# MAPPING THE PRODUCTION PROCESS: A CASE STUDY

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## ABSTRACT

The mapping of the design and construction process has been gaining momentum in the last few years. However, the focus has been on mapping the high level processes or the information required to perform certain processes. One such high level process that has enjoyed considerable success is the Process Protocol. It integrates the various participants of a project into multi-functional teams, operating within a stage-gate based project environment. This paper will present how process mapping can be used to increase transparency within a production environment. The case study examines a multi-million development project and it demonstrates how the introduction of mapping the design and production processes, based on the Process Protocol Model and principles, has improved communications, enabled increased design fixity and reduction of downtime caused by late deliveries of certain project activities and information. In addition the implementation issues involved in introducing such process mapping practices is examined and analysed in the case study project.

## KEYWORDS

Process Modelling, Design Management, Design Fixity, Production Modelling

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## INTRODUCTION

The need for the construction and built environment industries to improve their performance has been the issue of major activities in the UK in the last decade. Initiated by a number of government reports, the most recent being the Fairclough report (Fairclough 2002) on ‘rethinking construction innovation and research’. Indeed, a number of significant improvements have been realised in the previously somewhat sterile sector through the introduction of process thinking, value management and waste minimisation practices. This is also demonstrated by the significant amount of UK funding available for management processes both from the Engineering and Physical Sciences Research Council (EPSRC) at 19.4% and by the Department of Trade and Industry (DTI) at 13.% of available funding (Fairclough 2002). The results of this focused effort have been the generation and development of improved design and construction processes, design and project information management, to mention but few (Kagioglou et al. 1998).

Furthermore, current research on production within the management discipline is characterised by a wider and integrated perspective including social and environmental issues. In particular, there is a growing volume of research focusing upon the consolidation of the Just-In-Time (JIT) and the Total Quality Management (TQM) philosophies, with an array of other practices such as Total Productive Maintenance, Visual Management, and Re-engineering (Santos et al. 1999). Investigations sought to develop the content and structure of the core ideas underlying these theories, namely world-class manufacturing, agile production and lean production (Womack and Jones 1996; Gilgeous and Gilgeous 1999). Moreover, recent construction research have led to an array of corresponding construction practices, for instance, world-class construction, agile construction and lean construction (Pheng and Tan 1998). Nonetheless, the similarities of these theories often cause confusion and conflict among researchers and practitioners in the field (Santos et al 1999) in that the boundaries are rarely clear and the overlaps are not always admitted or pointed out by the authors. However, recent literature has brought about new prospects in assuming that the contemporary theories have common cores (Womack and Jones 1996; Koskela 1999), better known as production management (Lee 2001).

Process mapping has also been used as a means of illustrating the various processes and information flows within the design and construction process and has proved to be beneficial in terms of transparency and communications as well as a mechanism for managing project processes and forming the basis for continuous value management and improvement.

A significant impetus in the improvement process has been the introduction of ‘Lean’ practices from first principles (Koskela 1992; Womack and Jones 1996). The benefits of such improvements have been demonstrated by Al-Sudairi et al. (1999) in the simulation of the advantages of lean vs. traditional practices and Ballard et al. (2001) in the production system design in construction by the use of ‘end-means hierarchies’ and the method of last planner (Koskela 1999) amongst others.

This paper aims to demonstrate through a case study, how the use of process modelling in a production environment, based on the Process Protocol, enabled the reduction of the ‘soft’ wastes to improve communications, increase design fixity, reduce duplication of work, define roles and responsibilities and enable a 'pull' approach in delivering project deliverables [6].

## THE PROCESS PROTOCOL

The Process Protocol (see Kagioglou et al. 2000 for a detailed description) provides "a common set of definitions, documentation and procedures that provides the basis to allow a wide range of organisations involved in a construction project to work together seamlessly". It uses manufacturing experiences as a reference point and maps the entire project process from the client's recognition of a new or emerging need, through to operations and maintenance. The design and construction process is mapped by breaking it down into eight teams (Activity Zones), namely Development, Project, Resource, Design, Production, Facilities, Health & Safety and Legal, and Process Management; four broad stages, as in Pre-Project, Pre-Construction, Construction and Post-Construction; and ten phases. Some of the characteristics of the process protocol are:

- It takes a whole project view.
- It focuses on 'front-end' activities, paying attention to the 'identification, definition and evaluation of clients' requirements.'
- It provides the potential to establish consistency to reduce ambiguity, and provides the adoption of a standard approach to performance measurement, evaluation and control to facilitate continuous improvement in construction.
- The stage-gate/phase-review process approach used facilitates concurrency and progressive fixity and/or approval of information throughout the process. The 'gates' approach within the Process Protocol illustrate the need for completing all necessary phase activities before proceeding to the next phase ('hard' gates) or allow concurrency ('soft' gates) without jeopardising the overall project success.
- It enables co-ordination of the participants and activities in construction projects and identifies the responsible parties, by applying a 'pull' philosophy in producing and delivering predefined project deliverables
- It encourages the establishment of multi-functional teams including stakeholders. This fosters a team environment and encourages appropriate and timely communication and decision making.
- The Process Protocol Model and philosophies were employed in the case study presented in this paper for the mapping and management of the production process.

## RESEARCH METHODOLOGY

The case study presented in this paper was used to examine the effectiveness of the Process Protocol Model and to undertake research in the issues concerned in the implementation of such a model in a complex development project. It became obvious from the conception of the case study that a certain degree of intervention by the research team would be required if all the principles, philosophies and details of the Process

[6] The comments and conclusions arise out of the case study data and are those of the research team

Protocol were to be communicated and implemented by the case study project team. This meant that there would be an element of educating and training the project team as well as taking part in formulating the project and production maps for the project. In this paper only the production map elements are presented.

The research used an action research and observation model whereby the research investigator both enabled the case study project team to implement aspects of the Process Protocol and made observations of the progress of the project and the implementation of protocol principles.

The research was undertaken in close collaboration with the case study key project management staff and design consultants. Project tracking activities involved interviews and questionnaires as well as attendance at key meetings. The project was monitored in accordance with each of the Process Protocol deliverables and any new findings were incorporated in the project production map and are presented in this paper.

## THE CASE STUDY[7]

The case study project represents an unusual multimillion Brownfield inner city urban regeneration project. The development is multiuse with a number of different types of accommodation, each of which need to satisfy a number of different design and statutory requirements  Figure 1 illustrates the development, which is split into a number of separate blocks. The scheme consists of eight blocks, which are wrapped around a central courtyard. They provide a mixture of social housing, speculative office accommodation, key worker accommodation and a Pharmaceutical Manufacturing Unit (PMU), which is housed in the basement along with car parking facilities

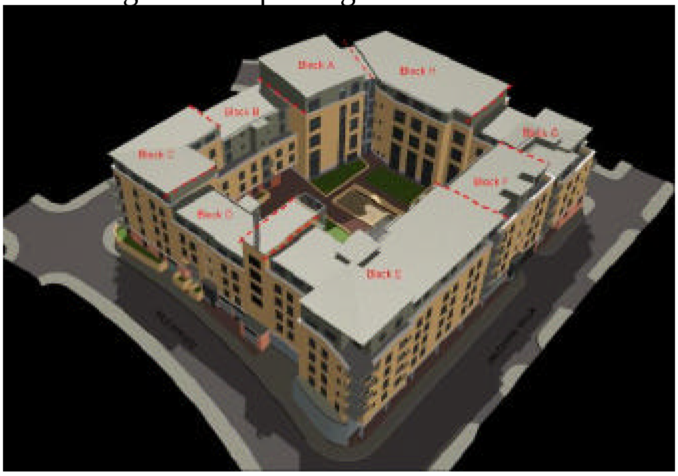

*Figure 1*: *The Case study development*

## PROJECT/PROCESS PHASES AND DELIVERABLES TOWARDS PROGRESSIVE DESIGN FIXITY

The Process Protocol Methodology advocates the use of distinctive phases within the design and construction process and it suggests a 'pull' system which is achieved through the identification and implementation of certain project/process deliverables, which are

[7] The case study and the participating companies will not be mentioned by name in this paper to ensure that they remain anonymous

reviewed in a number of predetermined phase reviews (usually at the end of each phase). Their use within the case study is described within this section.

The deliverables, which would be provided for the phase reviews and any subsequent reviews (mini phases), were decided for the project after close examination of the construction programme. These were sequenced depending on when the information was required for construction of the sub structure, PMU and the superstructure, for each individual block and also after deciding on appropriate lead times. The deliverables decided upon included:

- Structural Design Drawings
- Piling design
- Foundation works for Construction
- PMU substructure
- Superstructure Construction Blocks B, C and D

For each of the above deliverables specific design information was required and this was identified with a drawing number. Particular drawing numbers and drawing packages were predetermined and formed part of the information required schedule. After consultation and discussion with the design team the constituent drawings required for each of the deliverables was agreed with the team.

The specific design organisation that was responsible for the provision of key information was also agreed with the team. After the mini phase review dates (eleven in total for the development of the superstructure) had been agreed with the team, and the information was represented in the form of a map as illustrated in Figure 2.

This 'pull' approach had a positive impact on the project. The project manager initially presented the plan to the design team at a design team meeting. When the team had agreed dates at which they could provide key information the dates of the mini stage gates could be determined. As soon as these were mapped the individuals immediately started to discuss the provision of information with other design disciplines. They were then focusing more on hitting the deliverable as opposed to solely on the individual drawing document relevant to them. It was interesting to observe the changed behaviour of participants as they openly asked the other disciplines when they would provide them with the specific information they required to complete their part of the deliverable. Immediately they were prioritising the work needed to be done earliest in order to hit the gate (review point) on time. Each of the mini phase review meetings was conducted formally when progress was assessed. The reviews were undertaken at the time specified on the map and there was an improvement in the number of drawings provided on time. However there were some delays due to client changes and the apparent poor communication between the client and their representatives. Significantly the Engineers adopted the approach when providing their design programmes to the rest of the team. This programme illustrated when the stage gates were due, and identified the constituent drawings for which the engineers were responsible and when they could be provided. It was updated regularly and the approach made it easier for the Project Manager to monitor progress as it tied in directly with the design map.

This new approach did require a lot of effort and buy-in from all team members and it had succeeded to progressively fix a number of design elements but in some cases continuously changing design requirements were proven to be a strain in the process, in particular when there was a lack of transparency of various team member requirements, and this necessitated the strategic planning of design information requirements in the project. In order to address this problem the first thing that was undertaken was to obtain an updated procurement programme from the contractor and make this available to the design team. They could then understand the specific procurement packages and the time that information would be required by the procurement team. It was perhaps surprising that this information had not been made available more directly to the team before.

The dates on the 'information required schedule' (see figure 2) did correlate to the procurement programme but the simple act of being open with the document helped the design team understand the requirements of the contractors more and perhaps encouraged them to be more sympathetic to there needs.

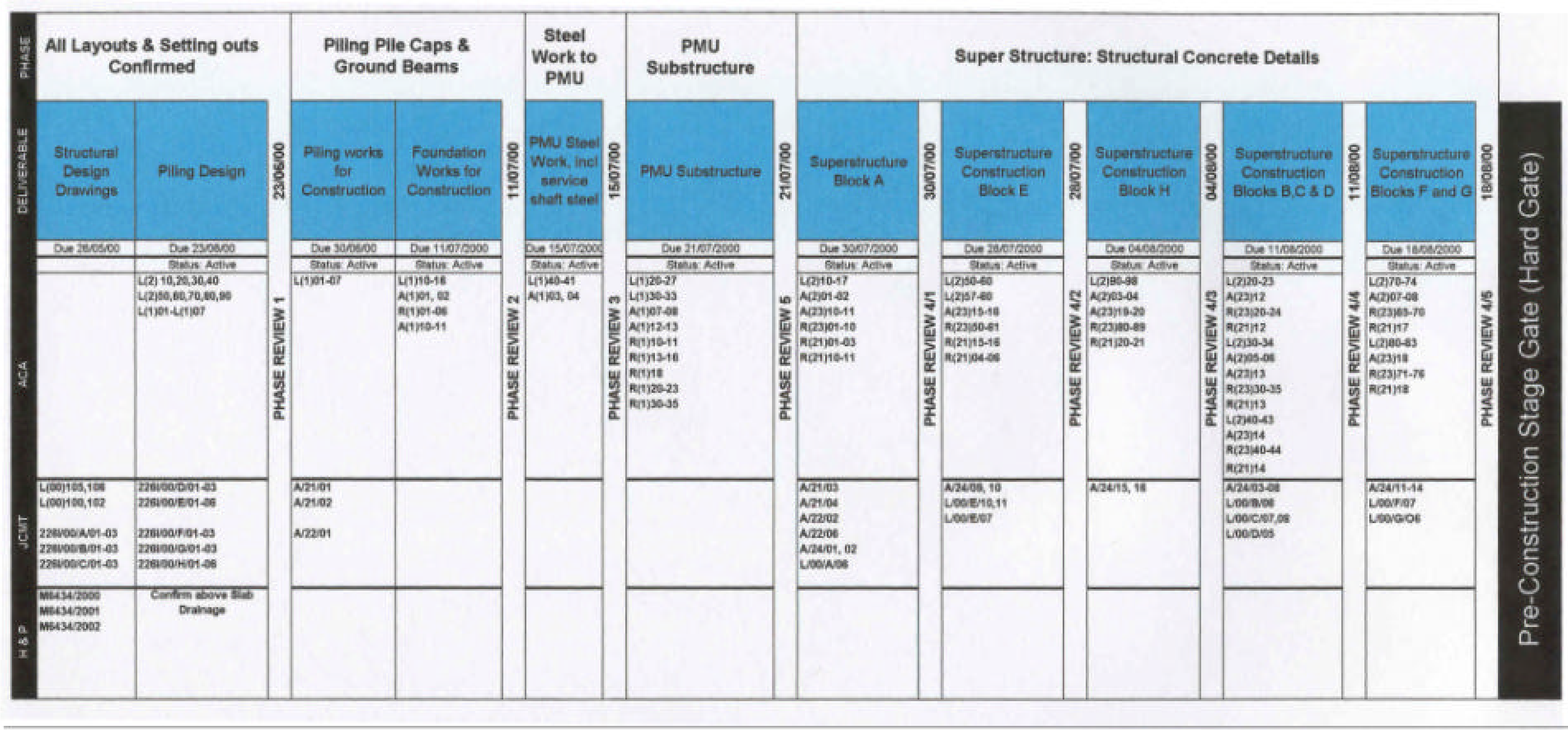


*Figure 2: Design Information Group Deliverable Map (Incl. Mini Phases)*

The procurement programme defined the required production packages and identified key dates for when design information needed to be provided, when enquiries needed to go out to the suppliers/sub contractors, and when enquiry's needed to be returned. It soon became clear that review meetings were a very important part of ensuring that the design is right (in terms of cost and buildability) by obtaining feedback from specialist suppliers and contractors.

In was also felt that it was important to be very specific about the types of meetings that were taking place and to ensure these were related to a specific procurement package and were not too general. It was therefore agreed that a meeting schedule be produced which outlined when they would take place, who would attend and what they would address regarding the specific procurement packages. The timing of these meetings was designed to tie in with the procurement schedule and were seen to provide more focus on specific aspects of the design development. Consequently they were well received by the team.

**Production Process Mapping**

Shortly after the implementation of the design deliverables and corresponding review meetings a new project manager was appointed who had a set of specific requirements. Having studied the principles of the Protocol and advocating its principles he requested a more specific map covering the production stage of the project with which he could monitor, communicate progress and examine improvements in production (reduce waste). The map was to incorporate three main types of information these being:

- Design information
- Consisting of specific drawings to be undertaken by specific disciplines (design team, specialist sub contractor) at a specific time
- Procurement information
- Dates at which work packages needed to go out/be received to sub contractors for pricing
- Production information
- Key elements on the construction programme which relate to specific work packages

The aim was to produce a map based tool, which would effectively represent the relationship between the three types information providing a clear and concise method of tracking project progress for the project manager and a communication tool for the team to refer to. The project manager was keen to develop a tool which would embrace all of the following principles as they are presented in the Process Protocol (Kagioglou et al. 2000):

- Project view (common project focus)
- Progressive design fixity
- Consistent process
- Identification of stakeholders

- Co-ordination

**Information strands**

The map consisted of 'information strands', which described the design and procurement process of each specific package. These then linked with key activities in the production stage providing the project manger with a holistic view of the design and production process for the given period. The map incorporated a time line in the same way as the design process maps had done and each activity was described by a simple information box (see figure 3).

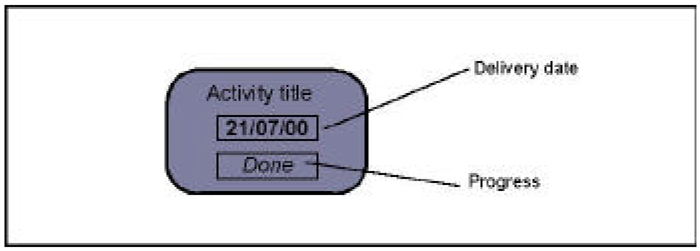


*Figure 3: Activity information box*

The specific work package was described by a package information box, which stated the title of the package and identified the champion responsible for delivery and the other main contributing organisations (see figure 4).

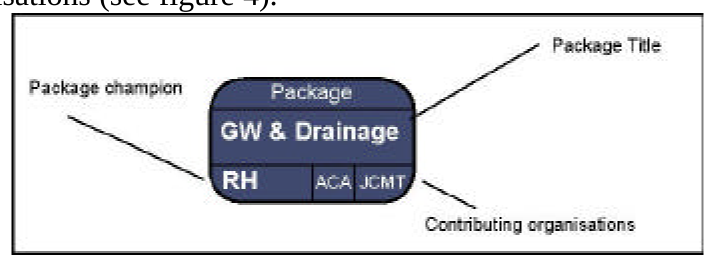


*Figure 4: Work package information box*

The information strand (see figure 5) allowed the project manager to track the progress of a specific work package regarding its constituent deliverables. The process began with the identification of specific design information that needed to go into each work package deliverable. The design team were then asked to provide an estimate of progress at each of the design meetings stating how much of their contribution was completed and how long it would take to complete the outstanding amount.

A picture of the progress of the overall design deliverable could quickly be ascertained. Once the design information for the deliverable was completed a meeting was held to undertake a technical review of the work and to obtain a group assessment of the design package to ensure effective co-ordination of design elements. The design issue date was viewed as being cast in stone in order to try and achieve design fixity at the scheduled dates and so as to not have a knock on effect with the procurement programme.

Once the package price had been estimated and designs had been agreed by the team the package was issued as a formal enquiry to the respective suppliers and subcontractors. Two weeks was given for the enquiry return. Once this was received a date was set by which time any subcontractor revisions would be required to be completed and agreed by. After any modifications or value engineering had been undertaken on the package and the sub contractor revisions stage was completed, an order was placed with the relevant suppliers at the correct time to allow them to successfully order or fabricate the required package elements. This off site start date was scheduled after consultation with the package contractors to enable sufficient time for preparatory work prior to the final on site start date.

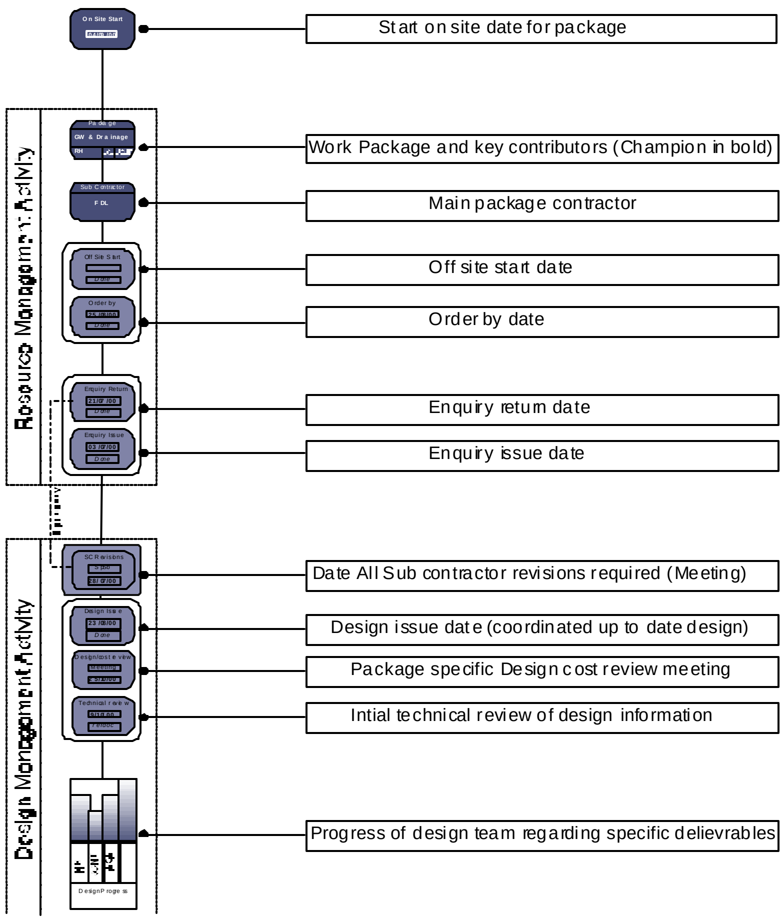


*Figure 5: Information Strand*

The information strand encompassed all of the above information and grouped the activities by relevant activity zone being design management, resource management or production management. The project manager could then track the entire package delivery process from design, costing through to value engineering with suppliers, and then ordering and finally construction.

Of course the production stage of a project is not made up of a single work package and so a production process map was developed that included all of the main work packages that were identified on the original project procurement plan, including:

- Groundwater and drainage
- Piling
- Structural steelwork (substructure and shaft)
- Concrete frame and floors
- M&E mains installation

Each of the information strands were mapped onto the overall production process map according to their on site start date along the map timeline (see a short illustration of the map in figure 6) . Key construction packages as described by the construction programme were also included in the production management activity zone on the map so the project manager and team could quickly identify when the work package deliverable was due to start on site and what other activities would be in progress at the time.

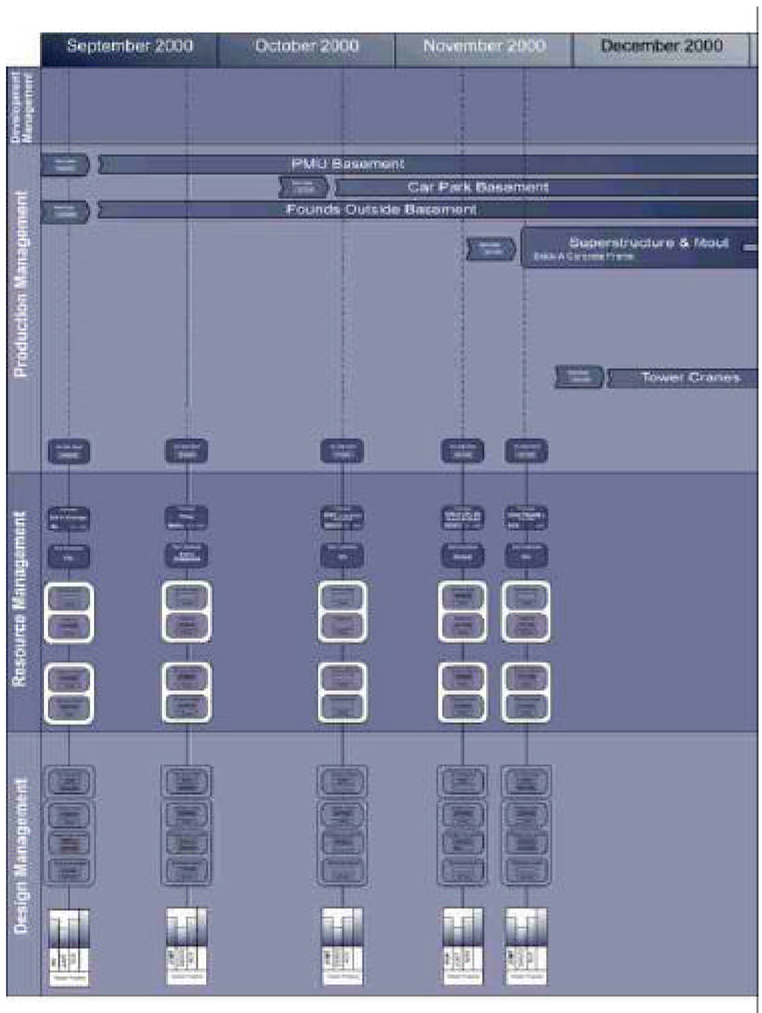


*Figure 6: The Production Process Map (brief illustration)*

A development management activity zone was also included on the map to identify forthcoming key events and milestones, which might affect the project.

The project manager utilised the Production Process Map to help structure and visualise critical information and to help to track and monitor progress by ensuring meetings were scheduled at the correct times and that information was submitted in accordance with the design, procurement and production programmes.

### Limitations

The map was limited in that any slippage in the delivery of the design information and any resultant change to meeting dates had to be rescheduled manually. Although this was not an insurmountable problem the efficiency of the tool could be enhanced considerably by automating the map so that it can be dynamically updated. Of greater significance was although the architect and contractor were agreed that the approach was very useful in integrating design, procurement and production activities the success of the use of the map and constituent information strands was in some instances hindered due to the contractor asking the design team to redesign packages so that they could meet the required budget.

## CONCLUSIONS

The management of the production process is an important element of the successful implementation of any project. This paper has presented how process mapping and the introduction of phases, phase reviews and deliverable sets within the production phase can be used to identify the dependencies of project information regardless of function of area of expertise. Furthermore, the production process map presented incorporate a number of novel techniques such as the information strands and the activity and workpackage box which when incorporate in the Process Protocol framework can offer real advantages in managing the design and production information. In particular, these features identify and reduce/eliminate the 'soft' wastes of the process in a collaborative and transparent manner.

The case study project briefly presented in this paper illustrated the real challenges facing project environments in terms of applying 'new' practices in a traditionally fragmented and resistant to change culture.

Increased benefits of process mapping in construction can be further realised with the simultaneous use of modern practices such as value stream analysis, value engineering, new forms of more collaborative contracts within an integrated supply chain environment.

Finally, the apparent limitation of the approach described in this paper will be the subject of further work and will be considered in a holistic manner which aims to increase the competitiveness and attractiveness of construction supply chain companies.

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