Bartlett Research

Paper Number 15

Understanding the Project Planning Process: Requirements Capture for the Virtual Construction Site

John Kelsey, Graham M Winch and Alan Penn

The Bartlett School of Architecture, Building,
Environmental Design and Planning
Faculty of the Built Environment

Bartlett Research

Paper Number 15

Bartlett Research Papers

Understanding the Project Planning Process: Requirements Capture for the Virtual Construction Site

John Kelsey, Graham M Winch and Alan Penn

This research is funded by the Engineering and Physical Sciences Research Council's research programme award no. GR/N00876 as part of the Innovative Manufacturing Initiative

Bartlett Research
The Bartlett School of Graduate Studies
University College London
Gower Street
London WC1E 6BT
tel 020 7679 5916
fax 020 7916 1887

Bartlett Research Papers ISSN 1352-2507

Executive Summary

In this paper the work of construction planners is considered with a view to discovering:

- how planning is undertaken generally
- how spatial planning is undertaken in particular
- what type of computer assisted decision support tool might be of use in the areas of visualisation and spatial planning.

To do this requires an understanding not only of planners' work but the context in which such work takes place. There is comparatively little written work on spatial planning in particular and little UK-based research on construction planning in general. Accordingly the paper is based on research carried out by interview with practising planners. In addition to planners employed by principal contractors, those of piling and M&E services contractors were also interviewed.

Pre-tender construction planning is where the main part of overall pre-execution construction planning takes place and therefore the paper focuses on this aspect. Pre-tender construction planning takes place alongside a number of tasks including those of procurement and contractors' design planning. It also takes place in a situation of great time pressure and uncertain design information.

The planner adds value at this stage by producing a method statement and programme, which:

- accurately communicates to the contractor's senior management the areas of significant risk to which they are exposed through undertaking to construct a particular building within a given time period

- effectively communicates to the client's advisors the contractor's competence to construct the required building.

The decision support tools used by the planner for scheduling are split into the Power Project and Primavera packages. The former tends to be used by those involved in smaller value works and the latter in larger value works. The main difference seems to be that Primavera requires a more logically disciplined approach to task planning. Those who plan lower value projects argue that they do not have the time to plan within the Primavera framework and that Power Project does the job they want it to do even if it is not as rigorous as Primavera.

The actors in the planning process include the client's consultants who provide design information, the contractor's own planning team and supply chain. However they also include a category described as 'constrainers' who are external actors who have the power to block the ability to carry out certain types of processes where, for instance, these encroach on their land rights or

highway management rules. Negotiations with these constrainers are an important part of the planning process.

Construction planning is closely inter-related with design/procurement planning and the paper sets out a sequence in which these activities are carried out.

The paper goes on to describe the planning process carried out by the principal contractor's team which goes through stages of identifying the product to be built, the main methods by which it is to be built and the works packages/overall time required to build it.

In the process of carrying this out, planners have to split up planned construction time/space/site resources between packages to ensure that the right site conditions can exist for individual package contractors to meet their part of the plan's targets. This includes principal contractors planning their own package of preliminary/temporary works and the overall site layout.

The specialist package contractors have a different set of problems. Their 'constrainers' are mainly other package contractors carrying out precedent and concurrent work whom they may not know and therefore with whom they cannot negotiate prior to tendering.

Piling is a spatially hungry activity. The space required is usually underestimated by design consultants and principal construction planners alike. What is underestimated is either the amount of working room required by piling machines or the quantity of support plant required for piling activities. Consequently piling package planners often find themselves having to plan works which are required to take place in very tight spatial conditions or time conditions or both.

Installation of mechanical and electrical services takes place at all stages of the building process but is particularly prominent at the finishing stages of construction. Package contractors in this area are forced to be very flexible in their working practices. However it must be asked whether planning (and execution) suffers under these conditions.

The aim of most planners in programming is to provide a reasonably robust schedule which will stand a certain amount of variation. This is required, not least, because the time required for each task in the schedule is subject to its own variability and a good plan must be able to cope with this. The financial consequences of potential late delivery cannot be wholly passed on to those package contractors deemed to have been responsible without making it uneconomic for smaller contractors to tender for work.

Adverse risk outcomes outside the contractor's control may also result in financial loss. It is not properly the job of the planner to quantify those risks (assuming they can be quantified). However these risks must clearly be identified in the plan so that they are fully understood at tender submission stage.

The main planning process outputs are method statements and bar chart programmes. Preparation/communication of those outputs is enhanced by the use of computer-based decision support tools. One of the outputs of the process is a set of work phase location plans whose preparation is usually a laborious manual affair which has no available form of computer-based support tool.

Learning outcomes from planning experience include better understanding of site/tender processes, M&E service work and the importance of communication skills.

There was plenty of support among interviewees for better support tools for communication with other planning actors. There was less enthusiasm for such tools as problem-solving aids except among those planners preparing work phase location plans.

The research poses questions about the trade-offs between i) stated construction periods and cost in the tendering process and ii) cost and the practice of concurrent design and construction. It also raises questions about information flows between principal and package contractors. The competence of designers as well as principal contractors in fully understanding M&E works is also questioned.

Further work on developing a support tool for spatial planning is supported. Suggested additional work includes the investigation of site planning, the performance of pre-tender plans in practice and re-thinking of the usual practice of splitting the construction process into single-trade packages.

Introduction

Construction project planning is back on the agenda. For the last 40 years it has been mainly associated with the critical path method, while the practice of planners has increasingly diverged from the theory. New forms of procurement – particularly integrated approaches such as turnkey and concession contracting – are allowing planners more time to plan than they have under traditional separated procurement. At the same time, client demands for safer, cheaper and faster construction can only be met by adding more intelligence to the construction planning process. For 40 years, construction planning has been almost synonymous with the critical path method and the Gantt chart, while most other aspects of the job have been left to judgement and experience.

The aim of the VIRCON project is to develop tools which can add greater intelligence to the construction planning process. There are two principal lines of development:

- To build on work on *4D planning* where the process is visualised by building the 3D product model through time according to the critical path network.
- To build on work on the spatial configuration of the constructed product by applying those analytic principles to space use on site during construction – what we have dubbed *critical space analysis* (CSA).

These analyses of critical path and critical space will then be combined into a *space-time broker* in the manner illustrated in figure 1.

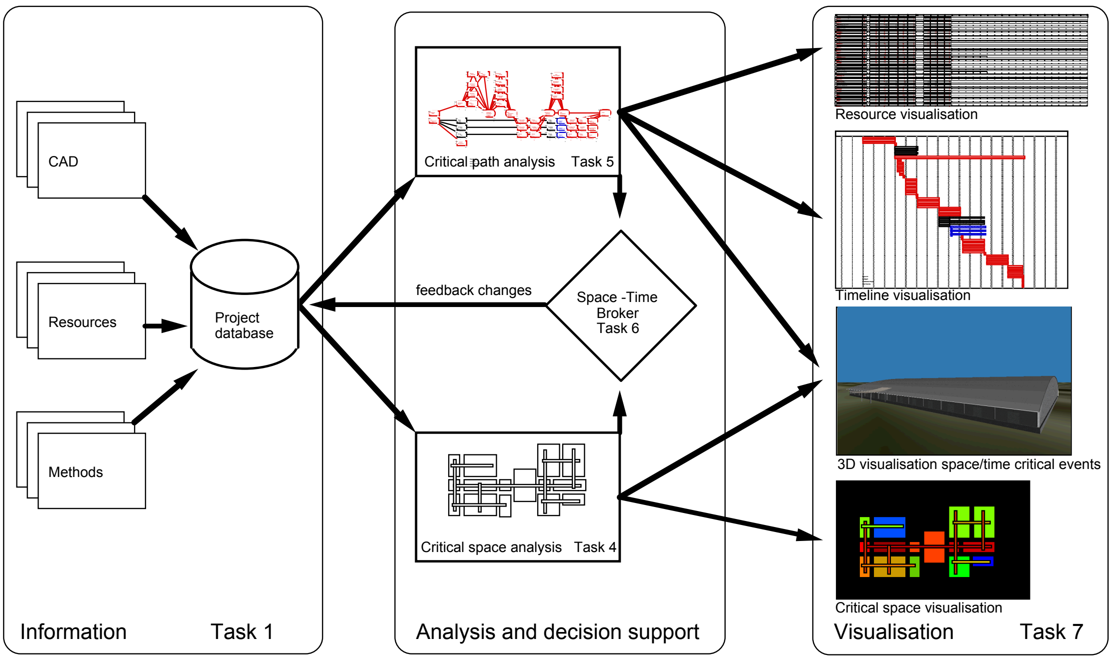

Figure 1 The VIRCON Vision

The research reported in this Bartlett Research Paper is the principal deliverable from Task 4 of the VIRCON research programme (the other deliverables are an early prototype and evaluation protocol for the VIRCON tool). As such, it constitutes the *requirements capture* for the space-time broker. Our initial researches found remarkably little information on how planners planned, as opposed to how theorists thought they ought to plan. So, the research reported here also adds to our knowledge about the state of the construction planning art in the larger UK contractors.

Aims and Methods

This section introduces the object of the research and its methodology.

Tasks

These are as follows:

- definition of the object and focus of the research
- review of recent literature
- analysis of interviews with planners conducted during Jul-Dec 2000
- presentation of the processes at work
- evaluation of the significance of the above for VIRCON and other construction-related issues

Object of the research - statement of the problem

The research aims to answer two questions.

The first is:

"how do construction planners:

- view their own work in general and

- go about planning (in real time and with deficient information) in relation to:

    - construction time
    - site layout
    - the spatial dynamics of work space allocation (between different tasks)
    - the overall management of the movement of plant, people and materials?"

The second is:

"how do construction planners:

- use computer-based decision support tools and

- think that better tools (involving a visualisation capacity) could assist them in spatial (and other) aspects of their planning work?"

Answers to the above questions form the requirements capture for the decision support software being developed as part of the VIRCON project.

Area of focus

It was originally intended that the research concentrate on post-tender, pre-construction planning as this seemed the most likely area where a computer-based visualisation tool might be useful. However this working paper concentrates on pre-tender construction planning as during the interviews it became clear that the pre-tender stage of planning was the main driver of the whole process from enquiry stage through tender submission up to commencement on site.

Although post-tender plans are revised as more design information becomes available the main parameters for the plan have already been set at tender stage. It is at the tender stage that contractors have to decide to undertake a certain set of risks and the method statement/plan provides one of the key pieces of analysis on which that decision will be taken.

In addition, planners frequently do not have time to undertake fundamental revisions of pre-tender plans. The time between acceptance of tender and start on site can often be less than or no longer than the original tender period and during this period they will normally have a further set of pre-tender enquiries to investigate.

Literature review

The literature review will not be comprehensive but focus on a few key contributions in recent years. The emphasis will be on spatial planning although aspects of the wider work of planning will also be considered.

Interviews

The field research was carried out by conducting interviews with eighteen planners drawn mainly from industrial partners in the VIRCON project. Two planners from an industrial partner on another research project related to spatial planning (Laing Construction) were also interviewed. The interviews were semi-structured which allowed a number of common questions to be put while allowing planners to talk about aspects of planning that particularly concerned them. This approach allowed issues to emerge which may not have been immediately apparent as planning issues.

The justification for this is that there is comparatively little research on dynamic spatial issues. A framework therefore needs to be established in which more rigorous empirical research can take place.

The heterogeneity of the employers of those interviewed was, however, useful for three reasons.

Firstly, the planning problem is a distributed one with higher level planning being carried out by principal contractors' or construction managers' planners and lower level more detailed planning being carried out by package contractors' planners. The latter, however, are not merely passive consumers of the planning work of the former but rather interact with them throughout the process.

Secondly, following on from this, both main groups of planners (principal contractor and package contractor) are in a good position to assess the performance of the other group as a whole. All the firms involved were naturally keen to present their best planners for interview and all the interviewees were indeed impressive. However the assessment by each group of the other (on a wider basis) suggests that there is significant room for improvement. This suggests that, while the interviewees themselves may be of high quality, they do necessarily a represent an unbiased sample of the quality of planners throughout the industry.

Thirdly, three of the principal contractors' senior planners have extensive experience in the training and management of younger planners. The assessment of their own learning processes and their views on the merits (or otherwise) of younger planners add further indications of where deficiencies may lie in the industry as a whole.

Process Analysis

The aim of the process analysis is to demonstrate:-

- How the planner adds value to the contracting organisation
- The place of construction planning within the planner’s job tasks
- The significant actors in the construction planning process
- The interaction between construction planning with design and procurement planning
- The place of construction planning goals within overall job goals
- The stages of the construction planning process showing the interaction between planning actors, data sources and tacit/explicit knowledge used by the contractor’s planning team actors

		THE THREE PERFORMANCE NEEDS		
		Goals	Design	Management
THE THREE LEVELS OF PERFORMANCE	Organisation Level	Organisation Goals	Organisation Design	Organization Management
	Process Level	**Process Goals**	**Process Design**	**Process Management**
	Job/Performer Level	Job Goals	Job Design	Job Management

Figure 2 – The nine performance variables (adapted from Rummler and Brache 1995)

It is intended that a formal process mapping method will be devised and set out in a future paper. For the time being the approach used is a more loosely structured one (Figure 2) following that used by Rummler and Brache (1995).

Their matrix interrelating the levels of needs and performance at job, process and organisation level provides a useful framework although organisation design/management and job management as such is outside the scope of this analysis. However job goals/design and organisation goals will feature as important aspects of the process context.

The state of the art in construction planning

This section examines recent research in the area of construction planning and its relevance to the research questions raised above. Some of the papers reviewed in this section are also reviewed in University of Wolverhampton (2001a).

Planning management

In an early paper (1987) Laufer and Tucker provide a critique of (US) construction planning. They complain that :-

- the planning and evaluation of planning processes are non-existent
- there is over-emphasis on critical path methods
- planners lack construction experience
- planners have poor information gathering methods
- planning is control-oriented instead of action-oriented
- plans are been poorly presented with overly-complex information.

In a subsequent paper (1994) Laufer and his colleagues look at the definition and allocation of planning work. They found that there was no clear system at work and planning was done in a multiplicity of ways. They call for the process to be properly co-ordinated by a single individual who will 'own' the planning process and improve communication. Firms needed to draw up a clear structure for planning at each phase.

Roles, responsibilities and scope

Laufer and Tucker (1988) discuss the problem of who should do construction planning and when they should do it. Existing literature supports the practice of:

- line managers having priority over professional planners (or at least having the last word)
- beginning with the longest lead time possible.

The specialist planner has the time to do the work but incomplete practical knowledge. The line manager has the practical knowledge but does not have the quality time to carry out the task. The specialist planner has better strategic decision-making skills than the short-term decision-making focus of the line manager. Line managers see the delegation of key decision-making to another as a threat to their position. These problems are also confirmed in a wider project management study in Laufer (1992). This can result in:

- the planner preparing a plan which has incomplete information and inadequate decision-making authority
- the line manager treating such plans as merely an irrelevant forecast prepared by another.

For the whole project process, the ability to influence cost diminishes rapidly over time (the greatest influence being at the design phase). However the greater the time between plan and implementation, the greater is the variance of actual schedule/cost against plan. Forecasting models are of limited use because :-

- there are uncertainties which cannot be quantified
- stochastic modelling does not identify the cause of variation
- forecasting models extrapolate from past trends which may not be valid for the future.

The benefits of planning are seen by mid-level managers as producing beneficial future states that would not have occurred and by top managers as preventing adverse future states that would otherwise have occurred. Accordingly the view of the benefits of planning varies within the organisation. The 'prevented' states can be difficult to identify and measure in economic terms.

The degree of detail in planning is also important. Too much results in an expensive plan which obscures the main features and which is difficult to update. Laufer and Tucker recommend that planning is at the lowest level of detail possible which should vary with the planning horizon. Longer term planning should focus on ideas rather than precision. As the horizon shortens planning should change from preventing states to affirming them (based on current decisions).

The role of the specialist consists in co-ordinating planning. Problems are caused by the inter-connectedness of decisions rather than the decisions themselves.

Top management needs to allow time to impart information to mid-level management. The planner needs to develop better communication skills. Respective roles for line/staff managers need to be better specified. It needs to be recognised by all that no single approach meets all situations.

Roles and responsibilities at site level planning

Laufer, Howell and Rosenfeld (1992) investigate site-level planning at three levels

- the foreman-to-crew level
- the supervisor-to-supervisor and foreman-to-supervisor level and
- the operation/systems analysis level.

The first level is required close to task execution as a low-level discretionary process. Late arrival of detailed task execution information and resource availability make this inevitable. (A previous study identified only one third of the sample projects where at the start of the contract there was a clear, stable scope and design.) There are clear benefits of greater foreman-level planning in improved productivity.

At the second level there are supervisor quality circle meetings for foreman and senior supervisors to identify problems, analyse them, arrive at possible solutions and plan solution implementation. Membership is at supervisor level because these employees tend to have a much smaller turnover than individual employers. Therefore any gains in their knowledge may be of greater benefit to their employer both directly and indirectly (in diffusion throughout the company). The existence of such meetings allows some quality time to the supervisors which is a requirement of planning. Benefits have been shown to exist although these tend to be on projects well-run in other respects.

The third level will normally involve someone outside the site management team looking at situations where problems/opportunities have been vaguely identified. Their job is to specify the problem/opportunity, collect relevant information to address the situation and implement/assess the changes. In one case the observation of a process through time-lapse photography led to changes in the design of component materials, in the installation sequence and in the quality acceptance criteria. In another case small tool availability was examined and improved through i) greater overall provision, ii) maintaining a consistent relationship between availability/demand and iii) allowing longer retention of specialised tools by particular gangs. The point was that the outside analyst could analyse situations which crossed responsibility boundaries which a high-level site manager would not have the time for.

Each of these three levels is a different process with different actors and used in combination they reinforce each other and make it easier for i) high-level planning to be properly diffused downwards and ii) low-level problems and solutions to be diffused upwards.

The need for planning – a survey of productivity loss studies

Thomas and Smith (1990) attempted to review and collate all available publicly reported studies on construction productivity loss. They attempted thereafter to weigh the opinions of the ‘experts’ as a two-man ‘jury’. They stress, therefore, that the final opinions are their judgement about the overall weight of all expert opinion (including their own). This means that their assessment of where the weight of opinion lies on any particular aspect of productivity loss may conflict with their own opinion as individual experts

1. They start by examining learning curve theory. The reason for this is that it is assumed that workers improve productivity over time by repeating similar operations. Any disruption to this pattern may, therefore, cause productivity ‘loss’ through interrupting the hoped-for learning gains. However they conclude that the curve ‘types’ proposed in the literature are cases of fitting curves to data rather than testing a hypothesis generated by some theory of learning. They suggest that those curves that have been ‘fitted’ point to a non-linear, phased learning pattern. They cite a substantial UN study carried out in 1965 which itself reviewed other studies carried out up to that time. This sets out the following criteria for repetition-based output gains:-

- Maximising identical operations
- Sufficient scale to allow specialisation and learning benefits
- Proper pre-planning/organisation of works
- Adequate day-to-day site management/supervision

A later Penn Transportation Institute study adds the following:-

- Minimal disruption
- Adequate resources readily available

2. The authors then examine the impact of productivity loss factors. They do report some significant productivity losses for environmental factors (temperature, humidity and weather events) but these tend to be operation-specific. They find significant general losses for out-of-sequence working but based on a very small number of studies. Similarly, for delays/interruptions, the authors report one study showing significant loss which not only affected output during the loss event itself but frequently for the rest of the shift on which it occurs even after they have ceased to have any ostensible direct effect. However the authors decline to admit this as a general case for the effect of interruptions/delays.

Studies conducted by Mobil suggest that 200 sq ft ($19m^2$) per person is required and that 50% more manhours are required when this declines to 110 sq ft ($10.4m^2$) which is an absolute minimum. For well-planned emergency labour-intensive short-term tasks, it is possible to manage with 100 sq ft ($9.4m^2$). Maximum productivity occurs at 320 sq ft ($30.2m^2$). The authors report that numerous other studies confirm 300 sq ft ($28.3m^2$) as the desirable lower limit to prevent loss of productivity.

There needs, however, to be a distinction drawn between *congestion* and *restricted access*. No hard and fast rules can be stated about the latter, but there is evidence that this causes substantial productivity loss (one study reports 58% as against 65% for congestion).

All agree that re-work is detrimental but the precise effects are obviously situation-specific.

3. The authors then turn to look at design and management factors. They find little hard evidence about design factors but the studies that there are suggest that the following might be significant:-

- Poor communication of design information (particularly in electrical work)
- Acceleration of design programme (without adequate coordination checks)
- Design which results in
    - minimal repetitive operations
    - sub-optimal component sizes
    - sub-optimal work sequences

In examining management factors (on steel and masonry work) the authors concluded that there is evidence pointing to significance of the following:-

- Poor material management:-
    - Poor labelling
    - Haphazard storage
- Poor site layout
- Work areas not being available
- Lack of scaffolding

Other studies show 41% losses due to the absence of supervisors. There are other management factors discussed but not found to be significant.

4. Examining other indirect factors, Thomas and Smith find that:-

- <u>Acceleration</u> can clearly be detrimental but this is situation-specific and works through effects on changes to work methods, overtime, task scheduling, shift patterns and overall workforce size. In addition there will be other effects via materials management, supervision and rate of resolution of arising site problems.

- <u>Overtime and shift patterns</u> can have detrimental effects. In particular long hours can cause losses through fatigue or through a Parkinson's Law effect whereby the job is stretched out. In addition where the pace of work is being 'forced' this may indicate the presence of other adverse factors which cause productivity losses on the job. The evidence, however, is mixed.

- <u>Overmanning</u> compared with 'normal' workforce causes losses – particularly where this exceeds +33% - however the effect is through lack of adequate support from supervision, material handling etc. (The same effect is true of too many <u>change orders</u>.)

5. In examining other studies Thomas and Smith concluded that the most comprehensive research on effects of disruption are those carried out at Pennsylvania State University. Other reports lack one or more essential ingredients for such a study.

For researching data for productivity improvement:-

- Contractors need to collect data at crew level
- This needs to be done on a daily basis for selected activities
- Analysis should be contemporary and not post-project

The most severe impacts on labour efficiency are caused by:-

- Out-of-sequence working
- Congestion
- Material (mis)management

- Weather events

However, other factors having an indirect effect on productivity are:-

- Overtime
- Absenteeism
- Over-manning
- Change orders

The authors stress the comparative paucity of useful, publicly available research in the area (up to 1989).

A traditional approach to site spatial problems

A UK approach to the problems of confined sites can be found in Burch (1985). Piecemeal redevelopment has forced contractors to work in confined sites with poor access. This causes problems in the delivery/offloading/storage of materials and restricted use of plant/equipment.

He points out that building on such sites demands good planning, understanding the requirements of police and local authorities, careful plant selection and allowance for reduced productivity. Subcontractor co-ordination problems arise in a confined space as do material delivery problems via restricted accesses.

Recent approaches to dynamic spatial planning

Thabet and Beliveau (1994) present the problems caused by internal materials storage, large single trade work space requirements and exclusive zone occupation by one trade. A 3D CAD work space availability model is developed in blocks. It seeks to match working space supply and demand while taking work continuity and variable productivity into account.

The modelling of space demand allows for an occupation space and a surrounding space. The latter is a dead safety space which allows for resource movements or models 'real' dead space which is occupied by the building product. It classifies activities by those which require exclusive occupation, those which can be performed co-spatially with other trades and those which require large proximity storage space for materials. Demand is divided into two groups, labour/equipment and materials demand.

The Space Capacity Factor (the ratio of demand to available) is developed from the above model as a potential congestion measure which allows scheduling resource variation decisions by the supervisor.

Riley and Sanvido (1995) structure spatial analysis. Construction-Space types are defined. These are broken down into process spaces occupied by activities which create product spaces which are occupied by the built product. The process spaces are divided into areas and paths. The areas are where work is performed or materials stored. The paths are the routes along which they move. Spaces are framed within a hierarchy of Building Level, Floor Level and Room Level. Their diagram of the construction space framework is shown in Figure 3.

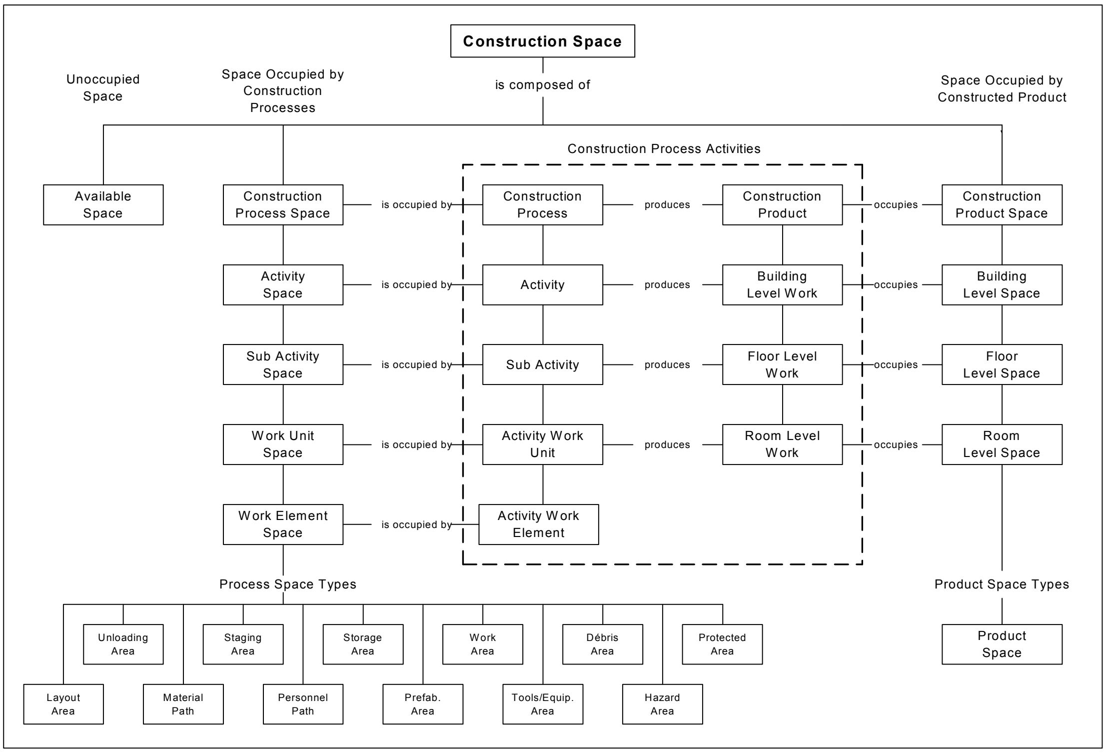

Figure 3 – Construction Space Decomposition (adapted from Riley and Sanvido 1995)

In a later paper (Riley and Sanvido 1997) the authors apply the general approach of the earlier paper to actual projects. They try to see if spatial conflicts could be avoided by using their methods and, conversely, the effects of the spatial conflicts that were not picked up.

They organised the process of :-

- identifying task space requirements
- generating layouts
- generating a task sequence
- identifying and resolving potential spatial conflicts

around ten case studies and subsequently tested them on two more.

A number of conflicts did occur and the most important factor seemed to be failure to plan material paths. Using and maintaining the plan requires considerable effort (although the authors point out that the process could be automated). Some site personnel felt that there were too many unknowns on site to be able to plan and it could, in any case be left to a superintendent. There is also the contractual point that giving subcontractors detailed planning instructions can rebound against the contractor if anything goes wrong. The authors counter the latter point by observing that the early input of subcontractors could help develop a productive sequence plan.

The authors concluded that space conflicts (or delays caused by potential space conflicts) could have been avoided by using their method. Interestingly they point out the problem of crews doing non-critical work early (in buffer or 'float' time) which may impair the completion of other more critical tasks. They advocate the maintenance of a large inventory of site materials to motivate the site manager to balance the available materials with the available space using better space planning.

Zouein and Tommelein (1999) create an heuristic which reflects an approximation to the sort of thought processes in a planner/supervisor's brain. They apply resources to (rectangular) space occupation in different time frames. They apply penalties for double handling and increasing distance movement of materials. The model works on a first-come-first-served basis (and is therefore path sensitive). However this is the way things work on site and that more detailed layout planning may be difficult when uncertainty is high.

Choo and Tommelein (1999 and 2000) discuss the problem of handling the information (from multiple sources), which assists planners in determining task interdependency assumptions for dynamic temporal planning. This requires a distributed information tool, which can be input from gang supervisor level upwards. Dynamic layout planning likewise requires a distributed tool to identify and manage potential spatial conflicts. Real time variations in performance will require continuous adjustment of the plan based on each week's achieved work and the following week's achievable work. This suggests that there would be benefit in integrating distributed input information tools for both task interdependency and layout requirements.

In how much detail should scheduling be shown, they ask. It should be explicit enough to communicate all relevant constraints to other parties. There are more theoretical issues like measuring the effects of distributed planning and co-ordination on overall project performance or determining measures of 'good' co-ordination (eg by the number of detected and avoided conflicts).

The benefit of this method is to require a single input of relevant data. Those allocating tasks and resources have an overview of the resource demand and can highlight at an early stage potential conflicts in space or resources. The 'last planner' at gang level will input his requirements during the previous week's planning.

Re-defining task interdependency at site level – the limitations of critical path methods

Ballard and Howell (1998) take ideas from the lean production system introduced by Toyota in vehicle manufacturing. Here the rule is to stop production rather than send a bad product further down the production line. The construction equivalent is to make only ‘quality assignments’ ie those assignments:-

- Which are sufficiently well defined
  - to be co-ordinated with other work and
  - for the inputs to be identified and assembled,
- For which
  - all materials are available
  - design is complete
  - precedent works are complete
- Which have priority in the critical path for delivery to the customer
- Which are commensurate in scale with the available labour for the coming week
- Which are carried out within a system where the causes of incomplete or poor quality assignments are investigated and identified

The paper asserts that tasks not meeting these criteria should be deferred (even if this means a short-term loss against programme) and analyses the benefits from following this course of action which they term as 'shielding' production.

The reliance on maximally flexible production results in non-conforming quality task assignments. This results in work flow uncertainty and loss of productivity for the task team and delayed start of downstream tasks. The performance of gangs involved in quality tasks improves. (Field research, they argue indicates that failure to complete tasks is largely due to missing materials or incomplete precedent tasks.) The idea of delaying some tasks in order to improve productivity is a hard one to sell to site management. However test project results suggest that shielding works.

This method re-defines precedent conditions for tasks to proceed. What it also highlights is the need for an integrated site and off-site task logic which includes material procurement/delivery together with design document execution and delivery.

Choo and his colleagues (1999) criticise plans based on critical path methods (CPM). The use of CPM models for weekly site management requires counter-intuitive ways of thinking. Individual supervisors use their own weekly work plans which are used in isolation and then discarded. Co-ordination is thus not effective and any learning remains inside the supervisor's head The paper therefore suggests a distributed database from which supervisors can make weekly plans and check resource availability. This enables them to check that they *can* do what the overall plan says they *should* do. This should result in an ability to carry out “quality assignments” (see Ballard and Howell 1998).

Information integration with other disciplines

Alshawi and Hassan (1999) point out that for construction planning to function as a control and decision-making tool it has to be ‘integrated’ with other disciplines such as design, estimating, site layout planning and material purchasing (among others). Past attempts at this have produced highly partial solutions of limited practical application.

The complexity of project processes, the lack of information management expertise (at project management level) together with the fragmented and adversarial nature of the industry raise difficulties for an integration project. However, without integration there is bound to be a substantial efficiency loss where planning has to support other disciplines or vice versa.

Data/process models, modelling methodology/tools and a structured framework are required to support data management/integration. The authors then describe a framework for integrating the construction data/information environment centred on the construction planning process. They describe planning object/process flow relationships (including those of construction methods, design and spatial requirements) and their interdependencies. They propose a prototype set of information management modules which might be used to implement an integration solution.

Discussion

Laufer and Tucker (1987) is particularly interesting in its criticism of planners' training and in the emphasis on communication. Some of the faults they describe appear to have been addressed in the UK although the planning and evaluation of the planning process itself is still a problem. It should be said that the complaint of planning being done in a multiplicity of ways is not necessarily a valid criticism. At different levels of planning different approaches may be warranted.

Their 1988 paper highlights the differences in time, information and decision-making endowments of specialists and line managers. It stresses the need for planners' communication skills (confirmed by findings described below). It is also useful in trying to conceptualise how planning adds value through the creation or avoidance of future states. The stress on the varying degree of detail is also important.

The paper draws upon the US practice of using planning specialists without practical site experience. In the UK many planners do have such experience and use contacts among past and present colleagues to source important practical information about site operations.

Current UK decision-making practice also appears to overcome some of the problems identified in this paper. Typically the planner prepares a plan in consultation with a line manager. This plan is used as a basis for evaluating the risks involved. The planning team decides appropriate methods and schedules. High-level management evaluates the risks involved in a tender offer and decides whether they are commensurate with the prospective rate of return.

Burch (1985), although dated, correctly identifies many of the current spatial problems which UK planners face.

The studies quoted in the survey by Thomas and Smith (1990) of productivity studies confirm that labour congestion is one of the factors behind the most severe impacts on labour efficiency. In addition it refers to the problem of restricted access, which supports the incorporation of path analysis in a spatial planning model. The importance of correct sequencing, site layout and material handling is also shown.

While out-of-sequence working is cited as a major cause of productivity loss, it may be the case that fear of potential congestion (and not only the non-performance of precedent tasks or non-availability of human/material resources) is a contributory prior factor. One of the wider implications of the survey is that poor planning and supervision is indirectly a major factor in productivity loss.

The paper by Thabet and Beliveau (1994) reports the modelling in 3D of the construction working space. The activity classification and the space capacity factor are, however, of limited usefulness other than telling the supervisor that he has a problem in a particular space. The paper does not bring in the subcontractors as potentially positive actors in spatial dispute resolution. However the description of an iterative procedure to manage space supply and demand is useful.

The usefulness of Riley and Sanvido's 1995 paper is not in its empirical content (interesting though that may be) but in the way it seeks to classify space and relate process to product. It provides a framework in which space-time conflicts can be analysed (the practical application of which is reported in their 1997 paper). It also formalises a floor by floor task sequencing system. The paper is limited in that it sticks very much to the internal superstructure activities. For instance, no 'plant path' is allowed for in the process space description for instance. In addition one must take issue on the material delivery question - particularly in UK site conditions. They rightly point out the potential resistance to acceptance of the method as an obstacle and scepticism about detailed planning in general.

Zouein and Tommelein (1999) formalise a dynamic exclusive zone occupation model. They do not model the material movement process itself which is a different (but very relevant) problem.

Comparing the foregoing three models, Thabet and Beliveau present a useful if limited model of work area planning. Riley and Sanvido build on this to provide a useful (if incomplete) theoretical framework on which to build a space planning tool which they then apply to real projects in their later paper. The approach is limited to internal works and thus avoids the spatial problems of the 'open site' and frame/cladding stages. Zouein and Tommelein limit themselves to an heuristic model which may be a good description of existing reality but does not necessarily take the planning problem further forward in terms of an improved process.

The approaches by Choo and Tommelein (1999/2000) and Choo and colleagues (1999) are currently difficult to apply to UK conditions (except perhaps on very large projects). For a shared information flow model to work here, it would require a shift in the mindset of the package contractor (some of whom seem to find it diificult to submit even a simple programme bar chart). The bottom-up approach for the shared database is intended to be user-friendly for subcontractors. However in UK conditions where sometimes there are no offices on site, it is difficult to see supervisors using it. There is also the issue of commercially significant data input and who 'owns' and manages the database.

While the logic of Ballard and Howell (1998) in arguing for ‘shielding production’ is compelling, we question whether this approach would actually work in a fragmented project coalition in the UK where each party has specific and separate responsibilities for which financial penalties may be imposed where late task execution occurs. Although the authors investigated US and Venezuelan projects there is here a potential criticism of the way some UK projects are organised where all actors in the project coalition do not have an incentive to allow the exclusive assignment of quality tasks.

The paper by Alshawi and Hassan (1999 p209) comes with the warning that “….this prototype has not yet been tested in the real world” when referring to their proposed information integration model.

The paper is, however, useful in two respects. Firstly it emphasises the interdependence of construction planning with design and procurement (which is confirmed by interview results later in this paper). Secondly there is no dispute that a greater degree of data structure integration is desirable. An attempt to build a conceptual model of an ideally integrated system is a useful exercise for the future even the proposed implementation tool has limited current practical application.

Summary

This section has looked at recent research related to construction planning in general and its spatial aspects in particular.

We find that:

- The acquisition of communication skills are an essential part of planners’ training.
- There is a potential tension between planning and operations management which is best resolved when planning is carried out by a planner as part of a team which includes an operational manager (as is now usual UK practice).
- Congestion and restricted access are major sources of productivity loss and require detailed spatial planning if they are to be overcome – particularly in the confined sites often found in the UK.
- Several conceptual models of spatial planning have been developed (particularly that of Riley and Sanvido) which provide a useful

framework in which to build a decision support tool for dynamic spatial construction planning.

- The inclusion of construction process space as a resource in a resource-constrained planning model is essential to improve on the traditional CPM approach. In a wider context there is a need to broaden the range of criteria (and therefore precedent task completions and resource availabilities) required to execute each site task.

- To be of significant use in the UK site level planning tools developed in the US require the co-operation of all actors in the typically fragmented construction coalition found here.

As far as coverage is concerned we find that:

- The project-level planning work of the planner is better covered than the long-term and organisational context in which he/she works.

- Site level planning is better covered than pre-construction planning.

- Site layout planning is better covered than dynamic spatial planning of construction processes.

What do planners do? – constraints and planning processes

This section describes the role of the planner as revealed in the interviews conducted between July and December 2000 with 18 planners whose assistance (and that of their employers) is gratefully acknowledged.

Experience at different project stages

Most of the planners interviewed were currently involved in planning at the pre-tender stage including assembly/presentation of the proposal/tender. About half of those were also involved at the post-tender pre-construction stage. Only a few were further involved during the site works. Generally, although a number of the interviewed planners had on-site experience the typical pattern is that a planner works either at the pre-tender, pre-execution stages or on site but not simultaneously. The exceptions tend to be where planners work for some time on a single large project. In such cases it may make sense (from the employer's point of view) for their work to carry on to the execution stage.

Most planners were involved in fairly limited supervision of one or two other staff - mainly as trainer-supervisors for younger planners. Also two had substantial supervisory duties as managers of a group of planners. All the piling contractor planners (and none of the remainder) carried out estimating work in addition to their planning duties.

Time

For traditional contracting by single stage tendering the period for the preparation of the construction plan was around 4-6 weeks for larger contracts and 3-4 weeks for smaller ones. The post-tender to start on site period showed somewhat greater variation from 2-13 weeks. For two stage tendering the first stage was similar to the single stage tender period but it was only at the subsequent stage that a price had to be presented. However for the *planners* the time frame was similar to the traditional method.

The planner working for a construction manager reported that he was brought in at a somewhat earlier stage (although still too late for his liking). The principal contractors were also involved in partnered contracts and PFI schemes where the periods were considerably longer (3-6 months and longer). On large civils contracts the periods were also longer (3 months).

These times however hide the fact that planners often work simultaneously on several tenders. The actual working time therefore which is available to them for preparing each tender submission is substantially less than the average tender period.

The effect of the shorter time constraints means that:

1. Contractors often only have time to find a workable plan and not an optimal one,

2. Contractors have little or no time to remedy the frequent information defects with which they are presented at tender stage. (Although requests for information - RFI's - are sent they are sometimes ignored or receive no reply until after the tender submission date.)

Quality and sufficiency of Information

The M&E planner commented that tender drawings were consistently very poor. Designers sometimes did not allow for any secondary steel support work, or installation space for service pipework. Curiously in some cases the weight of service pipework had not been allowed for although such weights are readily available. In some cases he had been obliged to reject drawings out of hand forcing a re-design of the frame in addition to the services themselves.

The three piling planners were likewise unimpressed with the quality of information they received. On a few occasions they had been consulted at an early stage about the specification. They had received a few good, well thought out specifications. However most were generic documents whose sole purpose was to protect the designer in the event of litigation. They were sometimes sent a huge pile of drawings which included everything from the roof details downwards. In these cases principal contractors had sub-contracted the responsibility of identifying drawings relevant to the piling process.

Perhaps more worrying for these planners, was that the voluminous information they received (including the scope of works) was still often inadequate and in the words of one planner 'showed a poor grasp of groundworks'. Some designs showed a lack of understanding of the space required by piling plant. They had rejected a number of designs as being impossible to construct. The most common fault was siting works too near confined boundaries making it impossible for plant to access the working area with sufficient working room.

The other problem was inadequacy of relevant non-design information. The proper planning of a piling operation requires the knowledge of the whereabouts of underground services and other obstacles (or nearby underground services or facilities that may be affected by vibration or other aspects of groundwork processes). It also requires knowledge of the working sequence of demolition and earthworks contractors with whom they have to co-ordinate their work. Since these are not known at tender stage they may have to guess these sequences or work out several different scenarios.

Of the remainder three thought the documents provided were reasonable (although none was particularly enthusiastic) while the other seven were fairly critical.

A number of planners had been involved in design and build contracts and there was perhaps some reluctance to make too much criticism of in-house design departments (although some was forthcoming nonetheless). They did point out that there was a benefit in having the design in-house in that problems could be sorted internally and that they were more likely to be consulted on buildability issues.

The design area which came in for greatest criticism was M&E which ties in with the views of the M&E planner. At least one planner complained that on some jobs there were no M&E drawings at all.

A number of planners were involved in two stage tendering and felt that the longer time period between receiving outline design information and actually having to submit a price did make drawing quality less of an issue.

The methods for dealing with the uncertainty caused by design information deficiencies were as follows:

1. Guess the missing information based on experience and past job records,
2. Qualify the submitted tender,
3. Assess the risk posed by the missing information and adjust the risk premium accordingly,
4. Take a strict contractual stance on site with regards to negotiating the cost of variations to the tender drawings/specifications/scope of works.

There is a fifth method which is an extension of method two. One contractor mentioned that for *partnered* contracts he was prepared to list all the risk items in the tender with prices attached - a sort of risk 'shopping list'. It was then up to the client to decide which risk items he wanted to take on board. Clearly method 4 would negate the point of having a partnered contract and none of the planners involved in such arrangements would use it in those circumstances.

What do planners deliver at tender stage?

Table 1 presents documents produced by the planner (usually as part of a team) at tender stage. These figures should be treated with care. The first four items were specifically mentioned by the interviewer and therefore those figures are probably reasonably accurate. For the remainder, the suspicion is that the figures are probably greater than those shown. Those items only mentioned by one planner have been omitted as being specific to that planner's type of work. Attention is drawn to the fact that two thirds of the planners use some form of phased work location drawings to assist their planning even if only a third of these form part of the tender documentation.

Obviously there are junior planners and office assistants to help with the assembly of these submissions. Nonetheless the obligation to produce and supervise the presentation of such packages must impinge further on the actual time that planners have for planning.

Non-financial information produced at tender stage mentioned by more than one planner			
	Internal only	**External Partnered only**	**External**
Items mentioned by the interviewer			
Method Statement			18
Programme Bar Chart			18
Critical Path Analysis	3		8
Risk Assessment	7	1	3
Additional items mentioned by the planners			
Preliminaries scheme/resources			5
Site Mobilisation/Layout drawings			5
Design Programme (for D&B)			6
Design Information requirement dates			5
Procurement Programme			6
Team details / cv's / organigrammes			7
Record / references of previous experience			3
Buildability/Programme/Value Eng. Options	1		3
Quality Assurance Plans and Procedure			6
Health and Safety Plans and Procedure			7
Environmental Protection Procedures			3
Phased Work Location Drawings	8		4
Overall Resource Schedules			3

Table 1 – Construction planners' deliverable output

Learning, decisions and decision support tools

Table 2 indicates what domain specific knowledge (Mayer 1992) planners think they have acquired which enables them to solve planning problems better than inexperienced planners.

Type of Learning mentioned by more than one planner	**No**
Better understanding of site processes and package contractors	7
Better understanding of M&E services and co-ordination with other trades	6
Development of better communication skills (including listening)	4
Experience through working on a wide range of projects	3
Better understanding of contracts and tender processes	3
Development of the ability to anticipate problems	2
Better understanding of the 3D/spatial aspects of the work (piling planners)	2
Development of a feel for task outputs and durations	2
Better understanding of supply chain management	2

Table 2 – Experienced-based learning outcomes

It should be pointed out that the site process learning represents 7 planners out of 18 whereas the Mechanical and Electrical services learning represents 6 out of 14. (The three piling planners only need to know enough to avoid damaging existing M&E services while the M&E planner should already have a good grasp of M&E services!)

Older planners were critical of (some) younger planners. One felt that two generations of planners (taking a generation at 15 years) had now appeared who had little site experience. The first generation of 'unsited' planners was now teaching the second. Another felt that the younger planners were too technology driven instead of concentrating on developing a basic understanding of construction problems.

Virtually all of the planners said that they had experienced jobs where they had come up with solutions that, had they been asked earlier, they would not have thought possible. A number mentioned spatial problems as examples of this.

What computer-based decision support tools do planners use?

Reference is made to Figure 4 which shows the preferred software and the value of recent contracts handled by each planner. It is clear that Primavera is preferred for large value contracts and Power Project for smaller ones. A thorough review of the capabilities of these and other Critical Path Analysis software can be found in University of Wolverhampton (2001b).

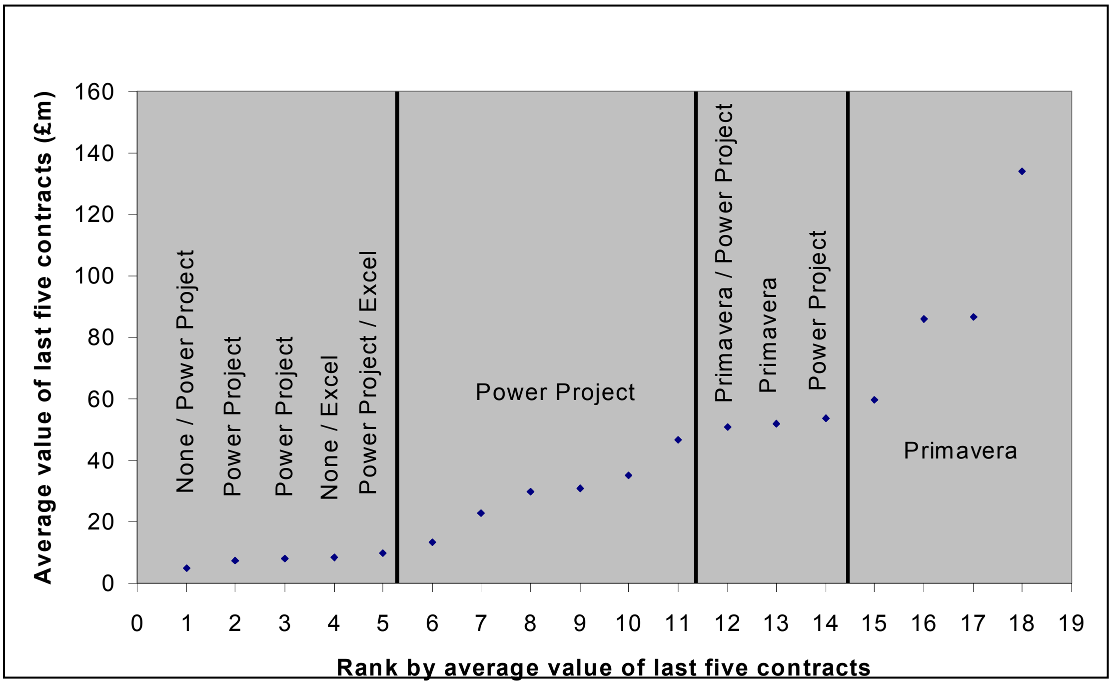

Figure 4 – Decision support tools used by construction planners

The Primavera users particularly praised its rigorous and disciplined task logic. The Power Project users criticised it for the same reason! The problem is that Primavera requires a substantial set-up time and considerable effort in maintenance and amendment. Amending one task in Primavera may force detailed adjustments of other tasks dependent on the amended task. Power Project will allow the last minute input of an 'illogical' task sequence which the planner believes will actually work but for which they do not have the time to re-input a new set of task dependencies. Those who have 6 months to work on a PFI project can afford the time to do this. Those who have to submit a tender in 3 weeks do not.

Power Project is easy to learn and easy to use (according to its protagonists). Its presentation capabilities are also praised. Users of both programs agree that Primavera does require a significant learning period.

Views on additional support tools

The interviewees were asked about their views on a visualisation tool which combined VR with scheduling capabilities.

Such a tool was seen as a potential aid to:

- Planning large, complex projects
- Preparing sequence plans
- Exploring alternative scenarios
- Solving complex spatial tasks
- Presenting tender submissions to clients
- Explaining spatial problems to clients and other contractors
- Educating trainee planners in spatial problems

Some planners were sceptical about it as an aid to problem solving but most were enthusiastic about it as a communication/presentation tool.

Such a tool however would have to:

- Be modular in design so that it could be used in a less disciplined way (like Power Project) or in a more disciplined way (like Primavera) according to the time available to the planner.

- Integrate with other data systems used by contractors

- Allow frequent amendment without excessive effort (very important)

- Be able to receive CAD drawings on CD-ROM from architects so that initial set-up time was reduced

Organisation goals

It is assumed that the major goal of the organisation is to generate revenue by winning and executing profitable contracts. While price still remains a major tender-winning factor, clients are increasingly using two-stage tendering to procure building works. At the first stage price is not an issue and it was reported by most planners involved in this type of tendering that the plan/method statement together with the site team offered by the contractor were the two most important non-price factors in securing progress to the second tender stage.

The organisational context of the construction planning process can be seen in Figure 5.

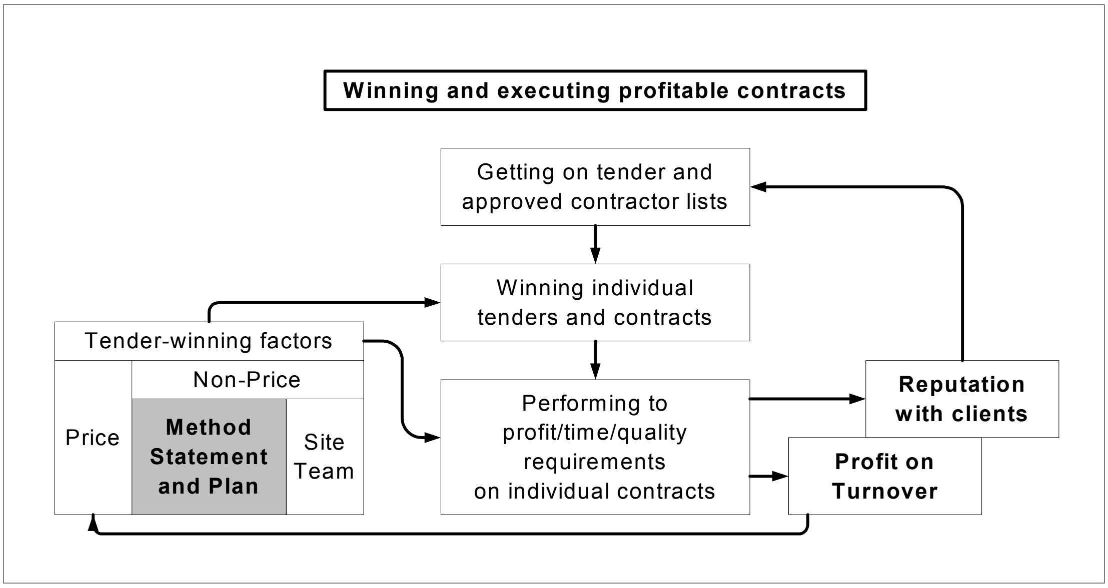

Figure 5 – Pre-tender Construction Planning as part of organisation goals

The problem of the indirect contribution of planners is similar to that of estimators. If plans are too ambitious (or prices too low) then there is a significant risk of the execution phase running over time (or cost) or of quality being compromised. If plans have too large a safety time buffer (or prices have too large a risk premium) then the work will not be won in the first place.

A positive indirect contribution in the accurate estimation of time, method and price yields dividends both in the present and future. In particular the enhancement of reputation assists in getting on tender lists and in being short-listed for works where the client will pay a premium for quality/timely execution.

Thus while the direct contribution of the planner lies in the contract-winning stage, the indirect contributions lie in the execution stage and consequent effects on reputation with clients.

Job goals and design

Very few planners were able to produce a written job description. Those that did, produced just that – a description of the planner's work rather than the goals of the job. This is not surprising since most job descriptions are written this way. The goals of the planning process form a subset of the goals of the job and the former will be described later. The job design however clearly includes a number of other tasks that are not pure construction planning as such.

It is important to appreciate that a construction planner does considerably more than construction planning as illustrated in Table 3. To economically justify their existence they have to work on far more *potential* contracts than the company actually wins. This combined with the short periods in which tenders have to be submitted (between receipt of tender documents and tender submission) means that the time available for planning contracts that the company actually undertakes is severely restricted.

Direct Construction Planning	**Other Direct Planning**
Pre-tender construction planning Post-tender pre-execution construction planning	Pre-tender procurement planning Pre-tender design planning
Commercial	**Administrative/training**
Risk assessment and review meetings	Tender package assembly/checking Supervising junior staff (or learning from senior staff)

Table 3 – Construction planning as part of a planner's job design

Process actors

Role	Description	Actors
Customer	Ordering built product, representing client's interests and supplying design information not controlled by the contractor	Client, Project Manager, Architect, QS, Structural / M&E Engineers
Performer	Planning construction as part of tender offer to supply built product	Principal contractor's planning team responsible to senior management
Supplier	Providing contractor with information on supply chain delivery capabilities	Trusted package contractors and specialist material suppliers
Constrainer	Controllers of the site and its environment who have the power to block or restrict construction operations	Client and/or client's landlord Utilities, adjoining owners, police, planning/highway authorities

Table 4 – Pre-tender construction planning process actors

Table 4 categorises the four types of actor in the construction planning process. Clearly the client and consultants initiate the process through the invitation to tender. The suppliers and constrainers determine the ability of the principal contractor to deliver the client's requirements, the former through their capacity and the latter by the extent of their agreement to allow the contractor to use the most efficient construction processes where these impinge on their particular domain. The principal contractor's planning team mediates between these other actors to form a viable plan.

Role	Description	Actors
Customer	Ordering part of built product, and supplying design information not controlled by the package contractor	Principal contractor
Performer	Planning specialist works as part of tender offer to supply relevant part of built product	Package contractor's planning team responsible to senior management
Supplier	Providing contractor with information on supply chain delivery capabilities	Trusted specialist material suppliers and plant hire companies
Constrainer	Controllers of the site and its environment who have the power to block or restrict construction operations	Principal contractor and other package contractors carrying out spatio-temporally precedent or concurrent works

Table 5 – Pre-tender package contract planning process actors

Table 5 shows the same set of actors for package contractors. The key difference between this and the previous table lies in those actors in the 'constrainer' category. Whereas for the principal contractor these are known, for the package contractor these may be unknown at the time of tendering (depending on the construction procurement method) and therefore no negotiation with them is possible. This makes it all the more important that the principal contractor's planner allows a sufficient distribution of space/other site resources to allow each package contractor to do their work unhindered.

Interrelationship of project programme planning processes

Figure 6 shows the overall pre-contract construction planning process highlighting :-

- The interdependency between construction site programme planning and design / procurement programme planning and

- The general sequence for determining the dates when design information is required from actors outside the principal contractor's supply chain.

- The substantial involvement of supply chain actors

- The important decision role of constrainer actors

The sequence of *action* which is being planned is clearly of the general form:

Design ➔ Procure ➔ Construct

However the actual *programme planning* process has to be in reverse as follows:

Construct ➔ Procure ➔ Design

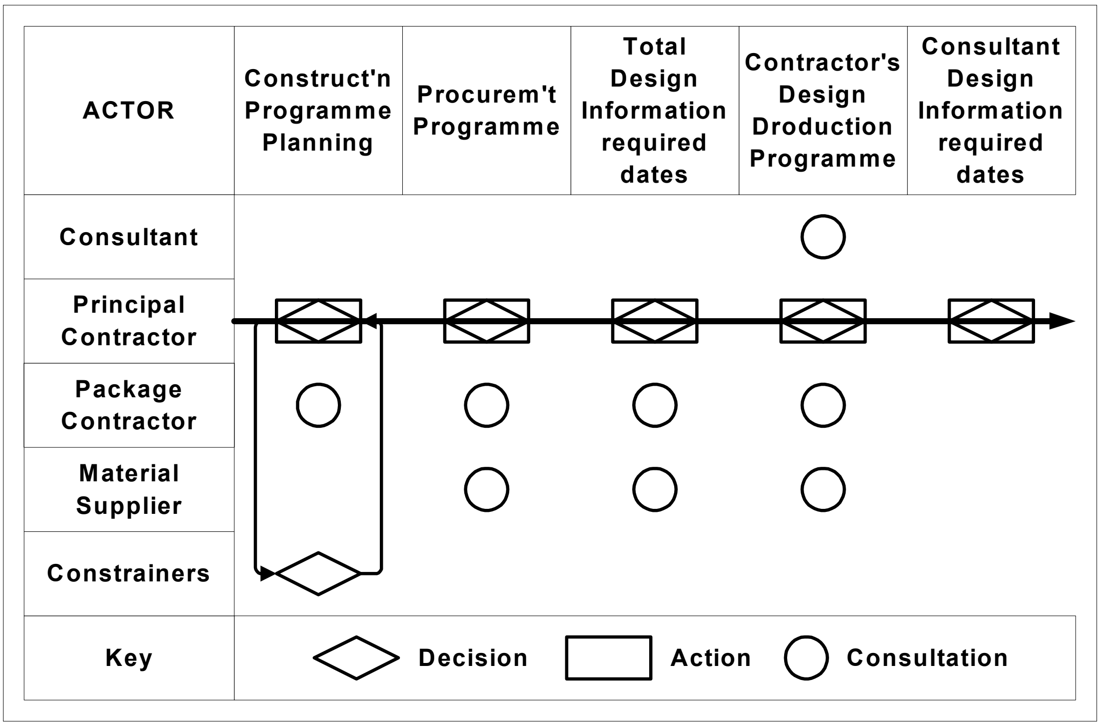

Figure 6 – The principal contractor's pre-contract construction planning process

This can be illustrated by the following sequence of programme planning.

Stage 1 - identification of the overall site construction programme

1.1 Breakdown of identified construction processes into packages according to supply chain capacities
1.2 Planning of sequential logic of processes/packages in time and space
1.3 Assessment of common site resources and temporary/enabling works required to service direct construction processes
1.4 Negotiation with constrainers (as defined above) to allow certain construction operations
1.5 Informal negotiation with supply chain representatives (and/or experienced in-house operations manager) to confirm or amend steps 1.1-1.4

Stage 2 - identification of the overall procurement programme

2.1 Identification of all key supply chain actors including those excluded from on-site construction processes
2.2 Identification of lead times for key supply items and package contractor tendering
2.3 Planning of sequential logic of procurement to support construction programme
2.4 Informal negotiation with supply chain representatives to confirm or amend steps 2.1-2.3

Stage 3 - identification of design information delivery dates required for procurement and construction

3.1 Identify all detailed design requirement dates (from all sources) to support construction and procurement processes

Stage 4 - identification of the contractor's design programme

4.1 Identification of temporary works design requirements
4.2 Identification of supply chain design responsibilities
4.3 Identification of supply chain information requirements to carry out design activities
4.4 Identification of client's consultants' lead times required to approve design data for which the contractor is responsible
4.5 Planning of sequential logic of contractor's design activities to support Stage 3 above

Stage 5 - identification of the detailed design data requirement dates from client's consultants

5.1 From Stages 3 and 4 above computation of all outline/detailed design requirement dates in order to support contractor's design, procurement and construction programmes (the output of which may require re-performance of Stages 1-4 above)

Output from stages 1.2, 2.3, 4.5 and 5.1 will form part of the tender submission.

As indicated under Stage 5 this is an iterative process and may require several passes before a viable integrated programme can be produced.

The interrelationship of design, procurement and construction programme planning results in two problems:

1) Inefficiency caused by planning with incorrect (or vague) data.
2) A potential mis-match between the dates that the contractor requires detailed design information (Stage 5 above) and the consultants' own detailed design output programme which (as far as the contractor is concerned) is a closed 'black box'.

However a few planners were interviewed whose employers managed the whole of the design and construction processes as principal contractors. They still found it difficult to reconcile the construction, procurement and detailed design method/programme planning requirements. The one exception was in the area of 'buildability' problems which they managed to address at an early stage by managing the whole design and build process.

There are several possible explanations for this.

1) Contractors are relatively inexperienced at overall design management,
2) Design itself consists of a set of 'wicked' problems which cannot necessarily be solved in an easily predictable time schedule.
3) Design activities are split and carried out by specialist offices whose outputs are interdependent. This results in design work having to be re-performed in the light of other offices' design outputs as directed by the overall design co-ordinator.

Interrelationship of decision actors in the construction planning process

Up to detailed design stage the client and the consultants negotiate both with each other and also with the local planning authority to arrive at an acceptable design. In this activity local planning authorities have to take note of objections by its own officers, the public and adjoining property owners at both outline and detailed planning application stage.

At the construction planning stage there is a number of decision actors. This makes the planner's negotiating skills all-important. Although package contractors do not decide whether or not to tender for part of the works at the *principal contractor's* pre-tender stage, if principal contractor planners do not have the tacit support of their supply chain at this stage (or confidence that such support will be forthcoming) then they are running a considerable risk.

There are further problems in negotiating with the 'constrainer' category of actors. If planning applications have been passed against the advice of local authority employees or in the teeth of strong objections by neighbouring owners then subsequent negotiations with these actors at the construction programme planning stage (Figure 6) may be all the more difficult.

The construction planning process

Process / job goals

Figure 7 suggests a scheme of goals which the planners have to fulfil in carrying out the planning process in the context of their job. The short-term goals of producing tender documentation and risk assessments are self-evident. The medium-term goals are perhaps less so. A planner performs the process of planning many times. Many of the actors who participate in one plan will also participate in others. Over time the planner has to either (at best) build up a good working relationship or (at worst) establish some form of peaceful co-existence with these other actors. Similarly over time planners must develop their own skills as well as those of their colleagues in order both to improve the competitive advantage of themselves as employees and the planning team in effectively carrying out the planning process.

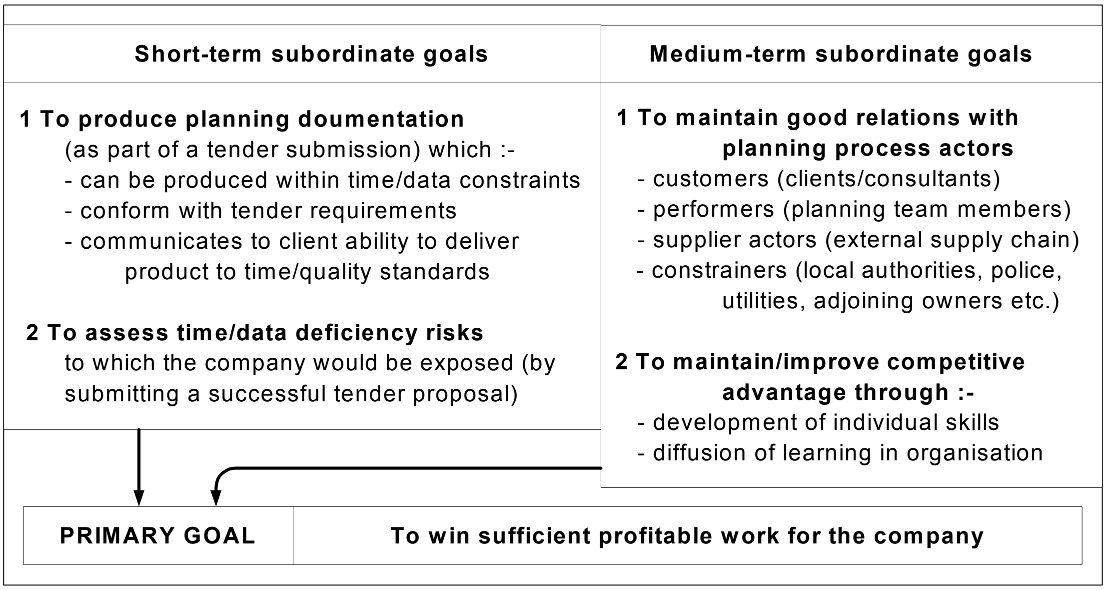

Figure 7 – Pre-tender construction as part of job goals

Generic process design and management

Figure 8 suggests a generic planning framework. Laufer and Tucker (1987) themselves state that the weakest stages of the planning process are in the planning cycle rather than the project cycle. In other words the planning of planning and the evaluation of the planning process suffer over time in subordination to the immediate needs of the current project plan being undertaken.

The speed at which planning has to be undertaken means that the process tends to plan itself by default. In view of the constraints which planners face this is understandable.

However it was clear from the interviews that a systematic review of project planning (and project review in general) was either rare or non-existent. A significant number of interviewees said that they did not tend to refer to past job records as they were either non-existent or inadequate. Project feedback does, of course, occur (negative feedback in particular). However, without systematic feedback it is not clear how learning and improvement of the planning process can take place at an organisational level. Total project review is necessary to establish the reasons for project execution shortcomings. However the actors most able to contribute to this process are those with the least motivation to expose their own errors.

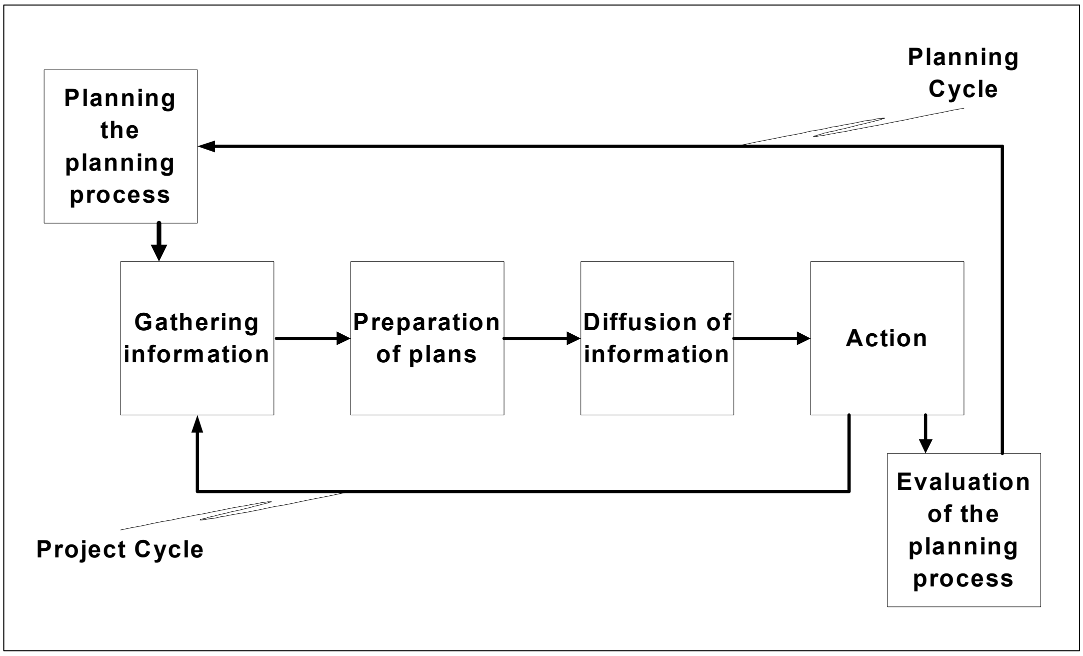

Figure 8 – Pre-tender construction planning – generic process – adapted from Laufer and Tucker (1987)

From tender documentation to Principal Contractor's tender plan

Figure 9 shows a conceptual logical network of planning activities. One important caveat needs to be borne in mind with this network. Experienced planners rarely carry out their analysis in the sequence shown. They will often carry out several steps simultaneously. This is often the case where they are planning a building of a type they have done already. They, therefore, frequently know quite a few of the 'answers' that each stage of analysis provides. The actual analysis (hopefully) validates their initial hunches. In addition they will often carry out several 'passes' through part or all of the network of activities.

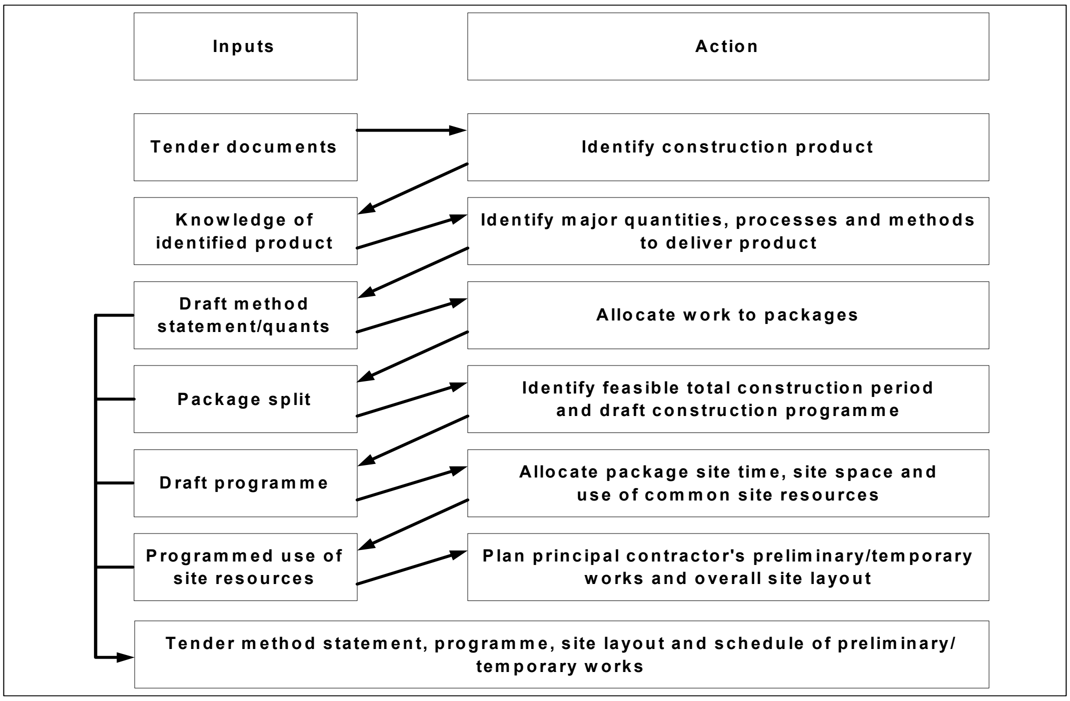

Figure 9 – Pre-tender construction planning sequence

Given the restricted time available to planners they have to set up negotiations and consultations with other actors at an early date. An initial judgement of the sort of problems they are likely to encounter allows them to do this. To enable tenders to be prepared and delivered on time, a set of default heuristics may have to be used to circumvent time-consuming passes through the activity network. Accordingly Figure 9 needs substantial further expansion and development in a further paper (as referred to in the Aims and Methods section above) to map the micro-structure of real-time planning activities within a constrained environment. This work is currently under way.

Actor	Data Sources	Product Identification	Methods/quantities	Work Package Split	Total Programme	Site resource allocation	Prelims/site layout
Planner	General construction knowledge	X					
	Procedural knowledge of construction processes		X	X		X	X
	Previous planning experience		X			X	X
	Site visit		X				X
	Experience of supply chain capacities and knowledge of package output times			X	X	X	
Operations Manager	Procedural knowledge of construction processes		X	X			X
	Experience of supply chain capacities			X			
Estimator	Knowledge of trade output rates				X	X	
Company	Previous job records		X	X			X
Client	Stated tender period				X		
Package Contractor	Required package periods, site space and use of common resources					X	
Constrainer	Internal policies and willingness to co-operate with principal contractor		X				X

Table 6 – Miscellaneous data input to the construction planning sequence

Table 6 attempts to show what tacit knowledge and other data (not arising directly from the planning process itself) each actor brings to each stage of construction planning as well as input from the previous stage (or other inputs such as previous job records held by the company). Table 7 attempts to show the major tasks involved in construction planning. The same caveat applies to Tables 6-7 as for Figure 9 above.

Construction Programme Planning Stage (Figures 6 and 9)	**Sub-stage**
Identify construction product	See Figure 10
Identify methods and major quantities	Identify product features and possible problem areas
	Identify site features and possible problem areas
	Identify major quantities of work to be performed
	Identify major construction processes and methods
	Negotiate with Police, planning/highway authorities and adjoining owners regarding accesses/deliveries/construction methods involving work/disruption/hazards outside the site
Works package split	Identify package split according to known supply chain capacities in order to ensure that package risks are owned by those most able to manage them
	Discuss with major potential package contractors
	Confirm package split
Overall construction Programme	Plan construction time without reference to stated tender construction period
	Compress construction time to stated tender period if possible
	Identify time risks posed by schedule compression
	Decide whether or not to recommend submission of non-conforming tender bid
Package Allocation - 1 time on site	Discuss package times allocated in draft programme with major potential package contractors
	Arrive at package times likely to be acceptable to package contractors (or equally tight for all)
	Revise draft programme accordingly
Package Allocation - 2 space on site	Determine plant movements, craneage, material deliveries, labour numbers and general work sequences
	Mark up plans with allocated work spaces for each week
	Discuss with package contractors and revise draft programme accordingly
Package Allocation – 3 common resources	Allocate (or change planned) site resources in discussion with package contractors/operations manager
Miscellaneous construction planning	Plan preliminary/temporary works and site layout

Table 7 – Task structure in construction planning sequence

Problems in identifying the product

Due to the design problems mentioned above the data received by the planner is frequently inadequate. Figure 10 shows the risk options which have to be chosen to deal with this problem. The above discussion on the design problem suggests that this may well be a continuing problem which has to be built into the planning process. However too much information can be as problematic as too little.

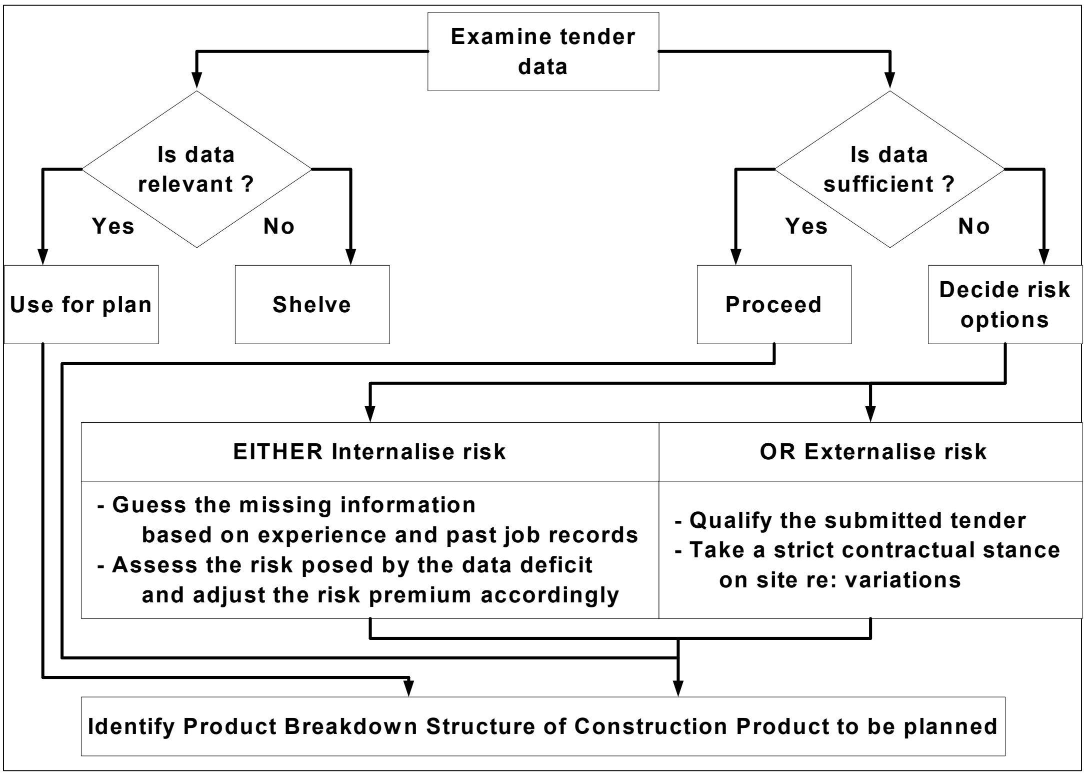

Figure 10 – Pre-tender construction planning – identifying the construction product

There is no formal physical output of this process as such but clearly there has to be some kind of Product Breakdown Structure created in the planner's mind before method/package planning can commence.

Identifying processes, methods and major quantities

Having identified a product breakdown structure the planner then proceeds to work out how to build it (usually in consultation with an experienced operations manager). Most proceed to undertake a site visit prior to method planning. Not everyone agrees with this. There are two points of view.

- The first says that if you plan the method before seeing the site conditions, then you will end up trying to adapt a possibly fundamentally inefficient method to the subsequently revealed site conditions instead of proceeding to an efficient solution with the maximum amount of data already available.

- The second says that if your mind is so coloured by the apparent problems posed by a difficult site you will see the site conditions as an insurmountable obstacle to employing the most efficient methods of construction.

Most planners favour the first approach.

Identifying packages

Interviewees were united in their approach to this (with a single exception). This view was that the packages should be split according to the known trade capacities of individual contractors.

The one dissenting voice on this aspect had three possible methods of approach.

1. Keep structural elements together,
2. Keep processes together which have to be carried out at the same time and at the same place,
3. Using either of the above, restrict packages according to the likely release dates of detailed design information - ie keep package variations to a minimum.

For example, working according to the second method on one job led this planner to combine the construction of an RC frame and the fixing of external rainwater goods into one package. Although it involved multiple trades, the package had common aspects of access and timing. It ensured all those doing the works understood the importance of inter-trade co-ordination.

The third method recognises the fundamental drawback of concurrent engineering, namely that variations cost more than identical works originally included in the contract. However the success of this method does depend on the design management being geared to releasing comprehensive design information for each part of the works in a buildable sequence.

One of the 'majority view' contractors did pose the problem of material warranty. On one contract where there was a large quantity of high performance steelwork in both the frame and the piling, he required the piling contractor to accept the steelworks contractor as a nominated supplier. This ensured that there was a single (material performance) warranty for the whole of the structural steelwork in the building.

There is a problem with the majority view package strategy. It is that if a contractor only ever packages work according to what *he believes* those contractors can do, while this may be a perfectly reasonable strategy for each contract, over time there is the risk that a possible avenue for process innovation will be shut off.

The second method effectively challenges contractors to think differently. In each package contract there is a general clause about co-ordinating work with other contractors. By combining trades in a single package it signals to the package contractors that certain areas of inter-trade co-ordination are critical.

Principal contractors' planners can only realistically plan down to the package level (broken down further into the main package components). It is package contractors' planners who have to turn these packages into a Work Breakdown Structure to yield a set of individual tasks.

Identifying total construction and allocated package times

Nearly all interviewees said that, having selected the construction method, they disregard the construction period stated in the tender and work out what time they think it ought to take to carry out the works. That is their 'optimal' period in the sense that it allows for the minimum but robust time buffers to cope with risks attached to critical packages. In nearly all cases this tends to be longer than the stated contract period in the tender documents. They then see what time they can trim off the 'optimal' period. This exercise helps them to evaluate the risks associated with attempting to construct the building within the time preferred by the client/consultant.

They often discuss this with estimators who have a knowledge of trade output rates. Although they will take note of this, many are sceptical about relying on such data. They prefer to use their own ‘feel’ for package times gained by experience.

Principal contractor planners do use critical path methods but their work is more in the nature of planning co-ordinators. They use critical path methods in a broad brush approach since they recognise that the people best placed to plan work in detail are the package contractors. In any case planning beyond a certain point yields negative marginal returns (Faniran, Love and Li 1999).

What is clear is that those interviewees who plan larger more complex projects over several months attach importance to their use of critical path methods. (The interviewees who preferred Primavera software to Power Project tended to make intensive use of critical path methods. These were used for higher value contracts as shown by Figure 4 above.) One of those is a package contractor so he has to plan in detail. The remainder recognise the limitations of the methods but point out that they have to allocate fairly the contract time between different package contractors and they have enough experience and understanding of task dependencies to develop a workable network model. This assists them in negotiating with the package contractors. It also helps them to understand where the greatest time-risk areas might lie.

They use conventional resource-levelling methods (through either re-scheduling and/or re-resourcing critical package plans or rescheduling non-critical ones) but often have to rely on their own resource estimates since they are frequently not forthcoming from some of the package contractors.

Virtually all planners said that they were not attempting to optimise the construction time but rather to get a realistic time which allowed a reasonable time buffer to take account of known risk areas. On the matter of flexibility they were more divided. Some pointed out that there comes a point where you have to close some options and then the cost of subsequent significant variations has to be claimed. Others expected to have a degree of flexibility or robustness (Rosenhead 1989) which would allow them to deal with a reasonable range of contingencies.

Most said that they would be prepared to 'walk away' from a contract (if the construction period stated in the tender was wholly unreasonable) by submission of a non-conforming bid. Most were prepared to submit a non-conforming bid if they felt that they could offer a lower price. A few would be prepared to submit a non-conforming bid at a *higher* price and a *shorter* construction period where they believed that time was of the essence to the client.

Allocating package space (over time)

The process of allocating package space over time is applied to solving three different broad types of spatial problem.

The first is that of 'open site' works involving demolition, piling, ground works, external services and substructure works. These involve large moving heavy plant which dominate the spatial analysis of work sequences. The problems are mainly two-dimensional with the exception of access ramp creation/removal sequences. The trick here is to minimise the number of working sequences (and associated set-up times) which each package has to carry out. Horizontal space buffers between packages are essential for both efficient working and safety. This sometimes necessitates some works (such as demolition or piling) being granted sole possession of the site.

The second is that of the building frame, cladding, roof and floor construction. There are some real three-dimensional problems here which require careful analysis to arrive at an efficient construction sequence. The main plant items involved are cranes and delivery vehicles (with scissor platforms, scaffolding and concrete pumps also playing a role). The trick here is to maintain a regular and balanced volume of work between the packages allowing them enough access to cranes, proximity storage (when required) and delivery space without transgressing the package dependency logic required by the construction sequence. A number of planners said that they prepared a 'material piece count' for this stage (and also for internal works) to check that their craneage and material hoisting capacity would be adequate at all times.

The occupation of scaffolding is often a vexed issue as is the issue of scaffolding itself. Several planners were less than complimentary about scaffolding contractors. The problem is that it is always subject to considerable variation and keeping scaffolding costs down on site is extremely difficult. Where possible planners choose methods that minimise scaffolding including the French system of access platforms built-in to the formwork (for RC frames). Where the building occupies the whole of the site, scaffolding is required simply to protect the public. So this is a problem that will remain.

The third type of problem is that of the internal components, finishes and services. The problems here are mainly related to material delivery/storage and working space for trade labour. Most planners prepare and use work location sequence diagrams for this area of spatial planning. Generally they like to keep trades apart from each other on different floors although inevitably this is not always possible. More than one planner said that they specifically used sequence plans for risk assessment.

If one compares spatial occupation planning with time planning it is easy to see that a prudent planner will allow 'float' between trades in space as well as time. One planner referred specifically to 'space buffers between trades'. He liked to have one empty floor between trades available for overspill proximity storage (or a temporary staging area for whenever the material delivery programme departed from the plan). Floor screeds are a problem area as they sterilise a whole floor for some time after the work is complete.

On sites with confined access it can be difficult to deliver materials and remove waste simultaneously. So one planner plans for material deliveries during the day and waste removal at night. Another planner complained that disposing of the packaging of delivered materials was now a bigger headache than actual building waste.

The planners were split on the issue of preparing material delivery schedules partly because the relevant information (involving the package contractors' supply chain) may not readily be available for those doing pre-tender planning in a few weeks.

Several mentioned the problem of using staircases for construction labour access to higher floors. One said that a minimum of three was preferred (one for access use by construction labour, one for backup access and one sealed off after completion of damage-prone works to the staircase itself).

There was more or less a unanimous view on siting hoists. This was a function of low-level access, high-level traffic minimisation and the use of future spaces within the finished building (lift shaft, atrium, reception area etc). The number of hoists usually followed a rule of thumb but most planners did check by other means that this was adequate. The location of the WC's was also an important factor!

Allocating package usage of common site resources

Having allocated package space over time, the planner can then calculate and allocate required site resources. The table suggests some basic factors which the planner will take into account in deciding upon these. Often, though, it is a matter of experience where a planner will (initially at least) say for example, ‘on a job this size, I know I will need two passenger/goods hoists and one material hoist.’ He may use subsequent analysis to test that opinion but more often than not experience will prove correct.

Planning the principal contractor’s own packages – prelims/temporary works

Having calculated and allocated required site resources, the planner can then specify and plan the works the principal contractor has to do to support the package contractors in terms of site infrastructure, support facilities and supervisory works. Where temporary works are required, it is important to identify these at an early stage, as design of these will typically be part of the principal contractor’s responsibilities.

Determining site layout and external space requirements

Finally, all of the foregoing plans have to be integrated within a general site layout, which can be sustained with minimal change during the construction period. Some of these problems are sorted out by the work phase analysis (such as the siting of hoists above)

There are very few 'green field' sites as a proportion of a contractor's work. Even for new build work there is generally some demolition work to be done first. Because of past problems with squatters, rates on empty properties and safety hazards posed by derelict buildings, building owners often have this work done first under a separate contract. This is understandable but can sometimes have unfortunate results. The demolition work will often involve providing temporary support to neighbouring structures. The demolition (or temporary works) contractor will generally use the cheapest method (such as raking shores) which may cause spatial problems for subsequent works.

This sometimes means that one of the first problems that the principal contractor has is to work out what works of the previous contractor have to be undone and replaced by more spatially efficient temporary works (often in consultation with the piling and earthworks contractors).

Barring the above problem the first main problem that nearly all planners mentioned was the external environment of the site. Existing and potential access points as well as possible approach routes have to be thought out (trying where possible to avoid residential streets and schools). Delicate negotiations with local authorities and police may have to take place.

Where the footprint of a building occupies the whole of a site, steel and cladding may have to be lifted into position directly off a truck parked on a public highway and/or pavement. This may entail the temporary closure of a road and/or street parking facilities. Site welfare facilities may have to be located on a gantry outside the site.

Both at and above ground level the site may be constrained by the presence of neighbouring buildings. In addition the need to use plant which overswings adjacent sites has to be negotiated beforehand with the relevant owners or authorities. Nearby overhead power lines also present a particularly hazardous constraint.

Crane bases are the priority item for external space. With a 1:1 footprint to site ratio, the planner will look for a climbing crane using either a lift shaft or atrium area inside the building. Where there are several cranes the erection sequence and interdependence is important. The planner will have to decide whether the first crane (erected by mobile crane) will be used to erect the next one, or, whether the cranes are to be erected independently.

Storage is generally kept to a minimum relying on just-in-time deliveries. Off-site warehouses near motorways are used to keep sites supplied. Readymix concrete delivery is almost always used. On one large contract (not in a city centre) a *supplier* put a temporary store on the site and issued one week's materials at a time (to each gang). This was the result of a partnered arrangement for supplying all materials for that contract.

Site offices are last on the list and some local authorities (eg Westminster) do not allow them. They have to be found in short-life leases in local offices.

Summary

Construction Planners add value for the contracting organisation by ensuring that estimating and tendering are based on a robust understanding of the methods, time and space required to carry out the tasks for each building contract and the corresponding risks involved.

They have to perform both planning and other work in a time- and information-constrained environment which requires considerable use of heuristics based on judgement and experience-based learning. Negotiation and communication is important in their work and for this reason many of the processes and task interdependencies in their work are iterative. Their longer-term objectives have to take account of potential long-term relationships with operational management colleagues and representatives of other organisations with whom they have to negotiate.

Pre-tender construction planning has to be understood within a framework which includes design and procurement planning. It is a high-level planning activity, which has to incorporate the many lower level plans of package contractors. It involves as much co-ordination of planning as direct planning although re-performance of lower-level planning may be required to confirm the robustness of the higher-level plan.

Spatial planning is an integral part of this process and is particularly problematic when construction processes have to occupy space outside the site, close to the site boundaries or internally where rapid trade sequences run the risk of congestion. Minimising necessary storage space and lifting plant required for vertical material movement by good material supply chain management and co-ordination (where possible) of package contractors' material delivery plans is also an important part of the work.

Specialist package contractors

Now we turn to two types of specialist package contractor selected by the VIRCON project for investigation – piling and M&E services contractors. Aspects of the planning work of these contractors will now be considered.

Piling Planning – a difficult package

It is useful to discuss piling at this point since this work has special spatial problems which have *temporal* consequences for principal contractors.

For the piling package contractor's planners, the key variables are the breakdown of the works into the main sections of work and the consideration of the existing ground conditions, nearby structures and buried services. The groundworks design will define the materials to be used - essentially then the problem is then the selection of an appropriate plant team to make space for, carry out pre-placement processes on, deliver, place and carry out post-placement processes to the relevant materials. Essentially it is a limited set of tasks carried out at a particular stage of the building process, albeit in sometimes very difficult conditions.

All the piling planners said that some principal contractor planners failed to understand the nature of piling and the space needed to execute it. The result was that some packages could not be constructed in the time allocation (from the total main contract period) which had been allowed by the principal contractor. They might attempt to re-negotiate the period with the principal contractor. If negotiations were unsuccessful, they were prepared to walk away from a job and cited examples where they had done so.

These planners allowed float in their tender period plans. There was an explicit float period disclosed in the tender submission as a protection against late completion. There was a further undisclosed risk float allowed against unexpected ground conditions, productivity risk, weather and adverse behaviour by other package contractors carrying out concurrent works. Since the information on ground conditions was often deficient and the behaviour of other contractors were outside their control they felt this justifiable.

However the total float was not necessarily proportional to the total package contract period - indeed quite the reverse. On a 15 week contract they might allow a 1 week float on the grounds that the period was long enough to allow 'catch-up' time in the event of problems. On a 2 week contract, however, they might allow a 2 week float because otherwise there was no time to correct any initial problems.

Planners' steps for piling site layout and dynamic spatial planning

1. Look at existing site accesses/levels, proposed access ramps, finished ground levels and pile capping levels. It may be that (for planning purposes) the site has to be treated as several mini-sites.
2. Look at size, shape and footprint:site ratio.

3. Look at grouping of piles.
4. Note problems of piles near site boundary (in some cases this will require going back to the contractor/designer and telling them to move some piles).
5. Look at Principal Contractor's programme and working sequence (if known) of precedent contractors (demolition), co-contractors (earthworks) and follow-on contractors (substructure).
6. Populate plan with scale models (paper cutouts) of plant.
7. Allow working area for plant. Develop sequence of dynamic plant paths which maintain continuous access to 2-3 positions simultaneously. This allows continuous and simultaneous execution of drilling/spoil removal and steel/concrete placement.
8. Decide whether the site area allows for on-site steel cage fabrication (preferred for greater control) or whether off-site fabrication is required.
9. Allow pedestrian working area (to avoid banksmen being trapped between plant and walls/boundaries).
10. Ensure adequate spoil exit and steel/concrete supply paths.
11. Calculate concrete quantities to get the total number of truckmixers on site at any one time (which are sometimes the constraint - not the piling rigs).
12. Essentially, on a tight site, the piling contractor has a moving site layout. The principle is to maximise space so as to minimise moves (and in particular minimising access ramp creation/removal).
13. Do sequential site diagrams to show site area 'sterilised' by works.

Implications of piling planning for principal contractors

Reading the above one cannot fail to be impressed by the critical nature of site space in a piling contractor's work. The failure by principal contractors to appreciate this has already been mentioned. However the spatially hungry nature of piling work makes it an absolutely critical item in principal contractor planning. Moreover it occurs almost right at the beginning of the works.

The piling planners generally have to work faster than their 'natural' productivity rates. By this is meant the maximum amount of work a piling contractor can do on a particular site without experiencing spatial congestion (leading to loss of productivity). They tend to have to work at below optimal construction time (and therefore at above minimum cost). While this may be due to ignorance by principal contractor planners there may be another factor at work. The dominant and early position of piling on the overall critical path is such that a principal contractor really cannot afford to get the piling duration wrong as it potentially holds up nearly every other package on the job.

There has to be a suspicion that some principal contractors are deliberately attempting to accelerate the piling process (at a recognised additional cost) in order to 'buy' time-risk insurance for the remainder of the packages. Given the number and uncertainty surrounding the remaining packages this would be entirely understandable. If principal contractors are attempting to buy ‘time insurance’ it might be an expensive method if the float allowed by the piling contractor is *inversely* proportional to the length of the piling package contract.

Given that this is the practice of at least some piling contractors it would be interesting to know the bases for calculating float used by other package contractors and how this affects the length of the principal contract.

M&E planning

From the M&E services planner viewpoint service works are carried out at virtually all stages of the construction process. The process can be described in five stages:

1. the (mainly) horizontal connection of services (at ground and underground level) from the external distribution system to the building,
2. the vertical distribution of services to all floors in the building,
3. the (mainly) horizontal distribution of those services throughout each floor as required,
4. the installation of pieces of equipment throughout (and outside) the building,
5. the testing and commissioning of all service systems.

The services planner has two fundamental tasks:

1. to break down the package into sub-packages,
2. to break down each of the sub-packages into the five stages above.

The planner then has to identify the common and/or co-ordinated tasks and which aspects of those sub-packages can be re-combined (as a set of tasks) at each of the five stages. (An example would be the installation of service riser supports, pipes and cables.)

For spatial planning purposes the M&E planner did extensive post-tender research with contractors carrying out precedent/concurrent works to discover when certain blocks (or nodes) on each floor could be occupied by service contractors. His view was that as long as he had possession of these areas (mainly service riser areas and machine rooms) he was prepared to work round whatever else was going on in the rest of that floor.

The output of services contractors can be large but much of it is small. Whatever the size it is vulnerable to damage. Most service contractors' output has to be attached to the work of other contractors. This means that the services contractors must interact far more with other contractors. The planning of the work involves a much more detailed understanding of other contractors' work. This involves not only understanding what tasks are precedent to and concurrent with their installation work but (perhaps even more important) what works happen afterwards (including their own).

Summary

Package contractors' planners like their counterparts working for principal contractors face a time- and information-constrained environment. In particular planning is made more difficult by their lack of knowledge of those likely to be employed to carry out precedent or concurrent tasks. Potential task time variability can therefore be greater as a proportion of the time allocated for the package contract than it is for the principal contractor who may be able to regain lost time by acceleration of subsequent packages.

The space and time required for specialist package operations is not always well understood either by principal contractors or designers. This can result in a difficult set of communication and negotiation tasks. In addition, package contractors performing precedent and concurrent tasks may be less than co-operative if the only incentives open to them relate solely to the completion of their own package.

The tendency of groundworks to ‘sterilise’ the entire site and the involvement of piling contractors early in the construction process leads principal contractors to bring pressure on them for early completion. This can often result in the piling contractor having to work under sub-optimal conditions of time, space or both. While the piling contractor may charge extra to compensate it still renders the planning of such works a difficult process.

Planning for package contractors is at a low and detailed level. However, M&E planners may also have to deal with several subcontractors and specialist material suppliers for which they need the higher-level planning skills of principal contractors’ planners. This is all the more so given that M&E works occur at all stages of the construction process.

A highly flexible planning approach is understandable from the viewpoint of an individual M & E package contractor who is not receiving ‘quality assignments’ (Ballard and Howell 1998) in terms of adequate spatial planning of precedent and concurrent trades by the principal contractor. The fact that this planning work has to be done after the award of the package contract poses an additional risk for the package contractor.

Process output, its diffusion, and missing tools

Method Statement and Programme

The method statement is a statement by experts for experts and therefore its communicative power to lay clients should not be a problem. However even in this document communicating aspects of ‘buildability’ to other experts can be difficult. It is normal for 2D ‘static’ plans to be part of the method statement to illustrate such problems – however they are limited in conveying 3D or dynamic spatial problems. Some planners, therefore, see potential in some form of computer-based visualisation aid as a useful addition to their communication toolbox.

The most common form of programme presentation is in the form of a bar chart. One planner pointed out that the wide use of such charts inside and outside the industry hides the fact that not everyone understands them. Therefore for a few clients he has expanded the presentation to include plans with marked dates showing expected stage completions. This is clearly another area where a dynamic visual presentation tool would be useful.

Other outputs – risk assessment, critical path analyses and work phase plans

Although a significant proportion of planners prepare these documents, nearly all are for internal consumption only. A number of planners mentioned the need for clear communication – in particular to their directors who have to take responsibility for the risks associated with each contract. Methods of carrying out and presenting risk assessments are too diverse to be discussed here. Critical path presentation is well established. They also complained that work phase location plans could be very tedious to prepare for a substantial multi-storey building. An additional tool, which would allow planners to prepare and (more importantly) change such plans, would be highly valuable for their hard-pressed time.

The communication of intermediate process outputs

Although the foregoing can be viewed as final planning outputs, presentation of intermediate stage outputs are important too. Some planners mentioned the need, for example, to reassure neighbouring owners about the proposed construction processes or to demonstrate the need for cranes to overswing adjoining property. Similarly, demonstrating problems to police and local authorities where the contractor requires on-street loading or the presence of gantry-mounted cabins can also be difficult without some form of visualisation tool.

Conclusions and recommendations

Conclusions

1. Most pre-construction planners are not paid to plan - they are paid to work in a team which prepares tender-winning submissions. This involves planning but considerably more besides.

2. The time and information constraints under which they work must, in a number of cases, compromise the quality of their output. They are sometimes forced to make semi-generic plans based on guesswork and experience. That many of these plans work at all is a tribute to their skill but raises questions about the sub-optimal nature of the process.

3. The planning process is a highly distributed one co-ordinated by planners. This requires them to be good negotiators, communicators (and listeners) as well as efficient information managers.

4. Planners have not only to understand construction technology but also the practical and political aspects of site management and operations - particularly in relation to the management and co-ordination of package contractors.

5. Planners have to understand the procurement process, supply chain management and its integration with site operations planning. They also have to understand the critical nature of the timing of design information flows.

6. The large number and variable nature of package contractors lead planners to be cautious about temporal planning. Each package on or near the critical path represents a time risk to the whole project. Accordingly a price has to be paid by the building owner where contractors tendering for each job either:

    - allow a substantial float in the construction period or
    - add a substantial risk premium to their tender price to offset the risk of damages for delayed completion

7. While explicit spatial planning has not figured largely in construction literature it is clearly an area to which planners attach great practical importance.

8. Most spatial planning uses heuristic methods based on experience. However some more structured and systematic examples can be found in sequenced work area allocation and in the planned management of movements of labour and materials.

9. Although planners learn considerably over time and make great use of experience in their planning work, they are still capable of surprise in

arriving at construction solutions - particularly spatially problematic ones.

10. There is enthusiastic support for the idea of a computer-based visualisation tool for communication and training. There is more mixed support for a decision support tool for solving planning problems and that mainly for large-scale, complex projects.

Recommendations

1. There are a number of clear instances of design information being produced, which displays a lack of understanding of the space required for construction processes (M&E works in particular). Consideration should be given to bringing contractors' planners into the design management process at an earlier stage than at present. This may result in additional salary costs, which will ultimately have to be passed on to the client. However an early inclusion of a contractor's planner may prove beneficial in the longer term.

2. Clients have the right to try and minimise the overall project period (including construction). However their attention needs to be drawn to all of the risks (including spatial congestion) involved in any consequential reduction of the construction period. They will then be in a better position to take an informed decision as to whether the time profile of project-generated net revenues justifies taking on such risks.

A decision-support tool for dynamic spatial construction planning would clearly be useful in implementing both of the above recommendations.

Areas for further research

1. The ongoing research into a computer-based visualisation tool should continue as clearly there is support for this although perhaps not entirely in the form that it was envisaged.

2. Some of the on-site planning research work carried out in the US could be tested to see if it was applicable to UK conditions. This would specifically involve observing spatial conflicts and/or seeing what prior planning might have averted them.

3. One obvious research question is how well can pre-construction planners' weekly work phase location plans be implemented on the site. Project review studies comparing pre-construction plans and actual performance might be instructive. In addition the frequent failure of the pre-construction plan to have greater influence on site planning (Egbu et al 1998) needs to be investigated more thoroughly.

References

Alshawi M and Hassan Z (1999) Integrated models for construction planning: object flow and relationship *Engineering Construction and Architectural Management* **6**

Ballard G and Howell G (1998) Shielding production: essential step in production control *Journal of Construction Engineering and Management* **124**

Burch T (1985) Planning and organisational problems associated with confined sites in CIOB *The Practice of Site Management* Vol 3, Ascot, CIOB

Choo H J and Tommelein I D (1999) Space scheduling using flow analysis *International Group for Lean Construction, Proceedings of the Seventh Conference* Berkeley, CA

Choo H J and Tommelein I D (2000) WorkMovePlan: database for distributed planning and coordination *International Group for Lean Construction, Proceedings of the Eighth Conference* Brighton, UK

Choo H J, Tommelein I D, Ballard G and Zabelle T R (1999) Workplan: constraint-based database for work package scheduling *Journal of Construction Engineering and Management* **125**

Egbu C O, Young B A and Torrance V B (1998) Planning and control process and techniques for refurbishment management *Construction Management and Economics* **16**

Faniran O O, Love P E D and Li H (1999) Optimal allocation of construction planning resources *Journal of Construction Engineering and Management* **125** No 5

Laufer A (1992) A micro view of the project planning process *Construction Management and Economics* **10**

Laufer A, Howell G A and Rosenfeld Y (1992) Three modes of short-term construction planning *Construction Management and Economics* **10**

Laufer A and Tucker R L (1987) Is construction project planning really doing its job? A critical examination of focus, role and process *Construction Management and Economics* **5**

Laufer A and Tucker R L (1988) Competence and timing dilemma in construction planning *Construction Management and Economics* **5**

Laufer A, Tucker R L, Shapira A and Shenhar A J (1994) The multiplicity concept in construction project planning *Construction Management and Economics* **11**

Mayer R E (1992) *Thinking, problem solving, cognition* (Second Edition) New York, W H Freeman

Riley D R and Sanvido V E (1995) Patterns of construction use in multi-story buildings *Journal of Construction Engineering and Management* **121** No 4

Riley D R and Sanvido V E (1997) Space planning method for multi-story building construction *Journal of Construction Engineering and Management* **123** No 2

Rosenhead J (1989) Robustness analysis: keeping your options open in Rosenhead J Ed *Rational Analysis for a problematic world* Chichester, John Wiley

Rummler G A and Brache A P (1995) *Improving Performance: How to Manage the White Space on the Organization Chart* San Francisco, Jossey-Bass

Thabet W Y and Beliveau Y J (1994) Modeling work space to schedule repetitive floors in multi-story buildings *Journal of Construction Engineering and Management* **120** No 1

Thomas H R Jnr and Smith G R (1990) *Loss of construction labor productivity due to inefficiencies and disruptions: the weight of expert opinion* PTI Report No 9019 Pennsylvania Transportation Institute, Pennsylvania State University

Zouein P P and Tommelein I D (1999) Dynamic layout planning using a hybrid incremental solution method *Journal of Construction Engineering and Management* **125** No 6

University of Wolverhampton (2001a) *The virtual construction site: technology opportunities and potential Volume 1: Emerging research initiatives.* Unpublished report.

University of Wolverhampton (2001b) *The virtual construction site: technology opportunities and potential Volume 2: Project planning software* Unpublished report.

Appendix

Background of interviewees

This section gives some basic age, employer, experience and educational data of those interviewed.

Age Profile	
25-29	2
30-34	3
35-39	1
40-44	4
45-49	4
50-54	3
55-59	1
Total	18

Table A1

Years of Planning Experience	
5- 9	4
10-14	2
15-19	4
20-24	4
25-29	2
30-34	1
35-39	1
Total	18

Table A2

Type of Employer	
Construction Manager	1
Management Contractor	13
Package Contractor	4
Total	18

Table A3

Formal Educational Attainment						
Firm Type	**Total**	**A Level**	**HNC**	**HND**	**BSc**	**MSc**
Constn Mgr/Mgmt Contractor	14	1	6	6		1
Package Contractor	4				3	1
Total	**18**	**1**	**2**	**6**	**3**	**2**

Table A4

The typical planner in this group is therefore in their 40's with around 20 years experience and educated to HNC/HND level.

It is interesting to note that the package contractors appear to be better educated than the principal contractors. However, as mentioned above, the sample is hardly an unbiased one and furthermore the type of package contractors (piling/M&E services) are those of a specialist nature requiring substantial technical knowledge.

There was no particular relationship between age and educational attainment. All the package contractor planners had several years of site experience. In the case of the principal contractor planners it was mainly the older ones who had such experience.

£10.00

Paper number 15

Bartlett Research Papers ISSN 1352-2507