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The right place at the right time: assisting spatio-temporal planning in construction

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ABSTRACT

This paper describes research carried out for requirements capture in the development of a computer-based decision support tool (VIRCON) for space-time scheduling and visualisation of construction tasks. The focus was on pre-tender work and involved interviews with construction planners. Both space-time scheduling and visualisation of tasks are largely informal/intuitive processes for planners. They form an important part of the planner's risk identification function. Planners tend to opt for a robust spatio-temporal schedule rather than an optimal one. They require decision support tools that are quick and easy to use rather than highly sophisticated. The research highlights the extent to which construction planning is a communicative and co-operative activity in addition to a complex problem-solving one. Questions arise about the cost to the client of non-involvement by the construction planner at the design stage, the costs of short pre-tender periods, inadequate design data and sub-optimal construction periods specified in tender documents.

Keywords: Communications, decision support tools, pre-tender planning, risk identification, space-time scheduling, task visualisation

INTRODUCTION

This research came about as a result of a collaborative project (2000-2003) between University College London (UCL), Wolverhampton University and Teesside University aimed at creating a tool to assist construction planners in spatio-temporal planning and in visualisation of construction tasks. The tool is called the Virtual Construction Site (VIRCON) and, for the avoidance of doubt, is completely separate from another tool created under the same name and described in Jaafari *et al.* (2001).

The aim of this part of the research was to establish the requirements for such a tool from construction planners working for leading contractors. A strong emphasis was placed on understanding the day-to-day practicalities of the planner's work and the context in which such a tool might be used. A much fuller description of this part of the work is given in Kelsey et al. (2001) and Winch and Kelsey (2003). A description of the tool as developed is given in Winch *et al*. (2003) Subsequent development of spatio-temporal planning concepts is given in Winch and North (2003).

The paper will concentrate on those findings related to the planner's work situation supplemented (in the findings) with some of their views on the planning process. (A detailed account of the planning process has been omitted for space reasons.)

OBJECTIVE OF THIS RESEARCH TASK

The research aimed to understand how construction planners:

- view their own work in general,
- 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) and the overall management of the movement of plant, people and materials,
- use computer-based decision support tools,
- think that better tools (involving a visualisation capacity) could assist them in spatial (and other) aspects of their planning work.

The answers to the above formed the requirements capture for the decision support software being developed as part of the VIRCON project.

The research concentrated 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.

METHODOLOGY

The field research was carried out by conducting interviews with eighteen UK planners drawn mainly from major general contractors with a few from specialist piling and M&E contractors. The interviews were semi-structured to allow planners to talk about aspects of planning that particularly concerned them and for 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 useful because 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.

RECENT RESEARCH

Recent literature reviews can be found in Winch and North (2003) and Heesom and Mahdjoubi (2002). Some relevant points (at the time the research was carried out) in Kelsey *et al*. (2001) were as follows:

- Organisation and management of the planning process as a whole is in need of considerable improvement (Laufer and Tucker 1987, Laufer et al. 1994)
- The acquisition of communication skills are an essential part of planners' training (Laufer and Tucker 1987,1988).
- There is a potential tension between planning and operations management (Laufer 1992) 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 (Thomas and Smith 1990, Burch 1985).

- Several conceptual models of spatial planning have been developed, which provide a useful framework in which to build a decision support tool for dynamic spatial construction planning (Thabet and Beliveau 1994, Riley and Sanvido 1995 and 1997). Models based on heuristics (Choo and Tommelein 1999) are also of interest to the extent that they 'work' and/or reflect the actual thought processes of planners.
- The inclusion of construction process space as a resource in a resource-constrained planning model is essential to improve on the traditional CPM approach (Goldratt 1997 deals with resource-constrained scheduling without being construction-specific.) In a wider context there is a need accept the limitations of CPM (Faniran *et al*. 1999) and broaden the range of criteria (and therefore precedent task completions and resource availabilities) required to execute each site task. (The fulfilment of all precedent conditions and refusal to proceed without such fulfilment provides those executing construction works with 'quality tasks' – see Ballard and Howell 1998).
- To be of significant use in the UK site level planning tools developed in the US require the co-operation of all actors (Laufer *et al*. 1992) in the typically fragmented construction coalition found here.
- Better methods for assembling, processing and distributing planning information are required and can be developed (Alshawi and Hassan 1999, Choo and Tommelein 1999, Choo *et al*. 2000)

As far as coverage is concerned we found that:
i) The project-level planning work of the planner is better covered than the long-term and organisational context in which he/she works.
ii) Site level planning is better covered than pre-construction planning.
iii) Site layout planning (e.g. Zouein and Tommelein 1999) is better covered than dynamic spatial planning of construction processes.

WHAT PLANNERS DO

This section describes some of the work of the planner as revealed in the interviews conducted between July and December 2000 with 18 planners (1 from a construction management company, 13 from general contractors and 4 from specialist contractors). Their age and experience is set out in Tables 1 and 2.

Age and experience

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 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.

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 1	

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 2	

Planning 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 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.

<u>What do planners deliver at tender stage?</u>

Table 3 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.

Construction planners' deliverable output

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 3

Learning, decisions and decision support tools used or desired

Table 4 indicates what domain specific knowledge planners think they have acquired which enables them to solve planning problems better than inexperienced planners.

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.

Experienced-based learning outcomes

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 4

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.

Figure 1 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 Heesom and Mahdjoubi (2002).

Decision support tools used by construction planners

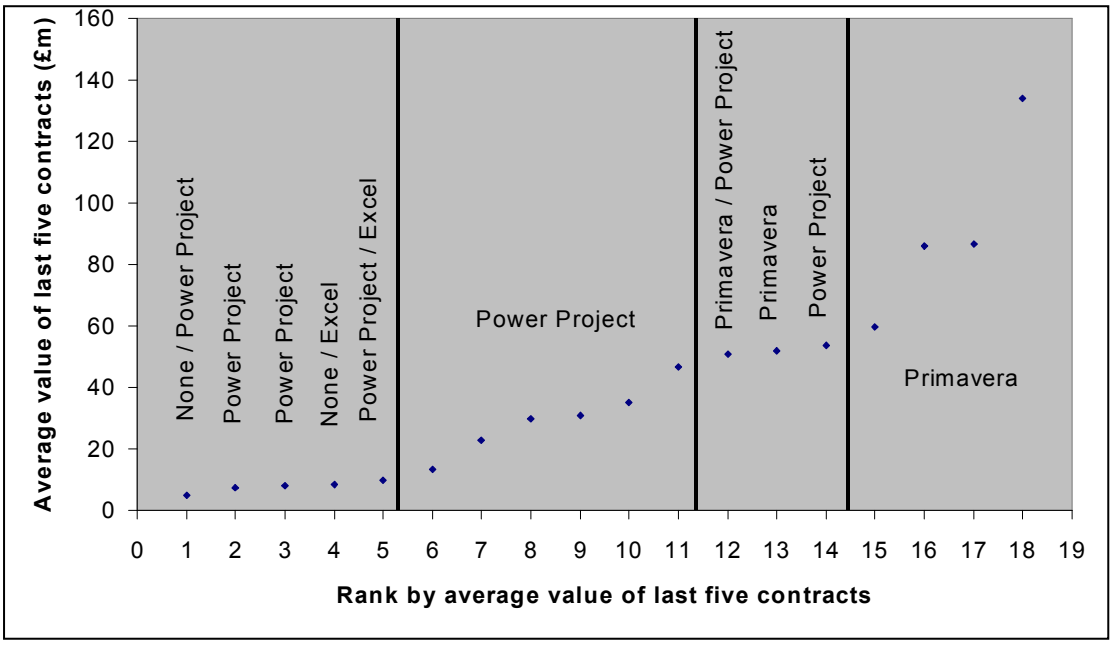

Figure 1

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.

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 2.

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.

Pre-tender Construction Planning as part of organisation goals

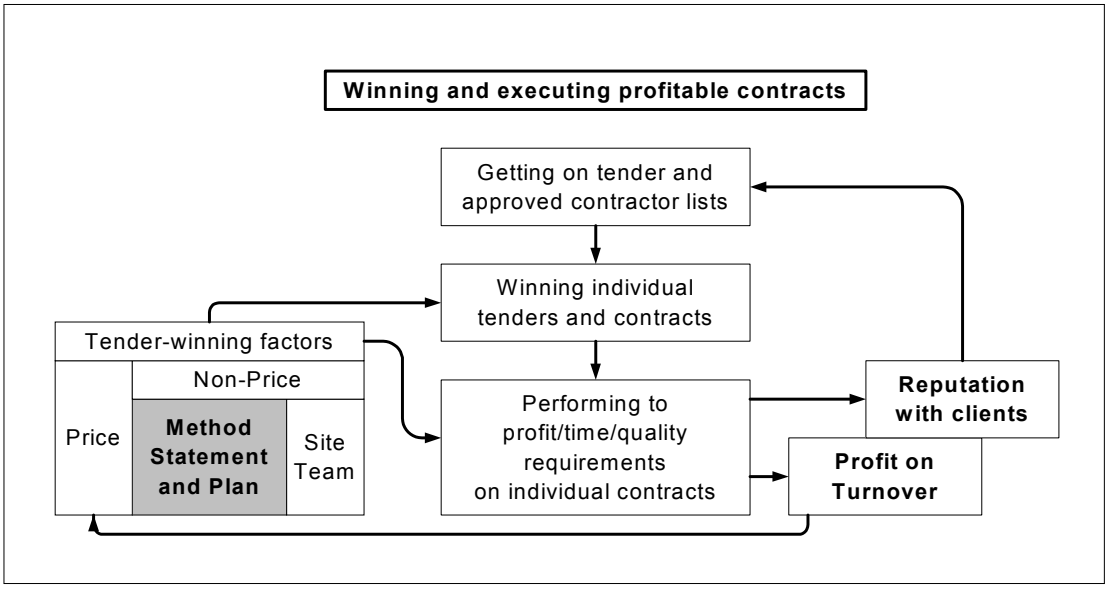

Figure 2

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. The job design however clearly includes a number of other tasks that are not pure construction planning as such (Table 5).

Direct Construction Planning	**Other Direct Planning**
Pre-tender construction planning Post-tender pre-execution 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 5 – Construction planning as part of a planner's job design

For planners 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.

CONCLUSIONS (INCLUDING ADDITIONAL VIEWS BY PLANNERS OF THE PLANNING PROCESS)

1. Most pre-construction planners are not paid to plan - they are paid to work in a team which prepares tender-winning submissions (with estimators and site managers). 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 to understand a) construction technology, b) the practical and political aspects of site management and operations - particularly in relation to the management and co-ordination of package contractors, c) procurement processes, supply chain management and their integration with site operations planning, d) the critical nature of the timing of design data flows.
5. 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.
6. 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.
7. While explicit spatial planning has not figured largely in construction literature it is clearly an area to which planners attach great practical importance. 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.
8. 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 and piling works in particular).
9. Clients have the right to try and minimise the overall project period (including construction). However planners need to draw their attention to <u>all</u> 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.
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.
11. Any such tool, however, needs to be flexible, bolt on to existing contractor's systems and be compatible with Architect's systems (e.g. AutoCAD). It also

needs to require as little manual input as possible and allow efficient use of planner's time.

NOTE

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