The applicability of project management software and advanced IT techniques in construction delays mitigation

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The aim of this paper is to identify the techniques which are used in the construction industry for monitoring and minimising the effects of delays and to establish how these techniques could make use of both the current computer technology and advanced IT tools, such as knowledge-based expert systems (KBESs) and visualisation techniques. First, the techniques identified are briefly presented. They are as-built method, time impact analysis method, and as-planned method. The paper describes a study of the software packages that was carried out as a product survey, with material being sourced from 33 software vendors. The software packages evaluated are presented under three basic criteria: general characteristics; technical features; and specialist features. General characteristics consist of the name of the system and the name and address of its vendor. The technical features consist of an analysis of the standard features which apply to commercially available project management software. Specialist features consist of an analysis of features which are applicable to delay management. Hardware and software requirements were reviewed to establish what is physically needed to operate the software package. KBESs and visualisation techniques in the field of project scheduling are also examined, with close attention being paid to systems which assist in the field of delay dispute resolution. Finally, the possible way forward is presented and demonstrated. Copyright © 1997 Elsevier Science Ltd and IPMA

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The society that we live in is experiencing an increase in the appointment of liability. This increase also manifests itself within the construction industry. Between 1973 and 1980 there was a 100% increase in construction-related litigation. It is widely held that with construction disputes, delay is the cause most often cited. In the past, delays in the completion of construction projects was an accepted condition in the construction industry. Today, with tight budgets on the part of the client, delays can become a very significant cost item. As a result, construction delays very often end up as construction claims (a recent survey by Bordoli and Baldwin found that 52% of UK construction projects end up with claims of some type).

Construction delays can occur due to a variety of reasons and can be caused by any participant concerned with a construction project. It is of the utmost importance that delays are properly classified when attempting to mitigate their effects or apportion liability. This is because the techniques employed vary with the circumstances surrounding the delay. In general, there are two main types of delay. These are:

- excusable,
- non-excusable.

Excusable delays may be further classified as 'compensable' or 'non-compensable'. It is also useful to identify those delays that are 'critical' and those which are 'non-critical'. Time-based construction claims can have a disastrous effect on construction projects. A cursory examination of
past claims points to severe financial consequences particularly on the part of the claimant, claims have also been known to destroy the viability of the entire undertaking for the client. It is for these reasons that effective control systems should be used to obviate, or minimise, the effects of time-based delays and their resulting disputes before the full blown claim situation is reached.

The control systems that should be used to obviate or mitigate time-based claims are already widely used by project managers in the construction industry. The primary control system used by project managers is the construction schedule.* Construction schedules, regardless of what form they take, are an important part of the management of the construction process. They provide the overall planning, monitoring and control mechanism by which the project team can ensure that the client’s objective is achieved. The importance of construction schedules takes on a particular significance when applied to the need to measure the effect of construction delays.5

At the most basic level, once a delay has been experienced and it has been established what type of delay is being dealt with, the construction schedule can be used to establish the length of the delay and its effect on the work remaining. By accurately establishing the effects of the delay in this manner the engineer and contractor can calculate the value of any required variation and the required length of extension of time, if any. In this instance the construction schedule can be used to minimise or obviate serious time-based disputes. There are a variety of ways in which a construction schedule can be presented. The more common types of construction schedule include: Gantt chart; activity on the arrow; precedence network; line of balance; and linear program. The use of any of these techniques depends on the nature of the project.

One of the more popular methods of measuring the length of a time-based dispute and its effect on the uncompleted work is by a network schedule. Bar charts, although an extremely useful, visual and graphical medium in construction scheduling, are less effective than network schedules in examining time-based construction disputes. Bar charts are a powerful communication tool, however, so they can play a significant part in demonstrating the results of a critical path analysis whether in a dispute situation or otherwise.

Schedules, which are based on networks, can assist in identifying the interrelationships among multiple causes of delay. This is important in cases where both the client and the contractor contribute to the project delay. In cases such as this, liability has to be identified so damages can be apportioned.

Construction schedules can play an important part in identifying, preparing, analysing or refuting delay claims because they can provide a precise medium for comparing and measuring time and meaning.

**Methods of analysis of delay-related claims**

There are a number of ways in which a construction programme or schedule can be used to identify, prepare, analyse or refute a time-based dispute or claim. The following methods are the most commonly used at the present time: as-built, time impact analysis, and as-planned.

The traditional method for determining the amount of delay is to compare the contractor’s planned schedule with calculated dates to an ‘as-built’ schedule that had substituted actual completion dates for all the activities. This method, however, has many disadvantages. As-built schedules are costly to prepare because of the amount of research necessary to determine the actual dates. Considerable judgement is also required, since detailed records are not always available and even if they are, work on the site does not necessarily match the theoretical sections of the network schedule. It is fair to say that this method of proving a delay is inappropriate unless the planned schedule can be proved to be reliable and reasonable.

Creating an accurate as-built schedule from daily site records, engineers’ diaries and other documentation is extremely difficult. This is particularly the case if the sequencing or relationships of the work have changed from the as-planned schedule.

These sequences and relationships are vitally important because they determine the length of the delay. Re-establishing the actual sequence from project records is very difficult. Although the as-built method can be very accurate for some types of delay, because of the above difficulties it can also be easily manipulated and distorted to reflect the position of the claimant.

As-built schedules may be prepared in a number of different ways. There is, therefore, no one as-built schedule methodology. One method is to research the actual start and finish dates for planned activities, record them, then calculate the extended project duration based on the original planned sequence. Another method is to compare the last monthly update to the initial, planned schedule if the schedule has been updated regularly. Another method is to prepare an as-built schedule that includes both actual dates and which sequences all activities whether they were included on the planned schedule or not. The choice of method depends on which activities have been delayed or what kind of delay must be measured, what information is available, and how economically it can be used.

In addition to the above method there are a number of other ways in which a schedule can be used to analyse time-based claims. The US Corps of Engineers uses a time impact analysis method (also known as ‘modified as built’ and ‘forensic scheduling’) that uses as-built dates only to the point in time when the delay started.7 In this method the schedule is updated to immediately prior to the commencement of the delay. The updated schedule then becomes the ‘base’ schedule that is then compared with the impacted completion date on another schedule on which the delay is included.

When implementing this method several procedures have to be followed. Firstly, the current status of the project must be determined independently from the contractor’s own project schedule. This is required because the contractor’s actual plan for pursuing the work may not be the same as that indicated on the submitted project schedule, or the schedule may not have been updated to reflect variations made earlier in the contract.

Secondly, it has been suggested that the scope of the variations be studied to ascertain what subsequent activities will be directly affected and how the schedule should be revised to accommodate the variation. If all the work, or part of the work, carried out under the variation does not fit an existing activity, new activities should be created and inserted into the schedule. Thirdly, the schedule, as revised, is used for new calculations to determine new critical paths.

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*The term ‘construction schedule’ is used, which is more acceptable to UK civil construction rather than the international term ‘project schedule’, in order to emphasise a construction phase of the project where delay-related claims occur.
and project completion dates. From the newly determined critical path and revised completion dates, extensions of time and other effects of the delay can be granted.

Another method of impacting a schedule to show the effect of changes and delays is to use an as-planned schedule. With the as-planned method of analysis the scope of the changed work is first reviewed to ascertain where and how the revisions (or delays) should be incorporated into the original schedule. The activity revisions are then incorporated into the original schedule. Revisions to subsequent activities caused by the change or delay are defined and made. The effect of the change on the schedule is determined by comparison of the approved schedules before and after all the variations have been incorporated into the schedule. With the as-planned method the contractor is only entitled to an extension of time if the scheduled completion date is delayed beyond the extended contract completion date. The as-planned method uses the planned schedule to measure the delay, regardless of whether the actual on-site construction differs from the planned.

The as-planned method differs from the two previous methods in that it can wait to include all information concerning all delays at one time rather than separate calculations for each delay. The two previous methods require a step-by-step analysis each time a delay occurs. Also, with the as-planned method the analysis must wait until all the contractor change order requests have been submitted.

It may also be the case that, without substantiation, as-planned schedules do not provide sufficient basis to measure contractor delay claims. This is the view sometimes expressed in the UK. To obviate this problem, the contractor should produce proof that performance according to the as-planned schedule was possible without the existence of the delay.

**Choice of method**

Any of the schedule analysis methods discussed above can be used to analyse a delay. The choice of method is dependent on the type of delay claim, the circumstances of the delay, the form of contract, applicable legislation, and the availability of accurate information. Although choice of method will be determined by the engineer, quantity surveyor, project manager or claims consultant dealing with the delay, general rules can be drafted to assist in the selection of a suitable method.

The time impact analysis method can be used to impact a schedule if the delays are recognised and can be analysed close to the date of the delay. This method may be unsuitable where the architect or engineer wish the extensions of time to be postponed until the end of the project. In circumstances such as this the time impact analysis method cannot be used due to the difficulty involved in reconstructing the status of the contract at the time of each delay. It may be better in this instance, to insert all the delays at once then analyse the effect on the as-planned schedule.

The time impact analysis method has other difficulties in its implementation. It is useful for a limited number of impacts but, when 300 or more combinations of excusable, non-excusable, compensable, and non-compensable delays exist, the mechanics of insertion, analysis, revised computations, and evaluations on a multi-activity schedule make the methodology unrealistic. In situations such as this it is preferable to insert all the delays at one time then produce a single impacted schedule.

The use of the as-built method is difficult because of the limitations of the critical path method. Construction schedules cannot really identify the realities of actual site construction. This problem is caused by the construction planner or scheduler applying hard logic to a soft logic situation. This means that an activity has been scheduled as a logical, sequential operation but when it comes to carrying out the operation on site, the activity can be carried out in a variety of ways and sequences. Also, site operations are not always performed continuously. Work may move to other locations or activities at other parts of the project before a given activity is completed.

Another, extremely important, disadvantage is that site records, engineers' diaries, and general historical project information may be missing or at best incomplete. This results in considerable time being expended in attempting to reconstruct the project's history from the above-mentioned documents. If this is the case then a great deal of judgement must be used to extrapolate key dates and actual sequences. This judgement, of course, can be manipulated to change the delay implications. It is for these reasons that measuring a delay from an as-planned schedule is more popular than measuring it from the as-built method.

Although using a network schedule to analyse a delay claim is a scientific exercise, much objective judgement is also needed to input information and to interpret the output. This fact, coupled with the fact that the baseline schedule must be accurate means that the schedule should be checked thoroughly before being used to analyse a delay claim.

**Computerised project planning and scheduling**

Which of the different delay analysis methods should be used depends on the individual circumstances of the project and of the delay. These facts should be examined in terms of the criteria previously discussed. Callahan and Hahns carried out an experiment in which they created a 6-month project schedule then impacted it using the as-built, time impact analysis, and as-planned methods. By using identical delays and the same schedule, he found that the as-built method resulted in a 4-week delay, the time impact analysis method a 3-week delay, and the as-planned method a 2-week delay.

The scheduling techniques described are well known in the industry at present. Progressive construction firms use formal scheduling procedures whenever the complexity of work tasks is high and the coordination of a multiplicity of different operatives and trades are required. In addition to assigning dates to project activities, scheduling is intended to facilitate the matching of resources of equipment, materials and labour with project work tasks over time. Good scheduling can reduce or eliminate bottlenecks and facilitate the procurement of critical activities, thereby ensuring timely completion of the project. All these facilities, if carried out manually, can be time consuming and labour intensive.

Sometimes the enormity of the project would render efficient project planning and scheduling unfeasible if it were not for the computerisation of the planning and scheduling duties.

With the continued development of easy-to-use computer software and improved graphical presentation media, many of the practical problems associated with formal scheduling mechanisms have been overcome.

Although it takes considerably more than a computer and some project management software to manage projects effectively, the advent of project management programs has revolutionised the practice of project management and has assisted project managers in expediting their duties.
more effectively than they have done in the past. Some of the functions involved in project management, especially those concerned with project control—delay management and claim mitigation come under this umbrella—were virtually impossible to execute with any great speed before computers were used.\(^9\)

The rapid growth in the availability and power of microcomputers, coupled with their continuously decreasing cost, has made it possible for construction managers to effectively and efficiently analyse the massive amounts of data necessary to monitor and control the progress of the many interrelated tasks that go together to make up a construction project. This facility has enabled professional and technical staff to spend a greater proportion of their time on specific project-related tasks rather than on the mechanistic administrative tasks that can now be carried out more efficiently by computer. Microcomputers have become commonplace tools in assisting project managers, planners and schedulers with the complex and time-consuming calculations involved in determining schedule dates and other information related to the scheduling process.\(^5\)

In common with most other business functions, the growing use of microcomputers has resulted in an unprecedented increase in the development and supply of bespoke software designed to fulfil specialised requirements. Accountancy, job costing and CAD are a small selection of specialised functions that software developers are providing specialised products for. The functions of project management, planning and scheduling have also attracted the attention of software houses. These software houses are in the business of writing and producing programs which fulfil a basic requirement of a business function such as scheduling and project management. By no means can it be said that each and every software house which produces a scheduling or project management package will fulfil the requirements of each and every user.

Certain packages may be more suitable for one application, user, or even industry, than another. This means that it is very much left to the user to make the decision as to which program to choose. This, of course, should be the case. Each user should select software which will be applicable to their own situation and should seek to optimise their selection at all times. This is relatively easy to implement in theory, but as there are 46 different project planning software packages on the market selecting one in practice may be very difficult.\(^10\)

The main activities that computerised planning and scheduling seek to improve are well known in the industry as are the main benefits that computerisation brings. We have to look at these benefits in much greater depth if we are to appreciate how much of a contribution the computerisation of the project management process could make in the field of time-based claim analysis.

**Software characteristics**

In order that the software and its relevance to delay and claim management can be discussed it is necessary to frame a checklist which will assist in the evaluation of the planning and scheduling software. The evaluation criteria used in this instance falls into three basic categories:

- **General characteristics**—these consist of the commercial name of the system, its list price, the name and address of the software house, and the sort of work for which it is designed.
- **Technical features**—these allow the examination of particular features such as graphical presentation, modelling, resource assignment, resource scheduling, multi-project capability, tracking, cost allocation, report formats, data transfer capability, etc.
- **Specialist features**—these help identify the specialist features that can be used in the field of delay and claim management and which can be used in addition to the basic features required by most planning and scheduling software packages.

The survey of commercially available packages was carried out in June/July 1993. Thirty three software vendors were identified from a software guide.\(^11\) These 33 vendors were responsible for the production and marketing of 46 individual programs in the area of project management and scheduling. Letters were sent to the vendors requesting detailed information regarding their products. Of these 33 companies, 12 did not reply at all and 21 replied by sending information. Of the 21 companies that replied, only 13 sent information considered sufficient and adequate for the purposes of this analysis. The products marketed by these companies form the basis for this study.

When microcomputer project management software first reached the marketplace, it seemed that the products could be grouped into one of two distinct categories. At the lower end the software was simple to use but provided very little functionality. At the higher end, on the other hand, it provided functionality but was too sophisticated for any but those who were already using mainframe project management software, and when compared with the mainframe, meant a reduction in speed and capacity and the inability to share a database. The majority of users wanted the functionality of the high end programs with the ease of use of the lower end products. As technology has moved forward, the gap between these two ends of the program spectrum has diminished. This has resulted in a wide range of software providing a wide range of capabilities and addressing the needs of most project managers.

Although a continuum still exists, it is useful to subdivide the continuum into four main groups to facilitate ease of understanding. This classification into groups has been made to permit the definition of individual requirements, allow the development of unique criteria for selecting software and identify some of the software which can be used to meet this criteria. Table 1 shows the details of the software packages examined in this study.

**Base level packages**

There must always be a low end of any range.\(^10\) When examining project management software it is useful to classify this level as the entry level. Although this level of software can be seen as very basic it does not mean it is useless. Every program on the market has a function for someone. It is only by comparison with the high level programs that the entry level programs appear deficient.

For the purposes of this study the examination of project planning software packages has been limited to mass market packages, advanced packages and sophisticated packages. The base level, for the most part, has been excluded from the study as it was felt that packages in this classification were not applicable to construction-related situations.

It is suffice to say that the majority of base level scheduling packages are little more than home management computerised appointment books or purely graphical tools with little or no database facilities. The former classification has tended to transform itself into the Personal
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<td>N</td>
<td>N</td>
<td>DOS/W</td>
<td>80286</td>
<td>3.5&amp;5.25</td>
<td>Fr&amp;G&amp;M</td>
<td>£3250</td>
<td>So</td>
</tr>
</tbody>
</table>

HD, Hard Disk; W, Windows; LAN, Local Area Network. Fr, French; Sp, Spanish; G, German; and M, Mandarin. MM, mass market level; A, advanced level; and So, sophisticated level.

*All data contained in this table have been abstracted from the manufacturers' specifications obtained in the vendors survey.
†Unlimited in this instance means theoretically unlimited.
‡The figures denoting the price are the listed retail price for single user purchases without any discount. For further information and clarification the software house should be contacted. Prices have been sourced from reference 11. (Some price updates are available from PC Magazine's survey, November 1995, published after the review of this paper.)
Information Manager Classification whereas the latter has transformed itself into the graphical or charting package which allows attractive, easy-to-read charts and graphs to be drawn by keystrokes or by mouse.

The base level package does not really lend itself to a construction environment although if the situation requires a mouse-drawn bar chart without the associated data normally associated with higher level software packages, then a base level package may be all that is required. It has previously been the case that such a situation, although in the construction environment, does not require graphical presentation. A system which is commonly used by construction clients is the pure database such as dBase or Database.

Many clients are only concerned with a few key dates in the construction process and are generally not interested in the comprehensive and detailed presentation of a contractor's or engineer's project plan or schedule. In an instance such as this then the database software can provide all the data manipulation that is required.

Table 1 contains details of the software packages used in this study. Each product has been allocated a category within which it can be described and evaluated. These categories are mass market level, advanced, and sophisticated. The packages were placed in these categories according to their apparent functionality and the type of work they are intended to carry out.

Mass market level packages
In terms of this study the mass market level of software packages represents the greatest part of the software under consideration. The distinction between the mass market level of programs and the base level is not great. Mass market programs are usually characterised by their attempt to provide 'a little something for everyone'.

The mass market software packages differentiate themselves from the base level packages by offering the user the facility of handling more activities, by permitting more user-defined options and by allowing, albeit in a limited mode, the user to perform certain control functions.

Packages in the mass market category are ones which provide the user with a set of tools and facilities which will allow them to carry out the most fundamental project management functions such as: to enter a certain level of cost data; to allow resources to be allocated to tasks; to provide a limited range of predetermined reports; and to allow the user to specify what type of view is required.

It must be stated that price is not an indication of the category in which the software package is assigned to, nor is it an indication of how powerful the package is. Notwithstanding this, there certainly appears to be a remarkable consistency in the pricing of the mass market products.

Out of the 16 software packages examined, nine fell into the mass market category. The prices of these products ranged from £195 to £2300 with the majority being priced around the £700/£800 mark.

Included in the mass market level are some very familiar products names, such as Powerproject Horizon, CA-Superproject, Hornet XK, Instaplan, Artemis Schedule Publisher, Pertmaster, On Target and Project Scheduler. These products, on the whole, provide a certain level of technical features that are commonly used in the construction industry.

Advanced packages
Advanced packages are identified by their ability to offer the user the facilities of packages at the mass market level but which also allow the user to carry out more project control functions. These functions include the ability to allocate variable resources to tasks, the ability to allocate different types of cost data to tasks, much more powerful user-defined reporting formats and the ability to carry out limited project tracking operations.

Packages at this level also offer more sophisticated features. At this level there should be sufficient capability to build an accurate model of the project and to track results against that model. For this level of functionality the user will pay a price. Packages in this market sector range from £1500 to £3800 with the majority of them costing more than £3000.

What does the user look for in advanced level packages? Advanced level packages will offer all the facilities that the mass market packages offer but will, in addition, offer greatly increased functionality. The advanced software packages really attempt to emulate the functionality and capabilities of the sophisticated mainframe-level packages whilst still trying to provide the user with a package which is easy to use and understand.

Sophisticated packages
Sophisticated packages are defined by the fact that they allow the user to create a bespoke system for a particular project. These packages allow the user to carry out full project control activities including full project tracking and updating.

The programs in this, the top group, offer most of the functions available in project management software. As a group they tend to permit highly detailed modelling of the project workscope and of resource and cost assignments. They all feature resource allocation and levelling, progress tracking, and user control over report content. The two programs included in this group are Artemis 7000 (from Lucas Management Systems) and OpenPlan (from Welcome Software Technology). These are the kinds of programs that are attractive to project control people who are used to working with mainframe-level packages or who need the functionality that such software offers. These programs are widely used in the construction industry.

Project management software packages at this level do not come cheap. The least expensive package costs about £1295 whilst the most expensive costs around £5000.

Specific features
The broad range of available software is apparent by a cursory look at Table 1 and the categories described above. In order that the correct software package is chosen for delay and claim work the following features also have to be taken into account.

Data input. Data input is, perhaps, one of the most important features for a mass market product. A product which is clearly targeted at this market has to provide a facility which is so easy to use that a beginner can, essentially, pick up the product and commence producing output from it. On the other hand it must not present a too simplistic image otherwise it will not appeal to experienced project managers familiar with project management software.

One of the most popular features with packages in this market is the compose-on-the-screen facility. This facility allows the user to create a bar chart or network on the screen as if he or she were drawing it on paper. Some writers are of the opinion that this feature is initially

112
attractive to new project management software users but that it could prove slow and tiresome to experienced users.\textsuperscript{10} The experienced user may find this particular feature a nuisance because it requires more key strokes and screen movement than some alternative solutions. These alternative solutions range from inputting to a form on the screen (one activity at a time), inputting to an input table on the screen (multiple activities), or inputting to an external file that is then read by the project management program (batch inputting).

Project tracking. This feature is, perhaps, one of the most important when examining the role of computerised project management software in time-based construction claims.

All the packages in the mass market category allow the user to prepare a project plan with varying degrees of cost and resource information. For complete project tracking, though, the packages must offer the user the capability of freezing a project plan, including the schedule, resource plan, and budget. Once this has been done the user must be able to enter actual start dates, actual completion dates, actual resource use and actual costs without changing the original data. This function allows the user to compare the actual results with the original intent. This facility is at the heart of the as-built method, time impact analysis method and as-planned method of delay and claim analysis.

Networking mode. Another function, which is important when selecting scheduling software for a particular application, is the networking protocol.

The term networking protocol means the method by which the user defines relationships between tasks.\textsuperscript{12} It is important to select a software package which allows the user to specify complete precedence relationships such as start-to-start, finish-to-finish, finish-to-start, start-to-finish, as well as specifying lead/lag durations.

Resource planning. Resource allocation and costing are important features in any project management and scheduling situation.\textsuperscript{13} This importance is increased considerably when the user requires the software to be used in a situation where control or modelling of resources and costs is necessary to mitigate the effects of a delay or claim. This feature is, therefore, one of the most important when selecting a software package for use in delay modelling.

When choosing a software package considerable care should be taken to ensure that the resource-based functions meet the criteria stipulated by the situation for which the package is being considered. It is not advisable to choose a package on the strength of vendors’ sales literature or even on the strength of short reviews. This is because, even after taking the above details into consideration, there can be minute differences which are important to the user. This is especially true of software packages which are likely to be employed in delay and claim situations.

Cost planning. In basic terms there are two primary ways in which project management software packages approach cost planning. The program can be written to deal with costs for each activity, which are determined by the definitions of the resources and their unit costs, or else the program can allow only costs that are fixed for each activity as a specific input rather than being calculated by the resource quantities and rates. In the resource-times-rate approach, the program usually also allows fixed cost inputs for materials and equipment items. Each of these approaches has variations in the way in which they operate.

\textbf{Macros.} This feature is frequently overlooked by purchasers when considering a potential software package. The ability to write, retain and use macros effectively can greatly increase a user’s speed, efficiency and accuracy when using a package. This is especially the case when the user carries out a certain action or activity on a regular basis.

Macros can be written to do virtually anything that the user could do with a number of keystrokes within the software package. Macros can play a very important part in the field of delay analysis and monitoring especially when the user wishes to obtain maximum accuracy in his or her actions.

Reports. This is another very important factor to consider when purchasing a project management software package. The whole point of having and using a piece of powerful and expensive software such as those shown in Table \ref{tab:1} is to provide and present reports to personnel or management who can then study the information contained in them and implement some form of action. If the package does not produce reports then there is not much point of having the software at all as it will become just another pretty graphical package. The ability to produce reports is what distinguishes the base level ‘personal organisers’ from the heavy duty project management packages.

\textbf{Data integration.} The ability to link up with other software packages is, perhaps, one of the most important features in today’s data transfer environment. The capability of exchanging data with spreadsheet packages, database management systems, statistical packages and ASCII files is so important that it requires special mention. Also included in this discussion is the capability of project management software packages to import and export data to/from word processing applications for the purposes of including in reports, graphics and/or data lists.

The data link feature is often overlooked when a user is considering purchasing a software package. This should not be the case. To extract the best from any project management software package it is necessary to have the facility to talk to other packages, especially ones which are recognised as industry standard such as Lotus 123, Microsoft Excel, dBase IV, Database, and Foxpro.

Although these categories are not exhaustive they can provide the reader with a useful framework for evaluating planning and scheduling software for use in delay and claim analysis work, as well as providing a summary of the software available on the market.

\textbf{Development of advanced IT applications}

Commercial computer applications in the field of project management have already been discussed and examined in the previous section. Unfortunately, these software packages are restricted to carrying out their tasks by a process of formal numerical analysis of relatively well-defined problems. The techniques and applications discussed in this section form the base for new types of computer-based aids for project management. Two of these aids, known as knowledge-based expert systems (KBESs) and visualisation techniques, are discussed in more detail below.

\textbf{Knowledge-based expert systems*}

An expert system is a computer program which provides

\footnotesize{\textsuperscript{*}The terms ‘knowledge-based system’ and ‘expert system’ will, for the purposes of this study, mean the same thing.}
by providing a report writing capability that can be used by the site engineer's superiors to review judgements and in hand. The final way the system supports analysis is comprehensive, hypertext-based, context sensitive help system. Change supports the site engineer is by providing a comprehensive section. Another KBES, called 'Superchange' on previous user responses. By doing so the system does not allow the engineer to forget a crucial part of the analysis and at the same time trains the engineer in the proper components of an analysis. The second way in which Superchange supports the site engineer is by providing a comprehensive, hypertext-based, context sensitive help system. The help system can provide explanation, court citations, examples, and quotations all related to the particular question in hand. The final way the system supports analysis is by providing a report writing capability that can be used by the site engineer’s superiors to review judgements and conclusions.

The development of Superchange was the result of the Changes clause in the FAR being so broad in scope. Due to this wide scope and the amount of work, which was the result of negotiating all the potential issues to establish if any of the legal issues were appropriate, it was decided to design an expert system whose function was to select the appropriate legal issues. The expert subsystem was called SELECTOR.

Other KBES developments examined (ESCHEDULER of Moselhi and Nicholas, CONSCHED of Warshawski and Shaked, and others) were more directly related to construction planning and scheduling in general, rather than to time-based delays and claims specifically.

Dym and Levitt suggest that the management of construction projects will still require many uniquely human skills, although KBESs for planning, scheduling, monitoring, and control will act as valuable decision support tools for construction professionals. They even suggest that legal and personnel management tasks can be aided by KBES technology.

From what has been previously discussed it can be seen that KBESs can play an important part in the construction process. At different levels of complexity the KBES will play a varying role. Tasks which are routine and repetitive could become fully automated whereas tasks which require substantial input from humans will use KBES technology in addition to the human input. Claim and delay resolutions tend, for the most part, to occur in the latter category.

**Visualisation and virtual reality techniques**

The main contributions of KBES and Hypertext applications in the claim and delay resolution, as presented above, is for decision making support during either plan formulation in order to avoid delays, or conflict resolution for claim analysis. Similar, 3D computer graphics is already applied as an aid for visual simulation of construction project progress. The ability to show a real picture of the work projects indicating deviation while simulating different ways from the planned schedule of project execution is very valuable for the managerial staff in order to identify 'delay prone' events in the construction process.

Other applications of visualisation techniques can already be found in the courts where the ability to explain your point showing the subsequent of delay (for example) to a non-expert in a very short allocated time is often vital. These cases are very rarely publicised for obvious reasons; only a number of computer bureaus, advertising these services, can provide a possible insight on the 'success' of this kind of application.

On the other hand, the increasing power of personal computers combined with experience of advanced visualisation tools, such as virtual reality software, has created a fruitful environment for more advanced construction applications.

Two projects are currently under development by the Virtual Construction Simulation Research Group at the University of Strathclyde. The first, called VR-Planner, aims to visualise in 3D a schedule of work simulating the construction process and on-site activities. The main goal of the system is to support the planning stage of the construction projects, providing a tool to help in 'trying' different ways of project execution. The ability to check buildability of the design as well as to coordinate both on-site and subcontractors' activities will significantly reduce the number of 'build-in-schedule' delays and therefore alleviate this kind of claim as a result.

Moreover, once a project is in the monitoring stage, the system can compare 'actual' vs 'planned' schedules,
highlighting places where delay (if any) occurred (see Appendix A). Such a presentation of 'problematic areas' combined with the above-described time-based dispute resolution techniques can not only facilitate conflict solving but also help in returning a project to schedule.

Another project, VR-Refurb, tackles a problem of tenants' involvement during refurbishment and modernisation of public housing estates. Here, in addition to the above-described benefits of visual planning, different details of a project (such as skip and scaffolding locations, decoration types) can be presented to, and agreed with, tenants (see Appendix B). Thus, many future conflicts can be prevented as well as possible delays and claims.

**Discussion**

It was concluded from the study that construction disputes result in a considerable amount of valuable time and resources being wasted and that the cause of dispute most often cited was delay. In examining types of delay it was found that there could be several outcomes depending on the apportioning of liability. These outcomes covered the fact that the delay could be due to different types of impact on the project schedule. Depending on the impact upon the schedule it was found that a delay situation could, all too easily, be transformed into a claim situation.

Delays and claims can also have their own outcome, such as arbitration, ADR (Alternative Dispute Resolution) or litigation, but construction schedules can play an important part in proving or disproving the basis of the delay or claim. It was also suggested that the use of schedules could, perhaps, mitigate the effects of a delay if their use was properly administered and interpreted by construction professionals involved on the project.

Once the study had identified that schedules could be used in delay and claim situations it recognised that there were three main ways in which they could be applied: as-built, time impact analysis, and as-planned methods.

It was also established that any of the three methods described above could be successfully used to analyse a construction delay. The choice of method, though, is dependent on a number of variables. These variables include the type of delay claim, the circumstances of delay, the form of contract, applicable legislation and the availability of accurate information.

In order to qualify the extent of use of the above techniques, reference was made to a recent paper by McLellan and Mansfield which pointed out that construction schedules were very rarely used for delay and claim analysis. The study undertaken by McLellan and Mansfield was based on information taken from Scottish-based private and public sector contractors, who were asked to complete a questionnaire which requested information on their use of project management techniques in their day-to-day operations.

Comment was also made on the fact that the majority of Contract Conditions in the UK at present have no contractual requirement for a schedule to be provided by the contractor and agreed by the client's representative.

In light of the above, the study points out that the use of project management and scheduling techniques in the construction industry in general can aid the project team in achieving their goal. This overall benefit, in addition to specific benefits in the area of delays and claims, means that the use of these scheduling techniques should be promoted.

The use of scheduling techniques in the area of delay and claim analysis would ensure that a reasonably precise record of what happened would be available and that apportionment would be easier. It may also be the case that proper usage of these techniques would mean that problems could be identified at an early stage thereby allowing appropriate corrective action to be taken.

The study also stated that although the use of these scheduling techniques can be accepted as being good for the construction industry it was also seen that the computerisation of the techniques had its own advantages.

It was established that sometimes the enormity of the project would render efficient proper planning and scheduling unfeasible if it were not for the computerisation of the planning and scheduling duties. This problem can be overcome with the use of easy-to-use computer software and improved graphical media which are widely available in today's market.

Basically, the rapid growth in the availability and power of microcomputers, coupled with their continually decreasing cost, has made it possible for construction managers to effectively and efficiently analyse the massive amounts of data necessary to monitor and control the progress of the many interrelated tasks that go together to make up a construction project. This, therefore, allows the manager to free up their time for other important tasks.

One of the most important features required in delay and claim work is the ability to produce and manipulate a schedule. This ability is at the heart of delay and claim work using project management software. The program must allow the user to sort out various components, such as least float or by early start, in order that a complete picture of the project can be obtained.

Resource planning is another feature which is essential in delay and claim work. The project is, essentially, a group of tasks requiring the use of resources, such as labour, plant, material and funding. These resources will, for the most part, be the basis for a claim resulting from a delay.

This means that the ability of a software package to control and manipulate resources will be invaluable when using it in a delay or claim situation.

It is also desirable in delay and claim work that the software package should allow the user to assign more than one resource to a task and that it allows limited and varied availability of resources at different points during the project. The ability to compare demand with availability and to show resource loading conflicts is also a requirement of packages which will be used in delay and claim work.

Another important feature which is desirable in software packages which will be used for delay and claim work is the ability to allocate budgets and costs to tasks within the project. It is a natural phase of the planning function to develop a project budget by tying that budget to the tasks of the project. Packages which can produce 'S' curve graphs and which produce cost/budget reports are ideal for delay and claim work as they allow the user to investigate the alternative impacts of the delay which will, subsequently, show the impact on the project expenditure.

Another requirement of project management software packages when looking at delay and claim situations, is the ability to produce comprehensive reports and graphics. This feature is important because the personnel who are using the package in the area of delays and claims must be able to communicate their data to other personnel involved in the project. The program should allow the user to manipulate the data to produce reports which can be tailored to the specific situation thereby allowing maximum flexibility.
One of the first concepts to become apparent when studying these project management software packages is that they can be divided into four main groups according to their level of functionality. This functionality is related to what type of work they will be used for and what type of environment they will be used in. The four groups that became apparent during the course of the study were the base level, mass market level, advanced, and sophisticated packages.

The discussion on KBESs appears to preclude them from being used in delay and claim situations. This is not the case. It seems that there is a need for a certain domain of knowledge to be represented in the area of delays and claims and that the systems discussed go some way to address that issue.

It appears that at this stage in the development of KBESs there is not much difference in a sophisticated package being used in a particular situation and in an expert system developed for the same situation. Expert systems may well be the way forward in delay and claim work, although for the moment it is felt that the use of an advanced or sophisticated scheduling package is more than enough to deal effectively with the techniques used in present day delay and claim applications.

The KBES technology would provide the greatest assistance in the scheduling process when it is linked to a suitable scheduling software package. The intellectual property, required in the field of delay and claim management, would still be supplied by the construction professional although it would be augmented by KBES technology.

This situation will, undoubtedly, change as KBES and visualisation technology becomes more sophisticated and complex. It should be possible in the future for a construction manager to plan a project using a project management scheduling software package, then to model the outcome of a project by employing KBES technology and to simulate the projects' execution visually. By doing this the manager can create 'what-if' scenarios, thereby highlighting actions or non-actions which could be the source of potential delays and claims.

At this moment in time it can be seen that KBES and visualisation technology can contribute significantly to the repetitive actions in construction planning. It can carry out the scheduling exercise with considerable speed and accuracy, thereby reducing the likelihood of errors and it is also possible that it will free up some of the construction manager's time. Unfortunately, when it comes to delay and claim management the construction manager cannot wholly rely on KBES technology. The scheduling process can be taken over by KBES technology but the legal and contractual input must be made by the construction personnel involved. Until this domain of knowledge is tapped and formalised and KBES technology is more advanced then it would seem that the use of a KBES in delay and claim management will be minimal.

Taking this into account, along with the level of functionality that the sophisticated scheduling packages offer, it can be said that delay and claim management can be carried out just as well with the use of a sophisticated package as it could be with a bespoke KBES. This is simply because sophisticated packages are very powerful development tools which are primarily used in situations where the user has to set up the scheduling software to suit his or her own particular needs thereby making the system bespoke.

Visualisation technology seems, at this stage, like a planner assistant and/or communication medium, contributing implicitly to delay and claim management.

The above discussion does not preclude advanced packages and mass market packages from being used in delay and claim management. It was stated earlier in this study that the choice of scheduling package is very much dependent on the user's requirements. If the user does not require the functionality and associated complexity of the sophisticated package then an advanced package or mass market package would be sufficient.

Summary

This paper describes the study which examined the role of project planning and scheduling techniques when applied to time-based dispute and claim management, ascertaining their applicability, and assessing the suitability of the software in the area as a whole. The paper briefly looked at the planning and scheduling techniques used by the industry, describing their likely uses and highlighting their main features. Once this was done it was necessary to choose a particular method that could be used to illustrate the techniques. To complete the background discussion on the application of project planning and scheduling techniques in the field of delay and claim management, the study comments on the extent to which these techniques are used in industry.

In looking at the application of commercial computer programs the study attempts to identify criteria which computerised project management programs would have to meet. The criteria chosen encompasses all the main project management functions such as scheduling, resource planning, budgeting, cost control, and reporting. This section of the study paves the way for the next main section that is concerned with identifying key features of commonly-used project planning software, which could be used in delay and claim environments.

To provide a suitable framework for a review of the scheduling software the study identifies a three-level approach. The software review criteria is broken down into general characteristics, technical features, and specialist features. The specialist features help to identify key features which the software package offers which may have particular value in delay or claim work.

In the course of identifying the characteristics described above it was found that when looking at the general characteristics it would be useful to categorise the software packages into four groups. These groups were identified by the type of application that the software package was normally used for. Four main groups were identified: base level, mass market level, advanced, and sophisticated packages. Only the three latter categories were studied in any great depth as it was found that packages in the base level were not applicable to construction-related project management situations. For the mass market, advanced and sophisticated packages the study addresses and discusses the technical and specific characteristics that each type of software program exhibits.

To complete the study of project management software techniques it was felt necessary to make some mention of developments made in the field of advanced IT. Examples of recent KBES research were reviewed and possible applications of visualisation techniques were presented.

Future work

The application of scheduling techniques, either conventional or advanced IT based, to the field of delay and claim
management should be encouraged. Conditions of contract should be developed which include clauses stipulating the use of schedules as a contract document. These schedules should be prepared by the contractor and the clients' project manager or representative to ensure that they are realistic and practical. They should be updated monthly with a baseline, as-planned and as-built schedule being produced. This would enable the construction professionals involved on the project to identify any potential delay situations and hopefully reduce the incidence of disputes and claims.

Once this utopian deal has been reached the use of the powerful software packages which are currently available can be used to plan and monitor projects with greater ease than was previously possible. Spending considerable sums of money on such software would be justified by the fact that all the conditions of a contract would require a schedule to be part of the contract documents and regular updating would also be required.

Leading on from this it can be seen that if a schedule is to be part of the contract documents then through time the amount of project data will build up. This data could then be used as a base for a knowledge domain for the further development of expert systems, which could in turn be used to manage the schedules required for a project as well as to create a visual communications medium.

Acknowledgement

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Appendix A—construction process visualisation

Figures A1 and A2 (see pp. 118–119) are images output from different stages of the visual simulation of the construction project taking place on a site on Montrose/Cochrane Street, Glasgow. This project has been carried out in a confined site in the city centre. The project includes integration of existing historical facade (shown semantically) within new construction. At the time of the publication, only the first stage of the project—New Construction—has been completed.
Figure A1  Simulation of work progress
Appendix B—refurbishment process visualisation

This project has been visualised in order to facilitate the planning and execution of re-roofing of 32 housing units. Figures B1 and B2 demonstrate visualisation as a communication tool. The images can be used for coordination of equipment and scaffolding location with both subcontractors and tenants.

Figure A2  Example of the use of colour to facilitate monitoring 'actual' versus 'planned' progress. Red is used here to mark delayed activities: green, activities out of planned progress but still not affecting project duration; and yellow, work that remains to be done (wall has been made transparent to show the place of this work). Please note in black and white version "red" is darker and "yellow" is lighter than the other colours.

Figure B1  Works on site: contractor’s view
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