic representations are, by definition, incompatible. So communications based on these local representations can not serve as a basis for electronic data interchange.

Improving the current situation requires an integrated product information model, that supports the derivation of view models for different application areas. With the use of a 'neutral' product model the future practise becomes as given in figure 5. Information integration requires the availability of an international accepted standardized methodology for modelling and exchanging product data. In Japan the large Building and Construction companies have adopted their own internal standards. Europe and the USA require multi vendor PDI-standards. For that reason ISO started some years ago an international standardization effort, called STEP (for STandard for the Exchange of Product model data). In the USA STEP found a national counterpart in the PDES organization (PDES, for Product Data Exchange

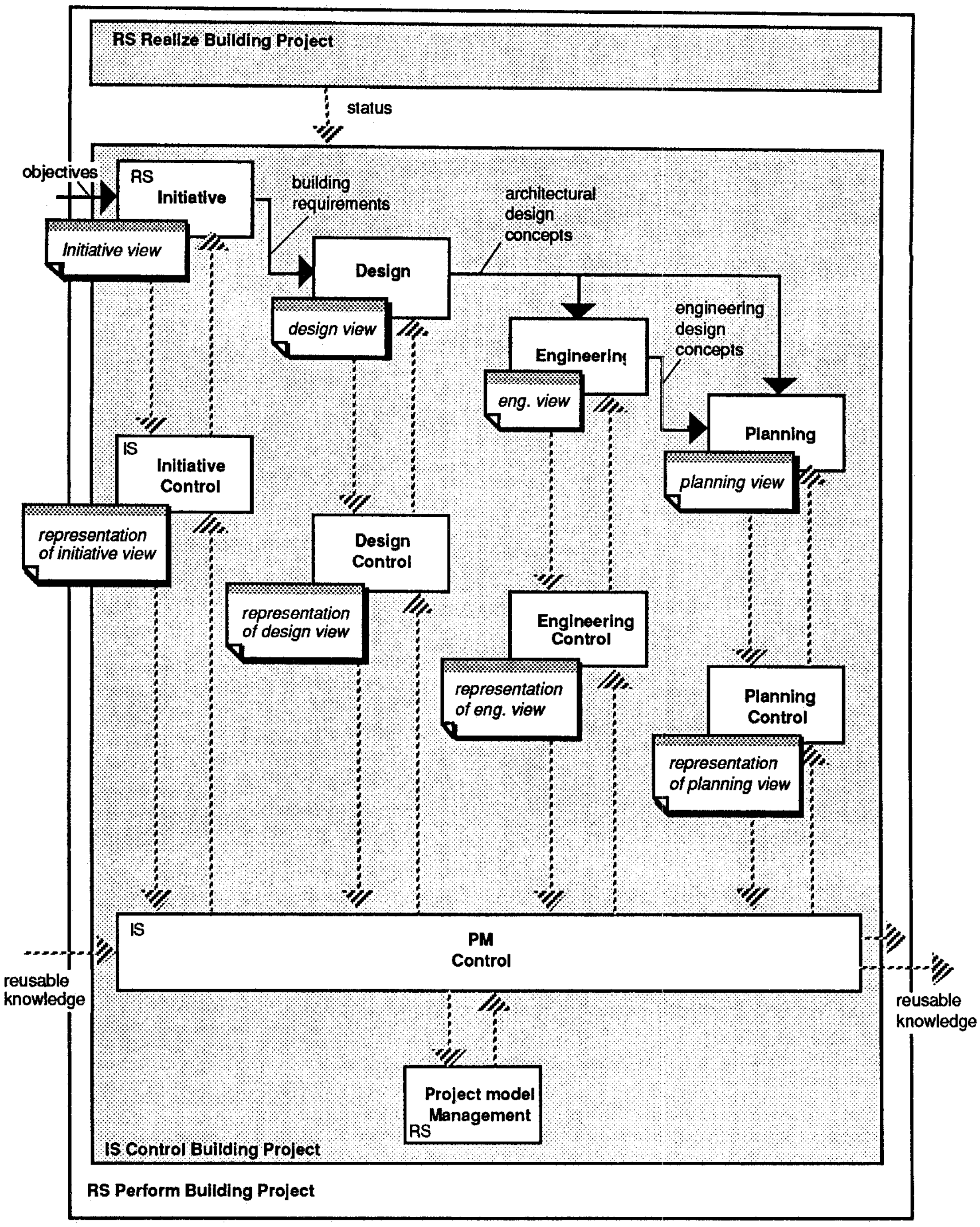

Figure 5 A new RS-IS combination performs the central project modelling management function. The RS Project model Management transforms local representations in global (neutral) representations and vice versa. The IS PM Control performs the communications required.

Standard). Both organizations agreed upon the final goal: the development of one international ISO-standard for the development and exchange of product model data.

The involvement of the Building and Construction industries however in STEP is very limited. Project modelling is not being considered.

6. INTEGRATION OF CASE TOOLS

Integration of CASE-tools means that a set of CASE-tools could work together as a whole, e.g. as an integrated environment. Most information modelling approaches currently use IDEF0 for process modelling and either IDEF1x, or NIAM for information modelling in the conceptual phase. For the development of detailed information models ISO/STEP uses EXPRESS, which therefore quickly is becoming a de facto standard. Several groups reported on the development of EXPRESS language bindings, e.g. EXPRESS_to_C, EXPRESS_to_ADA, EXPRESS_to_Eiffel and EXPRESS_to_SQL. Also the development of higher level translators, like: NIAM_to_EXPRESS, and Eiffel_to_EXPRESS, have been reported. It seems therefore that in the near future prototypes of integrated CASE-environments based on EXPRESS will become available.

Though EXPRESS is quite powerful as an information modelling language, it is not perfect. EXPRESS lacks true object orientation and does not support logic operations and layered modelling. R&D in the area of improved CASE environments, based on more powerful modelling languages, still is required [7].

So far we only mentioned the traditional CASE environment requirements. CIB however has important requirements of its own, e.g. the environment should support its users in the development of integrated product type models and project type models, based on standardized reference models (or meta models, if you like), like the General AEC Reference Model [1]. Important features of a CIB/CASE environment are: a methodology and tools to derive views and to integrate external models (like STEP resource models).

7. INTEGRATION OF THE INTEGRATION EFFORTS

Although we have discussed quite a number of integration requirements already, it is necessary to add one more to the list, e.g. the requirement that also the integration efforts presented so far will be integrated. The CASE environment required for our application field should (at least) be able to support the development of integrated product type models, or project type models. The product type models should contain a mechanism to derive multiple views. The formats of these views must be standardized. Based on the PDI-standards and EDI-standards the 'islands of technology' should be integrated and the mechanisms thus developed should be used in the (as then) integrated building and construction processes.

No effort to integrate the integration efforts has been reported. That leaves us again with a new kind of islands, 'islands of integration'.

8. CONCLUSIONS

Computer Integrated Building requires 'integration' on many different levels. Each higher level requires the support of the levels below. At the highest level the integration of building and construction processes requires the development of a reference architecture displaying the main RS-IS combinations of the Building and Construction industries together with the most important required IS-communications. At the next lower level, the integration of technologies requires the development of feed forward and feed backward mechanisms between the different 'islands of technology'. To implement these 'knowledge transfer mechanism', the next level of integration should integrate the many different CAxx tools available. This means the development and implementation of standards of information interchange, like EDI and STEP, and the possibility to derive different views on the product (or project) data. Important is that these developments strive for interoperability of standards. The derivation of views requires on the semantical level the development of integrated product type models, or project type models. And finally, the development of product type models and project type models requires a common methodology, supported by an suitable CASE environment, that enforces model compatibility (or integration).

As each of the five levels discussed above needs results from lower levels for successful integration efforts, it follows that the integration over these levels is also very important. Unfortunately, unlike other industries [2, 3, 4], the international Building and Construction community seems not to be sufficiently well organized to deal with the multi level integration requirements discussed in the paper.

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