An IT map for a generic design and construction process protocol.

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SUMMARY: *It is widely acknowledged that work undertaken later in any product development process costs relatively more than that conducted early in the process (Gause and Weinbery, 1989). Research currently underway at the University of Salford in the development of a generic design and construction process protocol has highlighted the need for greater "front-end" activity in the process. Many of the potential benefits associated with an improved process can only be realised with significant IT support. Indeed, the IT will only achieve profound change if its introduction and use is linked to changes in the overall conduct of the design and construction process.*

This paper looks to present a "vision for the future" regarding IT in construction. Much work has taken place in recent years looking to exploit the advantages of IT to the benefit of the design and construction process. However, too much of the work that currently exists is inappropriately focused upon the latter stages of the design and construction process. This is mainly attributed to the fact that the mechanistic approach to producing the building (product) at the construction stage has always been a major concern to the client and his team. An apparent lack of process thinking in the construction sector is also another major factor. In addition, the existence of IT rapid prototyping tools has been lacking in the last few years. This is now being remedied as the industry is now embarking on new ways of doing business, and the technology in terms of VR and 3D modelling which can support rapid prototyping is being progressively developed. This will ultimately result in a better structure of the overall process through the capabilities of IT.

This mis-alignment of research does not only occur between academia and industry. Within industry itself, the many participants common to the design and construction process also have distinct differences of opinion when asked to prioritise their IT needs. The results from a recent questionnaire survey of a broad spectrum of industrial and academic representatives will support this claim, and will demonstrate the need for a common, agreed process upon which design and construction work is based. Within a process oriented context this paper will therefore discuss the future IT needs of the industry, and will propose priority areas and an IT map for both industry and academia.

KEYWORDS: *construction, process, IT, strategy, future.*

1. INTRODUCTION.

Recent changes, both in the global market and in information and building technology, dictate a complete re-thinking of the way we design and construct our buildings. The construction industry, particularly in the UK, lags behind that of manufacturing in terms of both productivity and efficiency as there is no agreed procedural mechanism for doing the work. This is due mainly to the fragmented nature of the industry and operation of its activities, and the perceived uniqueness of construction projects, which also accounts in part for the slow uptake of new technology. Recent reports by the government and the research councils have addressed these issues and clearly stated that the way forward is to think of construction as a manufacturing process. The thinking behind this is that the construction industry needs to adopt techniques that have been developed based on new manufacturing and production theories. A recent major initiative IMI (Innovative Manufacturing Initiative) in the UK with a substantial amount of funding has started in order to encourage the adoption and use of manufacturing principles by the construction industry. The project described in this paper is funded by the IMI.

IT will play a major role in developing and adopting new processes. However, to date IT has been used as a support tool rather than a driver. The process is driven by needs and requirements. IT can respond to some of these needs and requirements by providing feasible solutions. In this paper, a process map is presented first. This map is briefly described, and then an IT equivalent is presented. This IT map builds on a list of priority topics for construction IT research developed by one of the authors (Aouad et al, 1997).

2. THE PROCESS MAP.

There have been major efforts, nationally and internationally, in defining process maps. These include BAA (BAA, 1994), Construct IT, British Telecommunications, RIBA (RIBA, 1980), CSIRO in Australia (Love, 1996), Sanvido in the USA (Sanvido, 1991, 1992). However, none of these process models has gained absolute recognition. This is mainly attributed to the fact that the change within the current process will be gradual and such recognition will occur over a long period of time. Perhaps absolute recognition will never occur.

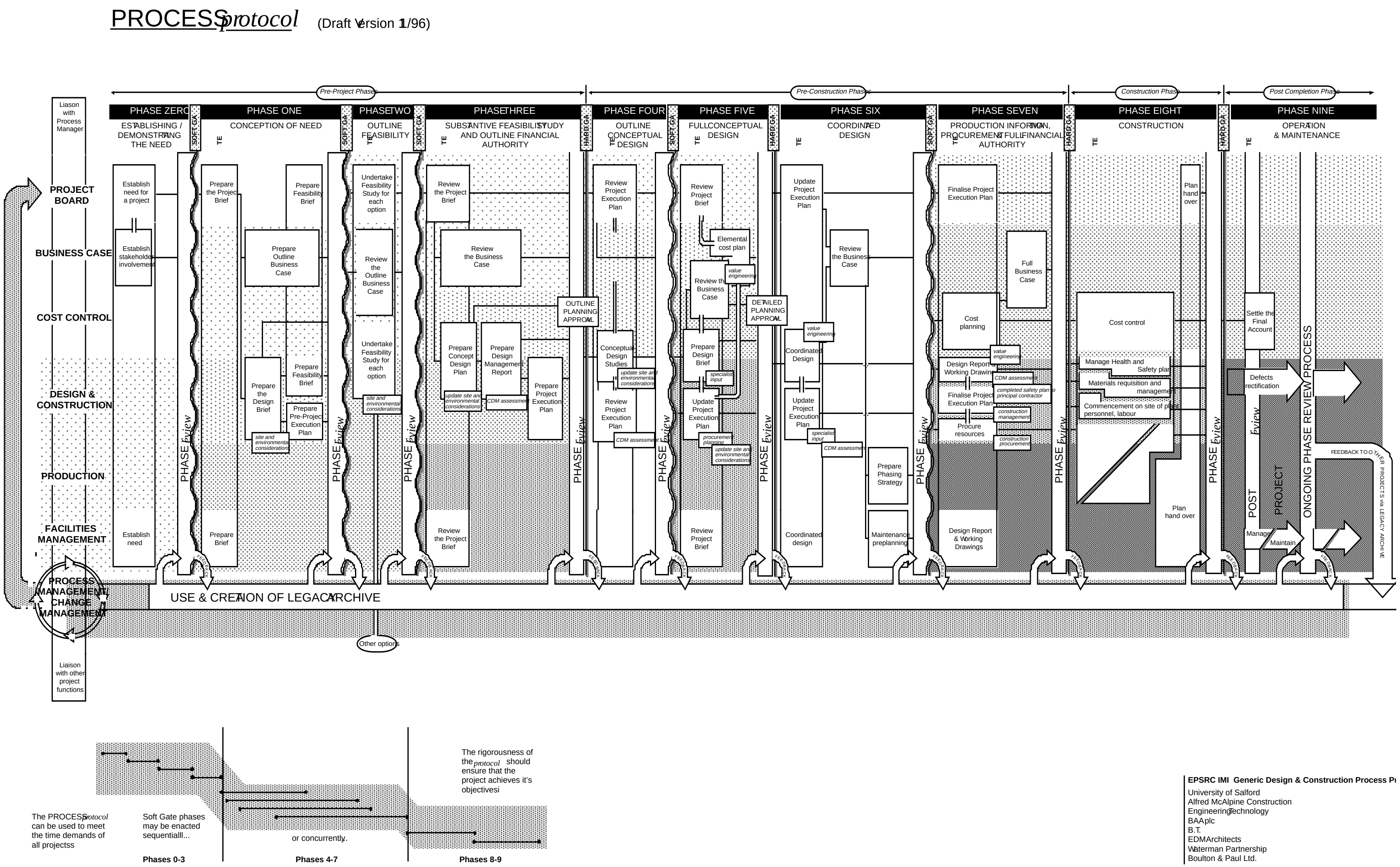

Fig. 1: The generic design and construction process map

This section briefly describes a re-engineered design and construction process model (Fig. 1) being developed at Salford in the UK, which covers those stages of construction projects, from feasibility to construction and operation (Sheath et al, 1996). This model is a process map which supports and encourages integration and proper co-ordination between the various participants or stakeholders of a construction project. The following are key features of this process map:

- the virtual company,
- emphasis on front end,
- design fixity,
- teamwork,
- communication,
- single contact point: project director/project board,
- change management,
- process management,
- process and project legacy archive, and finally
- soft and hard gates.

The virtual company concept involves getting all the stakeholders involved in a construction project to identify their objectives and interests. This helps at the requirements capture phase (Phases 0-1) ensuring that many of the major problems are solved through discussions and most of the requirements are identified by these various stakeholders. This will help in meeting the corporate virtual objectives and shared vision.

The generic design and construction process protocol has also highlighted the need for greater "front-end" activity in the process. Traditionally in the construction industry and unlike manufacturing, the emphasis is on the construction phase where contractual claims arise because of the unconstructable nature of design. The process map presented in this paper puts the argument that the emphasis on feasibility and design is of crucial importance. In manufacturing, this is the case and IT plays a great role in its rapid prototyping capabilities. The construction industry should also consider the rapid prototyping approach which can help solving most of the problems before construction begins. VR and 3D modelling tools provide the right medium for rapid prototyping purposes.

Design fixity involves the freezing of a certain phase with the agreement of the stockholders. For instance, the client can decide on fixing the design phase in order to avoid changes which may prove to be costly. Teamwork and communication are two major aspects of business process engineering. The process map promotes these two aspects through the concept of virtual company, which results in better relations between the project participants, and through IT-based communication. The single contact point, change and process manager ensures that the process is managed with some authority. Roles, rights, responsibilities are within the scope of the aforementioned concepts. The Legacy Archive ensures that best practice is captured and re-used. Finally, soft and hard gates ensure that major decisions are assessed and evaluated. The soft gate implies that decisions are approved conditionally. Hard gates indicate firm and final decisions regarding whether or not to proceed to the nest phase within the process. The overall process map is shown above. This process is described fully in another paper (Sheath et al, 1996).

The concepts outlined above, and central to the operation of the Process Protocol, are not unique to this “new way of working”. Many of the existing studies, both within construction and manufacturing, acknowledge such concepts as teamwork, design fixity, and stage-gate systems (Cooper, 1995). However, if such concepts are to fulfil their ultimate potential, it would appear that this will only occur with the support of IT tools and techniques. The next section will describe an IT Map which has been developed in order to demonstrate the potential of the use of IT in this context.

3. THE I.T. MAP.

The information requirements of the aforementioned reengineered processes need to be modelled. Technology can then be used to enhance integration and sharing of information. Technologies such as object oriented databases, virtual reality, expert systems, case-based reasoning, neural networks and traditional commercial packages can be used and integrated in order to illustrate these principles and to ensure that information can be shared between the various processes. This is a long term objective. This will allow the industry to realise the benefits which can be gained from coupling visualisation systems, knowledge based systems, and traditional commercial packages in support of the reengineered processes. In the long term, the client will have the ability to walk through the designed product using virtual reality based on information stored in the database. The quantity surveyor will be able to select the most appropriate procurement path using neural networks techniques, which are useful in handling un-structured information such as that of procurement. The designer will be able to select the most appropriate design using case-based reasoning involving cases where the fabrication processes were simplified. The project planner will be able to establish the project plan using a knowledge-based system coupled with project planning software. As these applications will be linked to an integrated database, this will ensure the integrity of information.

A large number of studies have been conducted by various researchers in order to highlight the benefits of using information technology in the construction industry (Betts, 1992; Brandon, 1993; Ibbs, 1986; Miyatake and Kangari, 1993; Nam and Tatum, 1992; O'Brien, 1991; Teicholz and Fisher, 1994; Tucker et al, 1994; Oliver, 1993; KPMG, 1993; IT2005, 1995). However, none of these studies tried to establish the priority topics for construction IT or establish an IT map. However, there have been major efforts in defining IT specifications and strategies for process maps. These include BAA, Construct IT, and IT2005. However, as the two aspects of process and IT are very much interlinked in a push/pull phenomena, it is expected that the development and adoption of IT maps will take a phenomenal amount of time.

A recent study at Salford has managed to identify the IT topics which will be of crucial importance to the industry in the next 10 years based on a questionnaire survey conducted in academia and industry. A total of 175 questionnaires were sent out into industry, of which 55 replied, a percentage return of 31.4%, which is almost a one-in-three return rate. The questionnaires were distributed in differing amounts to the three professions, and here is the return rate of each individual profession:

- Quantity Surveyors : 55 sent, 18 replies. Return rate = 33%;
- Contractors : 80 sent, 20 replies. Return rate = 25%;
- Architects : 40 sent, 17 replies. Return rate = 42%

In addition, 33 questionnaire were sent to construction IT academics with 14 replies (return rate = 42%).

The results of the questionnaire clearly indicate that communications and networking will be a major topic over the next ten years. This will ultimately give the process some push resulting in some maturity in reaching a consistent, predictable and improved process. The findings of this study have helped in proposing an IT map which reflects the needs and requirements of both industry and academia.

QS

❶ COMMUNICATIONS / NETWORKING
❷ DATABASES
❸ COMPUTER-AIDED ESTIMATING
❹ COMPUTER-AIDED DESIGN
❺ DATA INPUT TECHNOLOGY
❻ Integration
❼ Strategic planning
❽ Multi-media
❾ Geographic Information Systems
❿ Computer-aided planning
11 Simulation
12 Artificial intelligence
13 Virtual reality
14 CASE tools
15 Neural networks
16 Robotics

Contractors

❶ COMMUNICATIONS / NETWORKING
❷ COMPUTER-AIDED PLANNING
❸ STRATEGIC PLANNING
❹ DATABASES
❺ INTEGRATION
❻ Computer-aided estimating
❼ Computer-aided design
❽ Data Input technology
❾ Multi-media
❿ Geographic Information Systems
11 Simulation
12 Virtual reality
13 Artificial intelligence
14 CASE tools
15 Neural networks
16 Robotics

Architects

❶ COMMUNICATIONS / NETWORKING
❷= COMPUTER-AIDED DESIGN
❷= DATABASES
❹ INTEGRATION
❺ VIRTUAL REALITY
❻ Computer-aided planning
❼= Data input technology
❼= Strategic planning
❾ Simulation
❿ Computer-aided estimating
11 Multi-media
12= Artificial intelligence
12= Geographic Information Systems
14 CASE tools
15 Robotics
16 Neural networks

Academics

❶ COMMUNICATIONS / NETWORKING
❷ COMPUTER-AIDED PLANNING
❸ COMPUTER-AIDED DESIGN
❹ DATABASES
❺ DATA INPUT TECHNOLOGY
❻ Computer-aided estimating
❼ Simulation
❽ Multi-media
❾ Virtual reality
❿ Integration
11 Strategic planning
12 Geographic Information Systems
13 Artificial Intelligence
14 CASE tools
15 Neural networks
16 Robotics

Figure 2: The IT priority topics.

It is clearly shown in the previous figure (Fig. 2) that topics such as AI, neural networks, and Simulation are the least important for the progress of construction IT in the next 10 years. This paper argues that most of the aforementioned technologies will be beneficial at some stage of the process.

The IT solutions proposed in this paper have been developed in response to the following needs:
(1) Lack of process thinking within an IT map;
(2) Misuse of current IT tools;
(3) Confusion over linking business and IT strategies;
(4) Lack of understanding of IT capabilities; and
(5) The limitations of the current technology.

The IT map presented in this paper has been developed in relation to the process requirements. It is clearly shown that there are two types of IT which can support the process: the generic IT such as EDI, AI, Integrated databases and document management systems which can be used at any phase of the process in order to exchange information and support communication; and the IT specific solution which may be more helpful at a specific phase. For instance, CAD is useful at the design stage whereas computer aided planning is more appropriate at the construction stage.

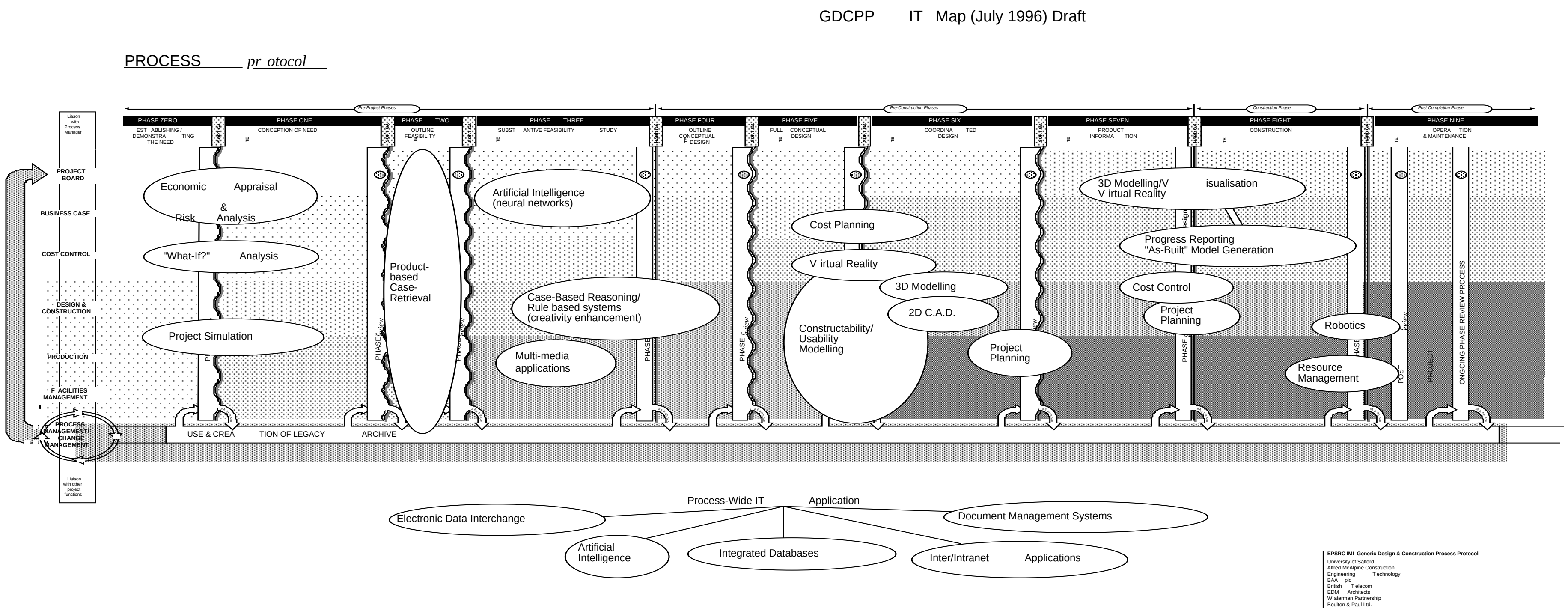

Figure 3: The IT map.

The IT map (Fig. 3) includes some of the technologies specified by industry and academia at the initial phase (pre-project phase), where simulation, 'what-if?' and economic appraisal tools are most appropriate. Potential project scenarios could be re-generated from an archived library of previous projects. These could include VR, 3D and other mediums. AI techniques including case-based reasoning, neural networks, fuzzy logic, genetic algorithms and KBS may be appropriate at the initial phase of design where the creativity issue of design plays a major role. CAD, VR and other tools are not able to capture the information required for this phase. The latter of these tools may prove helpful at the detailed design and construction phases. It is clearly shown on the IT map that there are many tools which can be used to support the various phases of the design and construction process. These tools are generic and can be used by any industry. It is the maturity of using an IT tool within an application context which will help the overall process through a technology push.

A large number of IT emerging tools are considered to be research tools. These will need to have a wider acceptance by the industry through the phases of testing, refining, accepting and finally customising. It is the customisation of the technology for a certain application which will form the starting point for the aforementioned technology push of the process. These issues are the subject of another paper being developed by the research team (Hinks et al, 1997)

The IT map presented in this paper supports the widely known themes within the computer integrated sector: visualisation, intelligence, communications and integration. Visualisation supports the simulation of information within the various phases of the process. Technologies which can be used include: VR, CAD and simulation tools. Powell (Powell, 1995) provides a good discussion of the use of VR as a visualisation and rapid prototyping tool. Artificial Intelligence helps in establishing decision support systems which may manage to automate some of the phases of the process. These include: Knowledge-based systems, neural networks, case-based reasoning and information management systems. Major works in this area include in neural networks (Moselhi & Hegazy, 1991; Boussabaine, 1996), in case-based reasoning (Watson & Marir, 1994; Simoff and Maher, 1996), and in KBS (Levitt & Kartam, 1990). Communication assists in a better co-ordination and management of the process. This includes: EDI, communication protocols: e-mail, web applications, and standards such as STEP, IAI (IFC industry foundation classes). Key research in this area includes (Bjork, 1989; Thorpe et al, 1994; Vice, 1996; STEP, 1990; Wix and Storer, 1996; Vanier & Turk, 1994). Finally, integration allows the sharing and exchange of information. This will entail linking the aforementioned technologies through integrated or distributed object oriented databases. Major projects include ICON (Aouad et al, 1994), OSCON (Aouad et al, 1996), SPACE (Alshawi et al, 1996), COMMIT (Rezgui, 1996), IDAC-2 (Powell, 1996), COMBINE (Augenbroe, 1993; Dubois, 1995), ATLAS (Atlas, 1992; Nedreven, 1994), MOB (OTH, 1994), COMBI (Ammerman, 1994), RATAS (Bjork, 1989), IRMA (Luiten, 1993), Fenves (1990), Froese (1994), Howard (1992), Kartam (1994). A good reference for work in this area can be found in Brandon and Betts (1995).

The four broad stages of the ten phases process map described earlier (namely pre-project, pre-construction, construction and post-construction) require different IT tools. As the pre-project phase relates to the question whether there should a decision regarding the acceptance of an idea for a project, it is expected that simulation, both visual and numerical to be a major feature of this stage. VR, 3D, economic appraisal tools are therefore the most appropriate. The key theme of visualisation is a main feature of this stage. In the pre-construction stage, the client needs are developed into a design solution. This requires the use of AI, CAD and VR tools. The key themes of visualisation and intelligence are dominant at this stage. The final stages of construction and operation involve the use of legacy applications such as planning, estimating, etc. The key themes of integration and communication are mainly associated with this stage. It has to be said however, most of the IT tools and themes are generic and can be used and associated with any of the phases or stages of the process map.

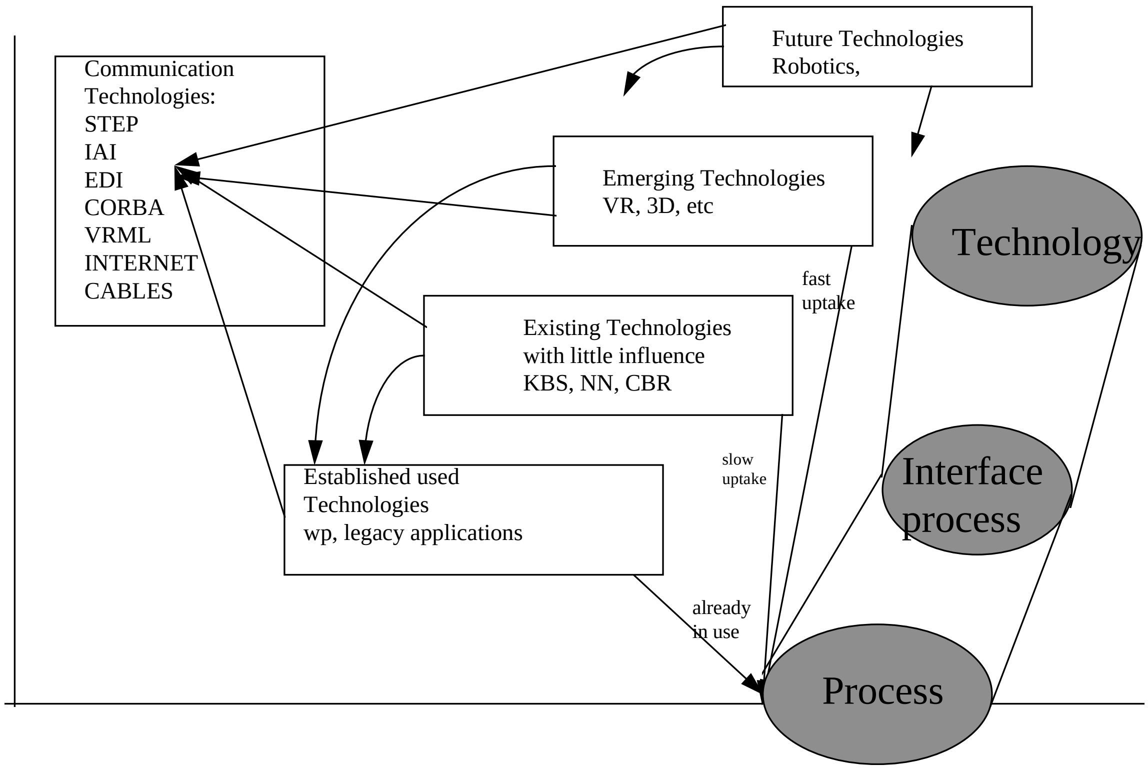

Figure 4: The IT and process intersection.

The IT priority topics list and the IT map have helped to identify five types of technologies which will help the process. These technologies are:

- Established used technologies: Office automated tools, computer aided planning, estimating, purchasing, etc.
- Existing technologies with little influence: knowledge base systems, neural networks, case based technologies, etc.
- Emerging technologies still considered as research tools: Virtual reality, 3D Modelling, CASE tools, etc.
- Future technologies: Robotics, automated tools, etc.
- Communication and standards technologies: STEP (Standard for the exchange of product data), IAI (International Alliance for Interoperability), EDI (Electronic Data Interchange), CORBA (Common Object Request Broker Application), VRML (Virtual reality modelling language), and Internet communication protocols.

These technologies when integrated will provide the right mechanism for a technology push of the process. However, it has to be said that the emerging and existing technologies will need to have a wider acceptance by the industry before a major impact on the process is realised. This will ultimately result in an improved interface process which will take advantage of the technology and the new ways of performing businesses. The overall picture of this scenario is shown diagrammatically in Fig. 4. It is predicted that this will happen in the next ten years (Aouad et al, 1997). Some indication on the type of applications which can be integrated and managed is shown below. The diagram is produced from the OSCON object oriented project database.

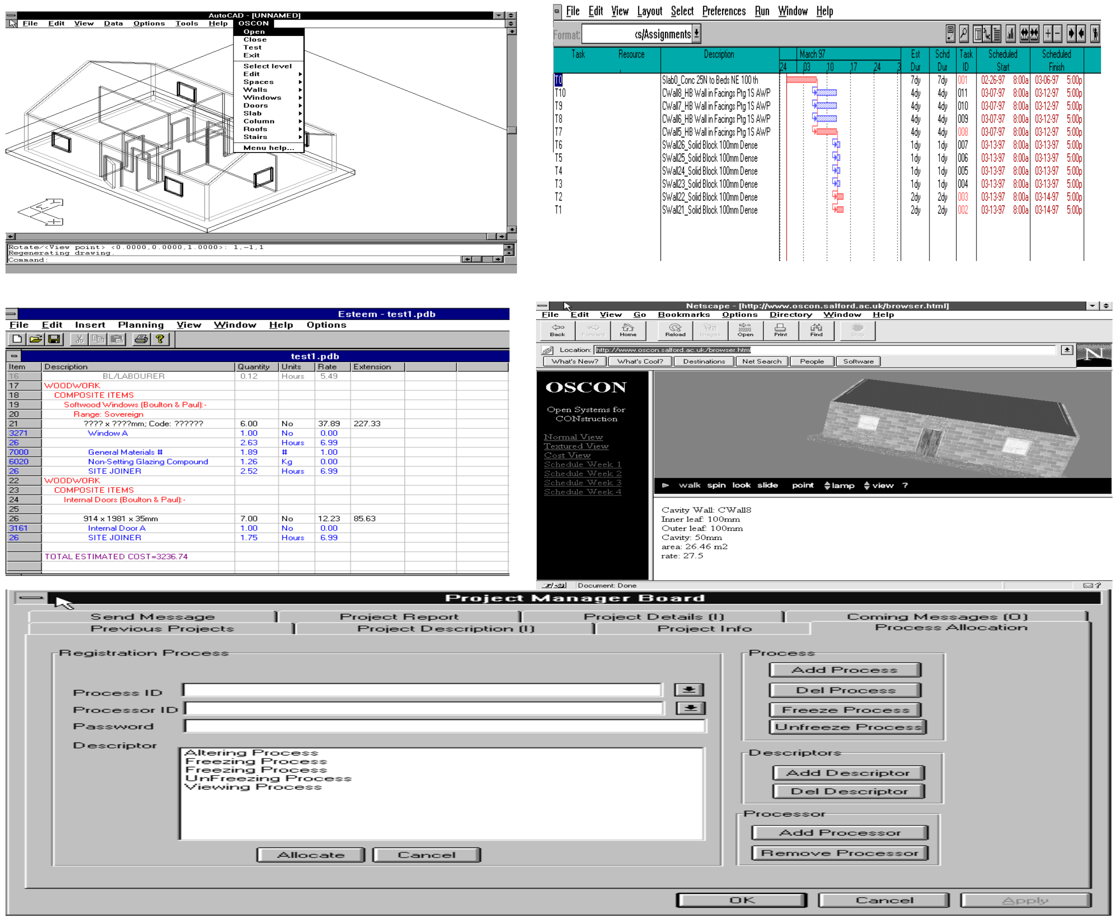

Figure 5: a snapshot of an integrated environment.

To conclude, the IT map will serve as a catalyst for the process and shouldn't be looked at as the main driver. The process is driven by needs and requirements and the technology can help in meeting these by providing the right mechanism for visualising, managing, communicating and integrating information which will result in a more consistent and improved process.

4. CONCLUSION.

This paper has introduced an IT map which can be looked at as a support tool for a generic design and construction process protocol. This IT map builds upon the results of a recent survey conducted in the UK regarding construction IT priority topics. It is concluded that an IT map should support the key themes of visualisation, intelligence, communication and integration which are vital for a process to survive. The generic and specific IT tools have also been discussed. The work presented here is still at the very early development stage. This map should however be used as a stimulator for ideas regarding developing IT solutions for the re-engineered design and construction processes. The technology is still developing, but a stage will be reached where the technology push will result in a consistent and co-ordinated process. This can only be tested by the industry which is the next stage of this research.

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