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Planiranje z omejenimi viri - Študij primera z uporabo Primavera project Planner verzija 3.1

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IZJAVA O AVTORSTVU

Podpisan **ŽIGA BABNIK** izjavljam, da sem avtor diplomske naloge z naslovom: »**PLANIRANJE Z OMEJENIMI RESURSI - ŠTUDIJ PRIMERA Z UPORABO PRIMAVERA PROJECT PLANNER VERSION 3.1**«.

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Izvleček**

V sklopu študentske izmenjave programa Socrates Erasmus sem bil v poletnem semestru študijskega leta 2005/06 gost na Project Management Centru na Istanbul Technical University v Turčiji, kjer sem napisal svoje diplomsko delo. V tem diplomskem delu bom predstavil proces planiranja z osnovnimi značilnostmi in metodami, ki morajo biti uporabljene tekom planiranja projekta v gradbeništvu z uporabo najbolj razširjene metode kritične poti. Predstavljen je teoretični vidik planiranja virov in njihova možnost uporabe z modernimi programskimi orodji; slednje je aplicirano na realen projektni plan, ki je izdelan v profesionalnem programu za planiranje in vodenje projektov Primavera Project Planner, verzija 3.1. Tehnike za planiranje virov so izravnavanje, razporejanje, kopičenje, zbiranje in glajenje. Za kontrolo projekta je prikazana metoda obvladovanja prisluzne vrednosti. Poleg že omenjenimi metodami in tehnikami sem se ukvarjal tudi s tem, kako naj profesionalci v gradbeništvu le-te uporabljajo, seveda s pomočjo programskih pripomočkov za planiranje in vodenje projektov skozi njihov celoten potek. Prisotna so tudi poročila, ki so na voljo po izdelanem planu in tekom same izvedbe, če plan vsebuje vse zahtevane podatke. To so poročila plana, poročilo kontrole virov in stroškov, nosilna poročila virov in stroškov, poročila o produktivnosti, stroških in ocenah, poročila o denarnem toku, tabelarična poročila o virih in stroških ter matrična poročila izdelana s pomočjo Primavera. Na koncu so predstavljene še rešitve, ki jih P3 ponuja za pošiljanje posameznih informacij med udeleženci projekta in hranjenje le-teh na spletu ali lokalnem strežniku, kot tudi udeleženci projekta, ki uporabljajo vire in vodijo projekt, ter njihove naloge in metode dela s pomočjo P3.

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Abstract

In the spring semester of the academic year 2005/06 I took part in the Socrates Erasmus student exchange, writing my graduation thesis at the Project Management Centre at Istanbul Technical University. In this thesis I will present the process of planning along with its basic properties and methods, which have to be used when planning a project in the construction sector, using the expanded Critical Path Method. I included some theoretical background of resource scheduling and its possibility of using it with modern software tools, which is presented on a real project prepared by using Primavera Project Planner Version 3.1, a modern programme for planning and managing projects. The techniques I dealt with are levelling, allocation, cumulation, aggregation and smoothing. In order to control the project, the Earned value analysis is presented as well. Apart from all the aforementioned methods and techniques, I also decided to portray how the professionals in construction should use these techniques with modern software tools for managing and planning the project during its life, including the reports that are made right after a particular plan is finished, as well as other reports compiled during the project, if the project contains all necessary data. These reports are: schedule, resource/cost control, resource/cost loading, productivity, cash flow, earned value, tabular resource/cost and matrix reports made with P3. In the end, the solutions for sending and sharing project data via the web or local servers between the members of a project team, as well as the responsibilities of the latter for resource scheduling and managing the project using P3 are depicted.

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ACRONYMS AND SYMBOLS

| | |
|------|--|
| PM | Project management |
| P3 | Primavera Project Planner Version 3.1 |
| CPM | Critical path method |
| AON | Activity on Node |
| ES | Early start time |
| EF | Early finish time |
| LS | Late start time |
| LF | Late finish time |
| DES | Activity description |
| OD | Original duration |
| FS | Finish to start relationships |
| SS | Start to start relationships |
| SF | Start to finish relationships |
| FF | Finish to finish relationships |
| TF | Total float |
| FF | Free float |
| PF | Phantom float |
| RCS | Resource constrained scheduling |
| RCPM | Resource constrained Critical path method |
| TW | Amount of work to be done |
| FR | Float remaining |
| EVA | The earned value analysis |
| PV | The planned value |
| AC | The actual cost |
| EV | The earned value |
| CV | Cost variance |
| SV | Schedule variance |
| ACWP | Actual cost for work performed |
| BCWP | Budgeted cost for work performed |
| BCWS | Planned value, or budgeted cost for work scheduled |

CPI Cost performance index
SPI Schedule performance index
PMC Project Management Centre
ITU Istanbul Technical University
MBB Molecular Biology Building
WBS Work breakdown structure
HTML Hyper Text Markup Language
PCM Project control manager
Y Activity duration

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Appendix A List of activities and their data

Appendix B The legend of added and used resources in the schedule

Appendix C Schedule of MBB

1 INTRODUCTION

1.1 Background

Project planning and programming is essential for successful project management (PM). Without planning it is difficult to envisage the successful conclusion of any project or the effective control of time, money or resources. There is more to planning a project than meets the eye and a great deal more involved than simply producing a programme. Planning is also essential when it comes to dealing with construction risks and device safe working methods. This is so through all the stages of the process, from inception all the way to design, tendering, construction and commissioning stages of a project.

The reasons for planning may be summarised as:

- To aid contract control,
- To establish realistic standards,
- To monitor performance in terms of output, time and money,
- To keep the schedule under constant review and take action when necessary to correct the situation with modern PM software.

1.2 Problem definition

Critical path analysis is the analytical technique used most frequently by the construction respondents during both the planning and control stages of managing a project. But in the pre-contract and contract planning, only time-line planning based on planner's experiences by the past projects is mostly used. The main goal is to be with a schedule as close as the real project will take on. It is necessary to adopt disposable resources and information into the project and use other techniques including resource scheduling for planning and earned value analysis for control. All types of information entered have to be updated in the software, although the project effect is weaker. Many construction companies in Slovenia and Turkey do not use planning techniques efficiently in that manner.

1.3 Objectives and methodology

In my thesis I will present particular fields within Project management which are used as theoretical background for planning: methods and techniques for planning, resource scheduling and presentation of all types of entered and updated data and evaluation methods, which are also provided by modern software tools. In addition to that, there is a real project schedule case and there are presented resource scheduling methods, tools and techniques using Primavera Project Planner Version 3.1 (P3). The advantages, results and benefits of scheduling in that way will also be presented as showing and sharing project data and reports.

I chose the P3 software package, because it is reliable, comprehensive and more professional in comparison to Microsoft Project which is mostly preferred because of its affordability.

2 PROJECT MANAGEMENT

2.1 Project organization and project planning

Project organization and project type are highly dependent on the type of a contract. Common contract types used in construction projects are:

- Lump-sum contract
- Turn key contract
- Build operate transfer contract
- Unit price contract and others

In this research, I decided to focus on the Lump-sum type, taking into consideration the fact that the latter is still the preferred option for many corporations and public institutions. Other types of contracts are out of the research scope.

The parameters below describe the distribution of responsibilities between parties and define the organizational layout for lump-sum contracts:

- The project functional requirements are prepared by the client.
- The project definition is prepared by the client.
- Design consultants are appointed by the client.
- A project manager from the client's own organization is sometimes appointed.
- Construction documentation is prepared by the consultants.
- A lump sum construction contract is awarded to the low bidder.
- A schedule is commonly prepared by the main contractor, otherwise by the client.

In a lump-sum project, detailed scheduling typically begins once the contractor has signed the contract with the client to construct the project. Since producing the detailed schedule can cost a substantial amount, it is not begun until the contract is awarded and it is completed as soon as possible. There are three primary reasons for preparing the schedule immediately:

- The contractor wants the schedule to control field operations.
- The planning and scheduling process is a tool to help print out and solve problems before they arise in the field.
- The client/contractor contract may require the presentation of a project schedule to the client/architect for use in monitoring the project.

The scheduling process being used in setting up project controls for lump-sum, linear construction process involves four phases: planning, scheduling, monitoring and controlling.

Project planning starts with the client's team or organization when a programme (or master schedule) is prepared by the client's agent, representative or a project manager. This sets out the broad framework of the project, including:

- key data for commencement and completion of the project,
- key data for design, tender and construction,
- overall programme and phasing,
- design and tendering periods,
- key data for commencement and completion of construction,
- stage or phased handover dates.



Figure 1: The project planning process

The main reasons for project planning are:

- to establish a realistic project master schedule or a programme on which the appointments of consultants and contractors and commission the occupancy phase of the scheme are based.
- to identify key dates or gateways at critical stages of the project.
- to facilitate control of the design and tendering process.

- to identify potential risks in order to progress and avoid possible delays of project completion and revenue generation.

2.2 Pre-contract planning

Pre-contract planning generally takes place during the period between the contract award and commencement of work on a site. This is the case for a project based on a traditional competitive tender, but differences may occur in procedures where other procurement arrangements are used.

Before work starts on a site, the contractor will develop the pre-tender programme into the contract master programme, showing the main construction operations to be carried out. Copies of this programme will be presented to the client's representative who will use it as a tool to monitor the contractor's overall progress during construction. The master programme will often show when information is required by the contractor and act as a prompt for an architect.

The master programme is the one that the client's team sees, but many contractors produce an inertial programme for their own use in order to save time and money. It is called a target programme with time taken out as planned - that is contracting.

In order to help the contractor organise and manage site activities at an operational level, the target programme will need to be developed in more detail. Most of the time bars on the target programme will represent the main work packages to be carried out by various sub-contractors and consequently each bar will be developed into a sub-contractor programme, showing the detailed activities to be carried out

However, to ensure that work packages start and finish on time, it is now usual for the contractor to produce a procurement programme for each subcontractor. This programme will show both negative and positive time. Negative time is the time needed before work starts on site to organise design and fabrication aspects of the package or to pre-order key materials with long lead times. Positive time is the time needed to carry out the subcontractor's work on site.

The main reasons for pre-contract planning are:

- to provide a broad outline schedule or strategy for the project,
- to comply with contract conditions,
- to establish a construction sequence on which the master programme may be based,
- to identify key project dates,
- to highlight key information requirements,
- to enable the assessment of contract budgets and cumulative value forecasts,
- to schedule key dates with respect to key material and subcontractor requirements.

2.3 Contract planning

During the contract stage, the master programme will be further developed. For instance, a stage programme might be prepared in order to show a part of the master programme in more detail.

Alternatively, the contractor might produce a series of short-term programmes at weekly or fortnightly intervals so as to schedule day-to-day work in detail. Contract planning is done by the main contractor in order to maintain control and ensure that the project is completed on time, within the cost limits established at the tender stage. Subcontractors contribute to the process either by submitting their work programme for approval or thought discussion with the main contractor.

As the contract progresses, the programme invariably changes from its original form. Delays occur, work is disrupted due to design changes and unforeseen events take place, such as the discovery of bad ground or contamination. This causes delay and/or disruption of the programme, recorded on a revised programme which should be constantly updated through the project as the work proceeds and as other problems arise. These programmes are often referred to as the as-built programmes or, alternatively, the programmes of the day and they are a vital tool, enabling the contractor to justify his entitlement to the extensions of time and/or additional payment for loss and expense.

Reasons for contract planning are:

- to monitor the master programme on a monthly, weekly and daily basis,
- to schedule site operations in detail in short term,
- to optimise and review resources,
- to keep the project under review and report on variances.

2.4 Method statement

The preparation of method statements forms is the essential part of the contractor's planning process as these underpin the programme and explain how the work is to be undertaken. Method statements convey different meanings to clients, consultants, subcontractors and main contractors. A method statement is not simply a list of construction operations with notes written alongside.

It is common practise to combine the construction and safety method statements for each work activity into a single document. This makes sense because safety is an integral factor in the planning process.

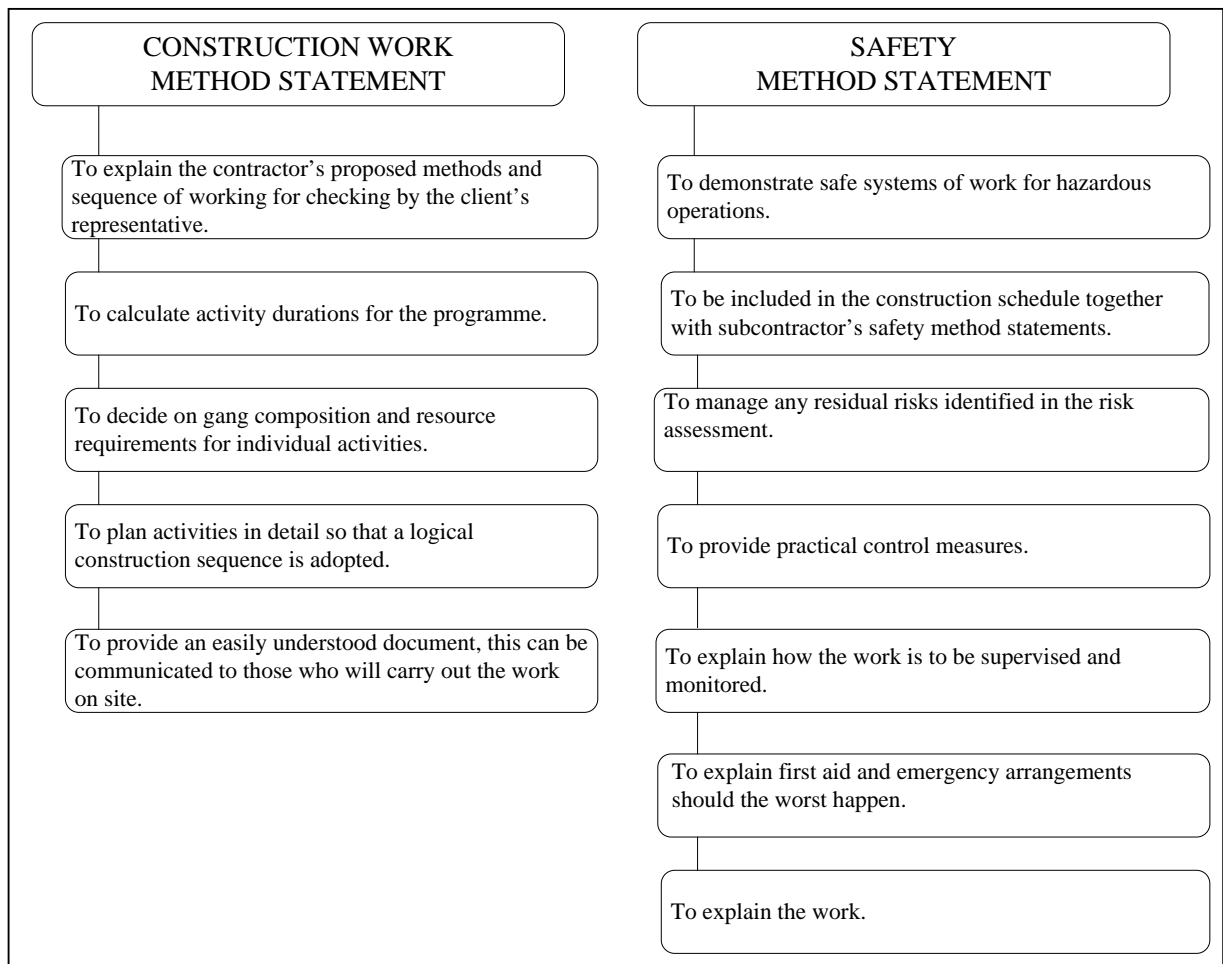


Figure 2: Construction work and safety method statements

2.5 Planning a project

When preparing any programme for a project, it is essential to follow a logical thought process in order to develop a realistic and a workable programme. Working knowledge of the development and construction processes is essential. The level of detail shown in the programme should be commensurate with the project stage under consideration and, wherever possible, activity durations should be based on empirical data or calculation.

Computer software should be used for speed, for considering "what if" options and for high quality professional presentations.

Planning a project requires a logical approach involving various steps or thought processes:

- getting a feel for the project,
- establishing key project dates,
- establishing key activities or events,
- assessing how long the activities will take,
- establishing the sequence,
- deciding which programming technique to use.

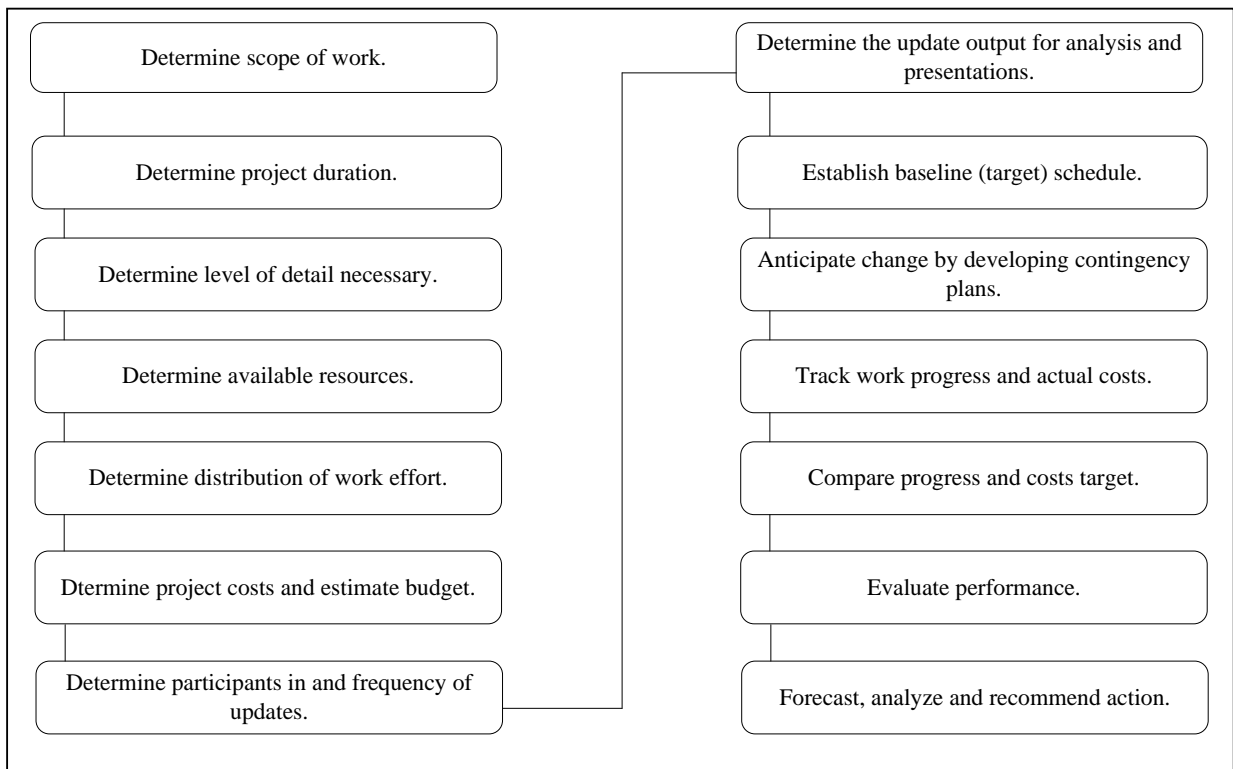


Figure 3: Steps in the planning and control process

The resources can comprise labour, equipment, material or other resources assigned to the activity when the baseline schedule is constructed.

2.6 Critical path method

The resurgence in the use of the Critical path method (CPM) in the late 1980s was mainly due to the introduction of the personal computer and developments in the user-friendly project software. Now, linked bar charts are more popular for most projects, but within the larger

schemes CPM still plays an important role, especially with the advent of cheaper software and hardware. There is little doubt that networks are here to stay, albeit that developments in project management software using precedence and linked bar charts presentation formats are largely preferred to arrow diagram techniques.

Whatever the case, as construction projects become larger and more complex to schedule and manage, project managers and larger contractors become increasingly reliant on computers to undertake project planning tasks; the use of project management software will become the norm. Of course, the computer has now become an everyday site tool for both, the construction manager and the planner.

2.6.1 Principles of network

PM software tools are using Activity on Node (AON) network for CPM analysis. The construction of an AON network is straightforward. All the scheduler has to do is to create a node for each activity and then connect the nodes by arcs as dictated by the precedence relations.

The duration of each activity is given, and the earliest and latest event times of the activity can be calculated by making forward and backward passes through the network. From this information, a schedule that will facilitate calculation of the total float or spare time for each activity can be produced.

The critical path can be identified by determining the following four parameters for each activity:

- ES - early start time: the earliest time at which the activity can start given that its precedent activities must be completed first.
- EF - early finish time, equal to the earliest start time for the activity plus the time required to complete the activity.
- LF - late finish time: the latest time at which the activity can be completed

without delaying the project.

- LS - late start time, equal to the latest finish time minus the time required to complete the activity.

Once the activities and their sequencing have been defined, the CPM diagram can be drawn. An examples of a CPM network diagram can be seen in Figure 14 and in Figure 4 using P3. The project management software carries out the time analysis for the programme sequence developed by the planner. This allows the operations to be sorted according to a particular priority, thereby enabling the critical path to be calculated and highlighted. The critical path is defined as the longest route through the sequence of operations which must be undertaken in order to complete the project.

2.6.2 Case using P3

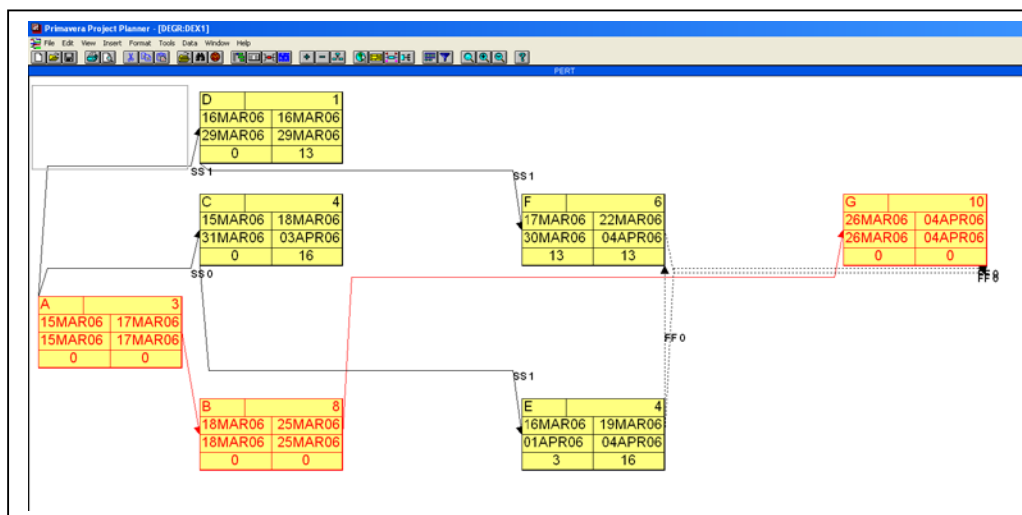


Figure 4: A network case of the schedule in P3

Table 1: The legend activity box configuration

| DES | Activity description | OD | Original duration |
|-----|----------------------|----|-------------------|
| ES | Early start | EF | Early finish |
| LS | Late start | LF | Late finish |
| FFL | Free float | TL | Total float |

When the late finish and the early finish dates are the same, the activity is referred to as critical.

2.6.3 Advantages of network

- Through the discipline of CPM, the user can achieve better planning due to the logical approach undertaken during the development of the construction sequence.
- Identification of critical operations on which effort and resources can be applied aids the contractor's management. This enables "management by exception" to be applied to critical activities.
- CPM allows the planner to express his ideas in graphical form. Recent developments in project management software allow networking on screen to be carried out.
- The planner has the facility to assign priorities for labour, plant, material and subcontractor resources to each operation on the network.
- Bar charts analysis aids understanding at site management level.
- The effect of changes and variations can be evaluated and time-cost optimisation analysis undertaken.
- Cash flow assessments and valuation forecasting information may be output in graphical format and readily updated during the project.
- Using laptop and site-based computers, progress may be speedily analysed and variety of management reports made available.

2.6.4 Disadvantages of network

- Several activities are in practice often scheduled to start just after the preceding one, so there is a complex concurrency, but with a delay at the beginning. This can be overcome by using a ladder diagram. This introduces concurrent activities with a "lead-lag" start and finish which can be likened to dummy activities but with a duration attached.
- In these situations precedence diagrams offer much more flexibility.
- For all the man-hours spent on in-company management training programmes learning to appreciate networks, they have never captivated managers in small and medium-sized companies.

2.7 Principles of bar charts and linked bar charts

The bar chart is laid out with the time-scale in days/weeks/months/years along the top axis and list of tasks or activities down the left hand side. The time required for each activity is represented by a horizontal line (or bar), with the length of the line indicating the duration of the activity. Most architects and site managers tend to have problems with understanding anything other than bar charts displays, even where network analysis has been stipulated in the contract documents as the project planning technique to be employed. However, bar charts have limitations and the key disadvantage is that they do not show dependency. Consequently, it is not easy to see the interrelationship between activities and how dependent they might be on one another. This is not so bad when it comes to a simple project, but where there are a large number of activities on the programme, real problems can arise for the manager. The problem can be overcome by using the linked bar chart.

Relationships used in linked bar charts include:

- Finish to start relationships FS
- Start to start relationships SS
- Start to finish relationships SF
- Finish to finish relationships FF

2.7.1 Case using P3

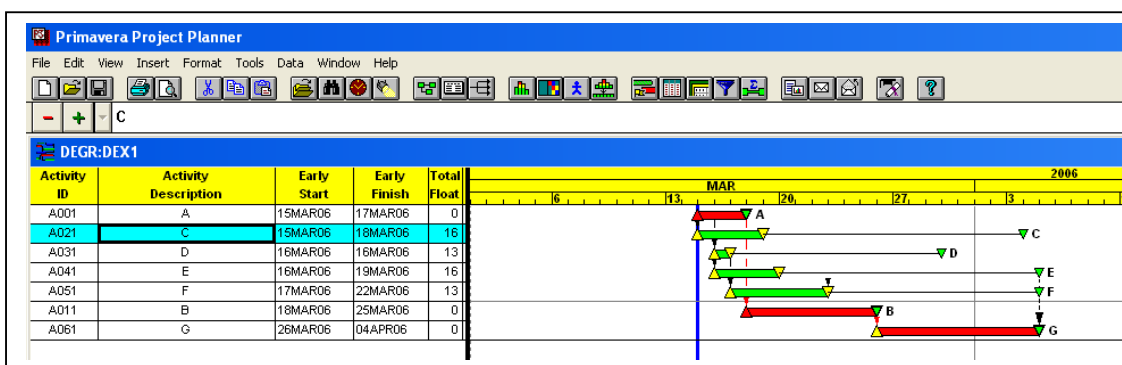


Figure 5: Presentation of bar charts in P3

There are a number of project management software packages available, which employ linked bar charts as the preferred display. Those include:

- CS Project Professional - Crest Software
- Hornet Windmill - Claremont Controls
- Microsoft Project - Microsoft Corporation
- Primavera Project Planner Version 3.1 – Primavera Systems, Inc.
- Power Project Professional - Asta Development

2.7.2 Advantages of bar charts and linked bar charts

- Simple format readily understood at all levels of management.
- Applicable at all stages of the planning process: project planning, pre-tender, pre-contract planning and contract planning.
- Particularly useful in showing the relationship between the pre-tender, master programme and short-term programmes.
- Clearly mimics the construction sequence – the use of linking between bars facilitates the overlapping of related operations.
- Easily updated at weekly and monthly intervals for review purposes and progress reports.
- Key milestone symbols may be introduced to highlight critical dates with regard to key contract stages, information requirements and as aid to subcontractor and materials procurement.
- Resources may be shown on the bar chart, which clearly relates labour, plant and subcontractors to the rate of working and helps the manager to see problems of continuity and waste.
- Facilitates the production of labour histograms, value-time forecasts, cumulative labour and plant forecasts and other project budgets so that actual progress may be charted against planned progress.
- Enables the contractor to quickly and simply fulfil contractual requirements to submit a programme prior to commencement of work on site.

- Readily updated with information such as key site deliveries, progress to date and delays, making it simple to produce an “as built” programme which may prove an asset to the contractor in forming contractual claims. The effect of the receipt of late information on programmed operations can be monitored and reported.
- Copies of the contract position at the date of a specific occurrence may provide evidence of the resulting delay.
- The bar chart programme can be used to form the basis of financial forecasting for both the client and the contractor.
- Computer printouts in full colour can be scaled down to A4 size, which is invaluable for management reports and ease of handling.

2.7.3 Disadvantages of bar charts and linked bar charts

- Gantt charts do not show dependency and therefore do not clearly indicate which operations directly relate to the successful completion of the project. This makes it difficult to apply management by exception.
- Logical links are used to overcome this problem but these can become confusing and difficult to interpret on complex projects.
- Consequently, complex interrelationships can not be clearly shown.

2.8 Activity duration estimating

Activity duration estimating is the process of taking information on the project scope, as well as the resources and then developing durations for input into schedules. The inputs for the estimates of duration typically originate from the person or the group on the project team who is most familiar with the nature of a specific activity. The estimate is often progressively elaborated and the process considers the quality and availability of the output data. The estimate can be assumed to be progressively more accurate and of known quality. The person or group on the project team who is most familiar with the nature of a specific activity should make, or at least approve the estimate. The project team can consider the project duration using probabilistic or deterministic techniques.

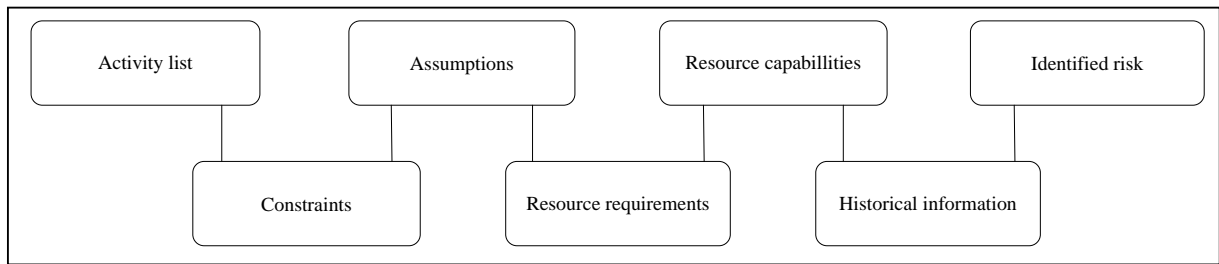


Figure 6: Inputs for activity duration estimation

2.8.1 Tools and techniques for activity duration estimation

2.8.1.1 Expert judgement

Expert judgement will often be required to assess the inputs for duration estimating. Such expertise may be provided by any group or an individual with specialized knowledge or training, and is available from many sources, including:

- other units within the performing organization,
- consultants,
- stakeholders, including customers,
- professional and technical associations,
- industry groups.

Durations are often difficult to estimate because of the number of factors that can influence them (e.g. resource levels, resource productivity). Expert judgement guided by historical information should be used whenever possible. If such expertise is not available, the estimates are inherently uncertain and risky.

2.8.1.2 Analogous estimating

Analogous estimating, also called top-down estimating, means using actual duration of a previous, similar activity. It is frequently used to estimate project duration when there is a limited amount of detailed information about the project (e.g. in the early phases). Analogous

estimating is a form of expert judgement and is most reliable when the previous activities are in fact similar and when the individuals preparing the estimates have the needed expertise.

2.8.1.3 Quantitatively based durations

The quantities to be performed for each specific work category (i.e. number of drawing, meters of cable, tons of steel, etc.) defined by the engineering/design effort, when multiplied by the productivity unit rate (i.e. hours per drawing, meters of cable per hour, etc.) can be used to estimate activity durations.

2.8.1.4 Reserve time (Contingency)

Project teams may choose to incorporate an additional time frame called time reserve, contingency, or buffer that can be added to the activity duration or elsewhere in the schedule as recognition of schedule risk. This reserve time can be a percentage of the estimated duration or a fixed number of work periods. The reserve time can later be reduced or eliminated, as more precise information about the project becomes available. Such reserve time should be documented along with other data and assumptions.

2.9 Resource scheduling

2.9.1 Float in resource scheduling

The concept of float has been adopted for use in resource constrained projects. Certain activities have float, which permits them to start later than their earlier dates. Total float (TF) is the number of days an activity can be delayed without a possible effect on the finish of the project. Correctly controlled, this float is valuable in regulating the use of labour, materials, cost and other resources. P3 bases the calculations of early and late dates and float for each activity on the network logic, data date, remaining durations and any imposed constraints. Early dates indicate the earliest start and finish dates on which an activity can be performed, taking network logic into consideration. Late dates represent the latest dates on which an activity can start and finish without the project being delayed. Float helps identifying schedule problems and analysis schedule status. P3 calculates TF as the difference between the late and early finish dates. A positive total float value represents the number of work periods an activity can slip before it possibly affects the project finish date. Free float (FF) equals the

amount of time the early start of an activity can be delayed without delaying the early start of a successor. Presentation of float is seen in cases 3.7.1. and 3.6.2.

$$FF = ES_2 - Y - ES_1 \quad (1)$$

$$TF = LF - ES - Y \quad (2)$$

Y (activity duration)

2.9.2 Float in resource constrained scheduling

The CPM generates useful information about the project, such as the shortest project duration, the critical path, TF and FF of each activity. Once resources are considered in the scheduling process, the information about the correct float has been lost. As a result, one or more paths become critical. The difference between "theoretical remaining" TF and the "actual remaining" is referred to as a phantom float (PF).

Since the schedule needs to be updated periodically based on current project performance, it is required to rebuild a resource constrained schedule when a certain amount of the latter has changed: activity duration extension, activity start/finish time change, etc.

This rescheduling normally generates a different schedule in terms of activity work sequence. The changed activity sequence occurs because current practical resource constrained scheduling (RCS) techniques employ certain priority rules (LS, TF, FF, etc.) and the updated activities data could affect those activity priority orders. The changed activity sequence could force the project manager to reorganize the project at high cost and the reorganization may be required every time the schedule is updated.

Regardless of the disadvantages, construction professionals are heavy users of the CPM and RCS techniques assisted by project management software. A traditional CPM schedule is not realistic because some resources are highly limited in practice. A resource constrained CPM (RCPM) technique that takes advantage of both CPM and RCS techniques will be presented in addition.

RCPM:

- considers resource availability, which makes a schedule more realistic,
- correctly identifies floats and the critical path,
- provides a stable schedule in a certain required level through the project duration.

2.9.2.1 Reasons for RCPM

Once resource constraints are applied, the activity sequence relies not only on technological relationships, but also on resource dependencies. Since the resource dependency is omitted in the backward pass, the late time of an activity that has resource dependency can be greater than the real values. If the late time of an activity is greater than the real value, the TF shall be increased by the difference. Furthermore, the increased TF or the late time could affect predecessors, depending on the network condition. Then, most critical activities become non-critical.

2.9.2.2 RCPM Algorithm

RCPM algorithm is mainly composed of five steps. An overview is shown in Table 2. In order to make the problem simple, the maximum of available resources amount is assumed constant for the whole project duration; and activity splitting and resource levelling are not considered. A fenced bar chart technique is adopted for convenience of identifying the activities relationships and daily resource requirements.

Table 2: RCPM Algorithm process overview

| STEP | FUNCTION |
|------|--|
| 1 | CPM forward and backward process |
| 2 | Serial resource constrained scheduling making resource links |
| 3 | Backward pass with technological and resource links |
| 4 | Finding unidentified resource links |
| 5 | Finding alternative schedules |

STEP 1: CPM

The CPM results of the schedule are shown in the figure xy, in which the early and late times are calculated and the critical path is identified. If the maximum available resources are

assumed as two for resource A (R(A)) and one for resource B (R(B)), days 3 – 6 are over the given resource limit. Now an RCS technique is required to remove these resource overuses.

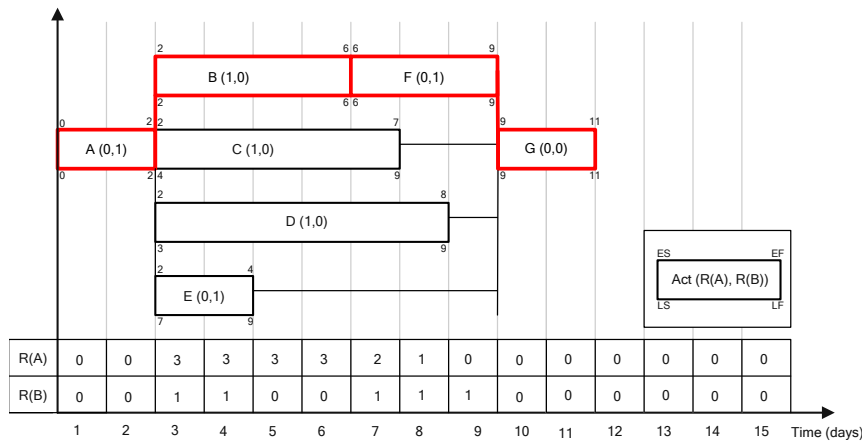


Figure 7: The CPM analysis of the schedule

STEP 2: SERIAL METHOD WITH CREATING RESOURCE CONSTRAINED LINK

Dependency caused by the resource transfer can be treated as a logical relationship in the CPM. At this point, one or more resource links can be created between the current activity and all or some of the just completed activities the time extension of which directly affects the start time of the current activity due to a resource limit. If there is no such completed activity, then a resource link can be created for an activity according to various priority rules. For simplicity, the priority is given to the activity that has the highest resource requirement (combined amount for multiple resource types). A tie can be resolved by the smaller activity identification. Once resource links are created, any time extension of the predecessor will delay the start time of the current activity.

In the example schedule, activities A, B and D can be scheduled as indicated by the original CPM schedule. Activity C should be delayed until enough resources are available because it cannot be scheduled as originally due to the limit of R(A). Activity C can start right after activity B's completion, which is the earliest possible start time for activity C. Since activity B's completion releases one of R(A), which is enough for activity C's performance for the whole duration, a resource link can be added between activities B and C as shown in the

figure 8. Activities F, E and G do not encounter any resource limit, so they can be scheduled as in the initial relationship. The figure 8 is showing that no activity can start earlier than the current start time and that overall duration has been extended by two days, due to the chain effect of activity C's delay.

As a result of step 2, resource links are created and the scheduled start and end times of an activity automatically become ES and LF, but LS and LF are still not identified at this step.

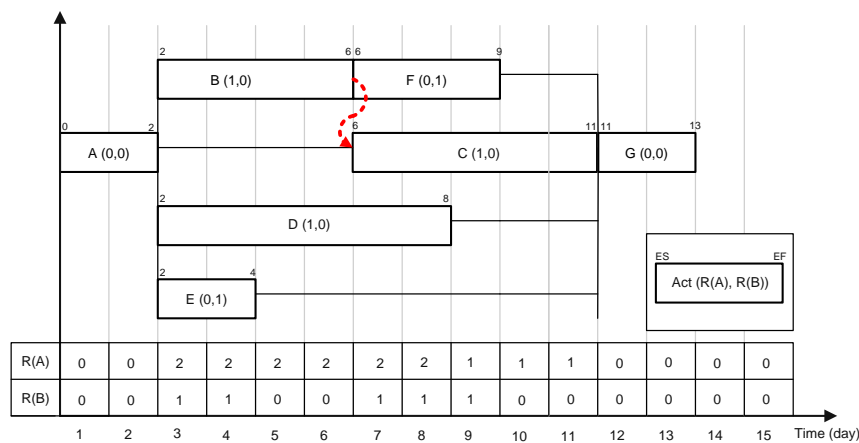


Figure 8: Creating a resource constrained link

STEP 3: BACWARD PROCESS

A backward pass is required to find LS and LF considering both the resource links and the original technological relationship. The figure 9 displays results such as late times and the critical path.

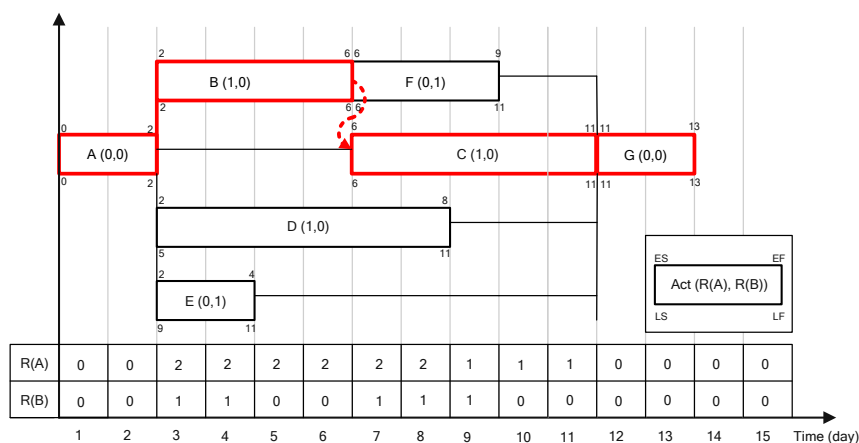


Figure 9: Schedule in step 3

STEP 4: FINDING MORE RESOURCE LINKS

In the result of step 3, the TF of a critical activity is obvious in that any delay of it will extend the project completion time. This means we do not need to check it anymore for its correct float. Activity for which TF is other than zero may not have its full floats if there is any resource constraint for the TF period. In the figure 9, for instance, activity E cannot have its full TF because activity F requires one of resource B and the availability of this resource is only one. This is the case because resource links in step 2 are created only when the prescheduled activities release resources with their completion, enabling the delayed activity to start immediately. In other words, there are no resource links between activities, if the completion of the pre-scheduled activities does not immediately affect the delayed activity's start, although the released resources are transferred to the delayed activity. In order to find those unidentified resource dependencies, every activity of nonzero TF will be checked by delaying the completion time day by day, and a resource link will be created between activities that have resource dependency. In the schedule, activities D, E, and F have total floats of 3, 7, and 2, respectively. Activities D and F can have their full TF, but activity E cannot have its full TF due to the limit of resource B and activity F. Hence, a resource-constrained link between activities E and F is created as shown in the figure 10.

This final schedule may be acceptable within the current known conditions such as resource limit, technological dependency, equipment condition, material delivery time, etc., but the RCPM algorithm continues for one more step in order to find alternative schedules. Due to

the characteristics of the resource link, an activity that has successors by resource links may be delayed beyond its TF period without affecting the project completion time.

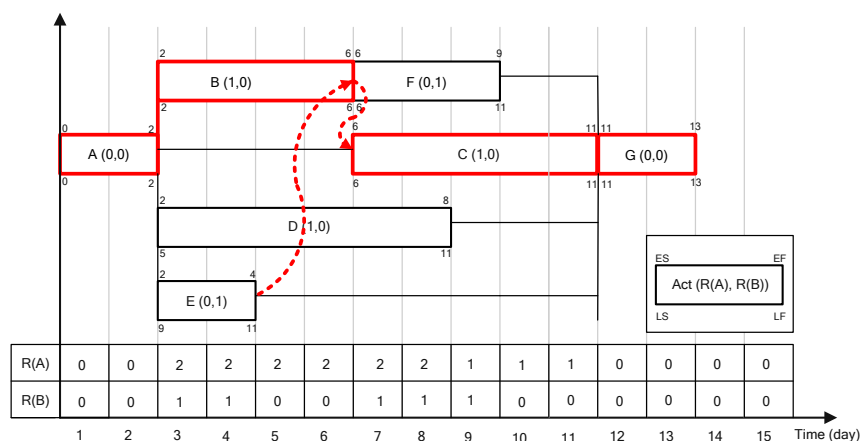


Figure 10: Schedule in step 4

STEP 5: FINDING ALTERNATIVE SCHEDULE

In this step, every activity that has a successor by a resource link will be checked for whether an alternative schedule is available. The original resource link from activity E to activity F is removed and a new link from activity F to activity E is created as shown in figure 11. In this schedule, activities E and F have become critical because of the new link caused by resource B. This schedule appears inferior to the previous one because it makes two additional activities critical. This could be valuable in some special cases. For instance, if activity E's start from the original schedule seen in the figure 7 should be delayed at least five days due to certain reasons that were not considered during the scheduling process, such as unexpected equipment repair, material delivery delay, etc., the project completion will be extended by more than one day, since the TF of activity E is only four. In this special case the alternative schedule can be employed.

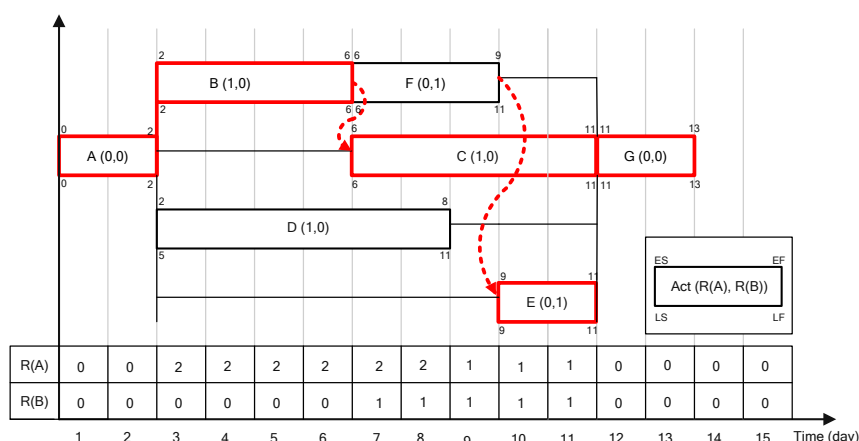


Figure 11: Alternative schedule in step 5

2.9.2.3 RCPM System

A prototype system has been developed to implement the proposed algorithm using Visual Basic 6.0, Visual C++ 6.0 and Ra (P3 API). Most functions to implement the RCPM procedures are written in C++ and built into a DLL file. The Visual Basic part reads required data directly from P3 and executes the procedures communicating with functions in the DLL file.

On the other hand planners use RCPM scheduling when they recognize the resource constrained problem, with dummy activities and their relationships. It is also possible to define the dependency in resource constrained scheduling in that way.

2.9.3 Methods and techniques for Resource scheduling

During the time analysis we obtained the early and late start and finish times of the activities. During these procedures no resources were assigned to the activities. Nevertheless, the completion of individual tasks requires different resources in practice – manpower, machines, materials and subcontractors. The limitations of these resources can influence the start and the finish of activities and sometimes the duration of the project. On the other hand, even if the resource requirements for projects are far below the limitations, a good arrangement of the activities can cut the peak resource requirement and thus makes the project more efficient. No

doubt, systematic and optimal planning of resource demand can cut the project cost and its importance is therefore growing.

The heuristic procedures that optimize resource handling procedures can be divided into two groups. One, when the assumption of limited resources has to be satisfied. Procedures that arrange activities in this way can lengthen the project duration that has been gained from the ordinary time analysis. These kinds of procedures are called resource allocation procedures. Procedures of the second group can not change the duration of the project. In these cases more efficient resource utilization is the main goal. These methods are known as resource levelling. Procedures that allow the change of project duration are the topic of Resource Allocation (limited resources).

Terms of allocation and levelling and are widely used in the above mentioned sense, but other definitions are also used in practice. An often used approach is the one within which the term levelling covers all the resource optimization procedures and the term of resource allocation stands for the assignment of resources to the tasks of the project. The term resource allocation is used as a method that helps to utilize resources on the most efficient level in a way that allows the lengthening of the duration of the project. However, to avoid confusion, the term allocation with limited resources or levelling by keeping the project duration will always be indicated in the text.

2.9.3.1 Using optimal procedure

Both types of allocation methods are optimization problems in mathematical sense. The planner wants to make a schedule that satisfies all the resource limitations but causes the least increase in project duration in case of resource allocation (limited resources). When the project duration is fixed he or she wants to level the schedule so that the peak resource requirements will be as small as possible. Operational research offers a wide variety of different optimization techniques. Mathematical models for allocation and levelling can be created that can be later solved by Linear Programming, Integer Programming or other methods, e.g. different kinds of enumeration. The application of these models cannot be found in practice. The reason for this is that these models work with so many variables – even in the

case of a relatively small network. That makes the computational process very slow. The other side of the coin is that engineers know well that due to the bias in duration and resource estimation the optimal solution is just fiction and a close optimal solution from the practical point of view can be as good as a real optimum from the mathematical point of view. According to the above mentioned reasons, algorithms based on heuristic rules are instead of being based on the exact optimization procedures, based on practice.

2.9.3.2 Resource levelling

Resource levelling is also known as levelling within the float or smoothing is used when resource limits are far beyond the requirements, therefore they do not have any influence on the duration of the project. It is also used when the amounts of required resources are based on estimations and therefore a resource profile that is closed to the planned resource profile can be satisfactory. The efficient utilization of resources, that is, a better distribution of them can make the project more successful. The ideal resource profiles can be seen in the figure xy. Generally speaking, it can be stated that the closer the resource profile is to the ideal form, the lower the overall cost will be. Every sudden rise in the resource histogram, especially after the peak, is usually solved by hiring extra personnel, which results in extra costs.

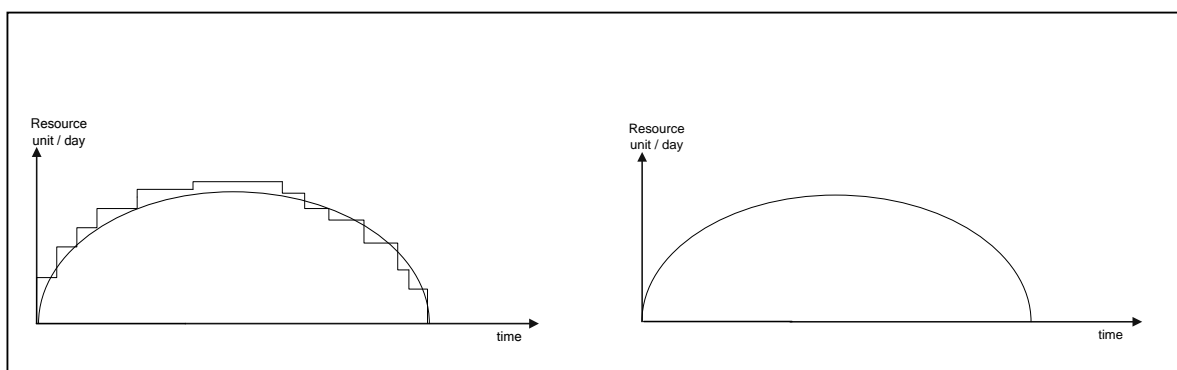


Figure 12: Ideal resource profiles

Resource levelling procedures are based on the idea of rescheduling activities within the limit of the early start and late finish times. A heuristic approach that uses the same thought will be presented below.

For the sake of simplicity it is assumed that there are no maximal types of precedence relationships in the network for which levelling is required. Finally, it has to be mentioned that the desired resource profile to which the resources will be smoothed can take any form. This depends on the planner.

Table 3: The legend of notation used in algorithm

| | |
|-------------|---|
| N | set of activities |
| A | set of precedence relationships |
| N | number of activities in the network |
| I | notation of an activity, $i=1 \dots n$ |
| S | start activity; no precedence relation runs into this activity |
| T | finish activity; no precedence relationships runs out of this activity |
| τ_i | duration time of activity i |
| f | the f^{th} day of the project |
| R_i | required amount of resource per time unit for activity i |
| SR_f | value of the resource histogram on the day f |
| ES / EF_i | earliest start/finish of activity i |
| LS / LF_i | latest start/finish of activity i |
| G_f | the desired amount of resource on the f^{th} day |
| V | $\sum (G_f - SR_f)^2; (f = 0 \dots p)$ the value of deviation between the desired and the actual resource diagram |
| S_i / F_i | scheduled start/finish of activity i |
| D_i | the maximal possible shift for activity i |

The algorithm is based on the observation that activities have to be rescheduled within the limits of their total or free float. The reverse order of the time analysis has to be followed. An activity can be taken into account if all the successor activities have been rescheduled. This implies that the algorithm has to be started with the finish activity. The activity has to be shifted to where it gives the smallest value of V. The iteration is finished when all the activities have been taken into account. In case of changes of any start time the whole

procedure can be repeated. To start the levelling, time analysis has to be performed and the resource histogram arranged for early starts has to be done.

2.9.3.2.1 Levelling algorithm

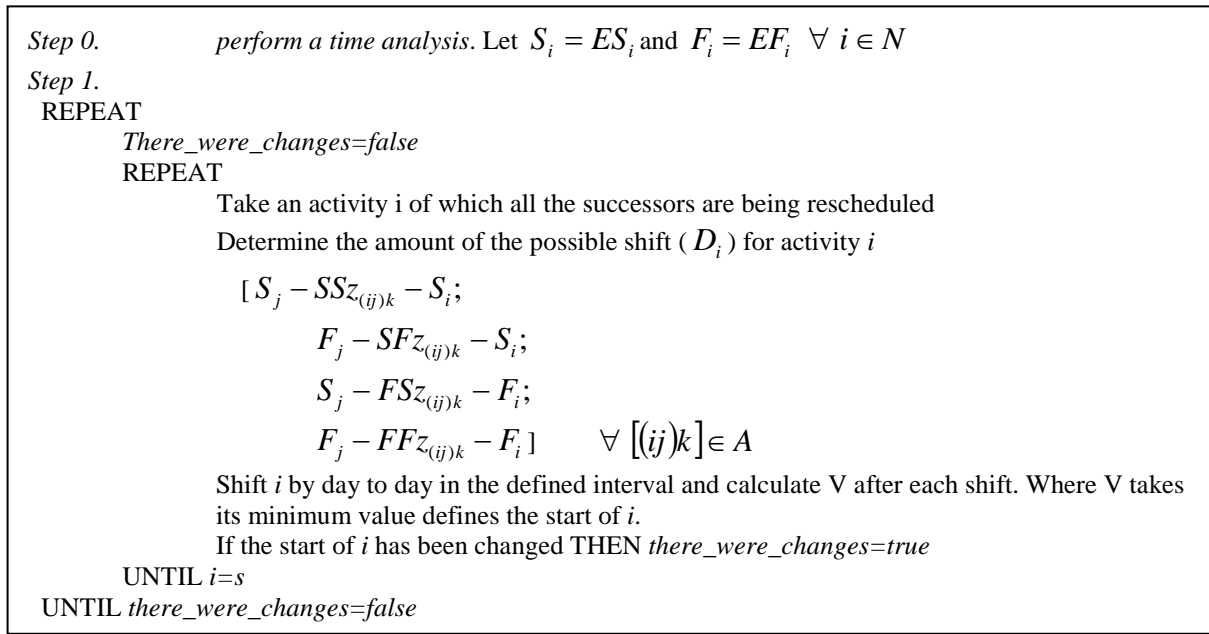


Figure 13: Levelling algorithm

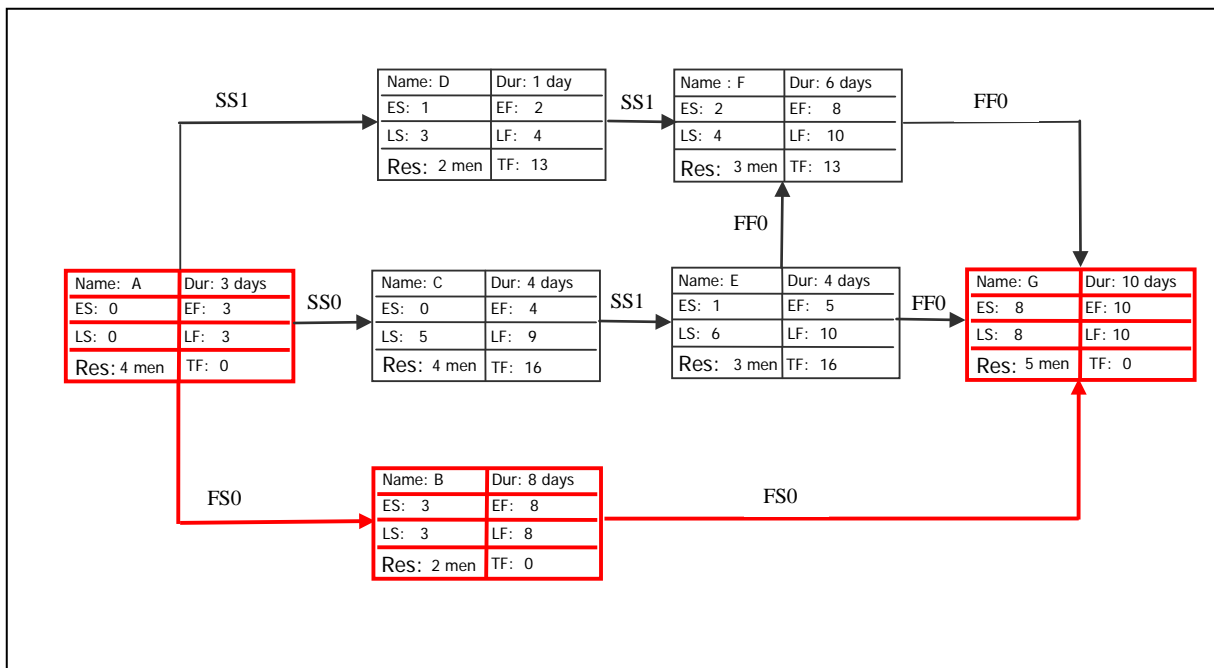
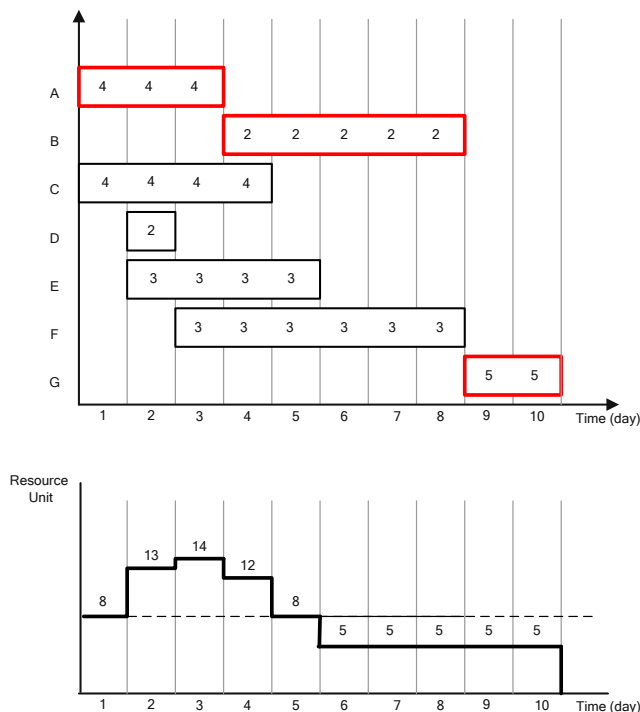


Figure 14: Time analysis of example project to illustrate the resource levelling procedure

Table 4: The legend of activity box configuration

| | | | |
|------|-----------------------|-----|----------------------|
| Name | Activity name | LS | Activity late start |
| Dur | Activity duration | LF | Activity late finish |
| ES | Activity early start | Res | Resource |
| EF | Activity early finish | TF | Total float |



Desired resource profil:

$$G_f = 8 \quad f = (0..p)$$

$$V = \sum (G_f - SR_f)^2 = 122 \quad (3)$$

Figure 15: Results of the time analysis and the resource histogram

In the first step we have to choose the activity which has to be shifted. Activity G is critical, therefore it cannot be shifted. A new activity has to be chosen. Activity B is also critical, so activity F is chosen for further computations. The maximum possible shift is two days. The deviation from desired profile is $V=122$ if the shift is zero days. One day shift will decrease the deviation to $V=62$, so activity F has to be shifted by two days.

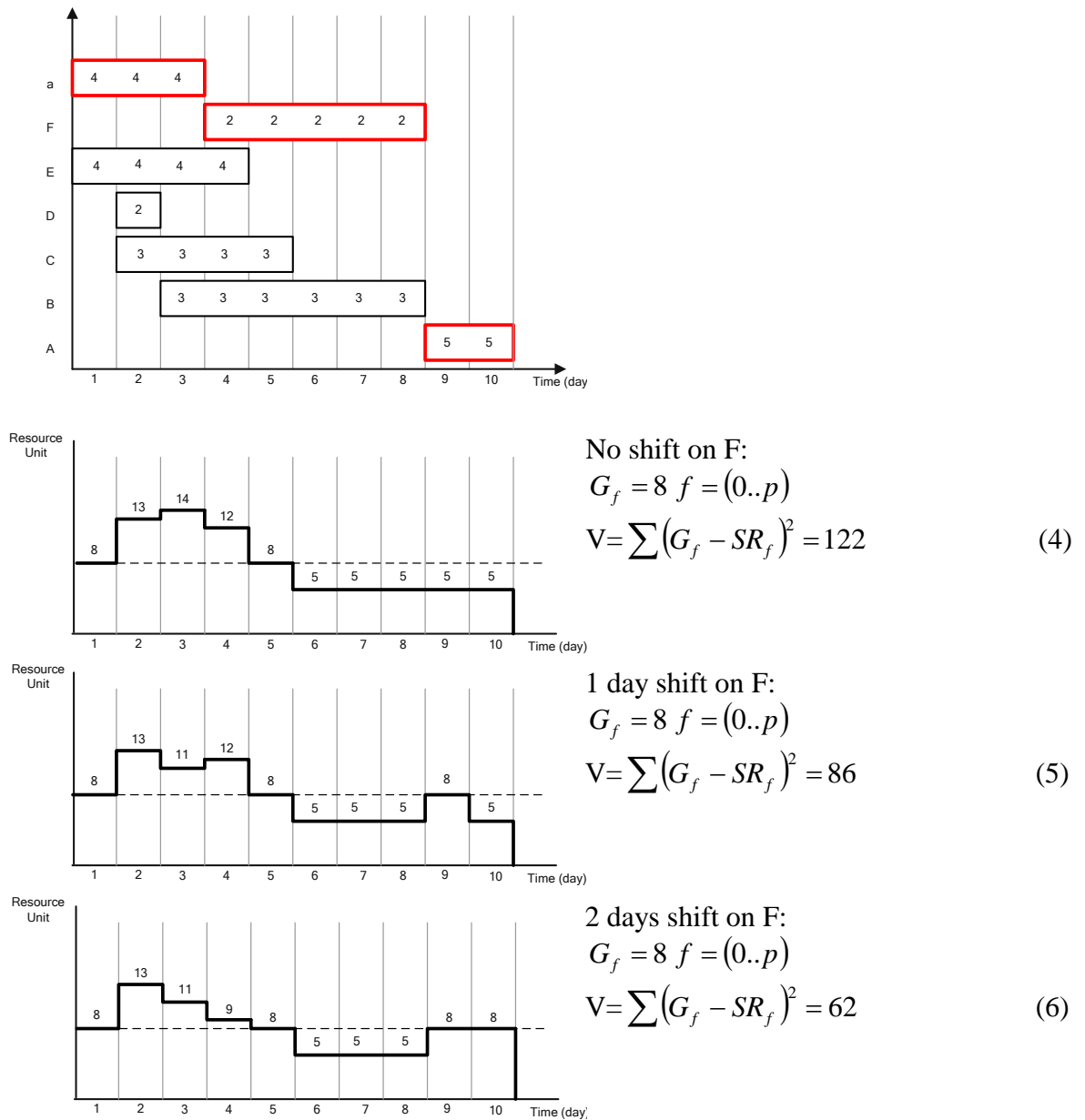


Figure 16: Resource levelling; examining activity F

We continue with rescheduling activities. Activity E gets the shift for three days and activity D for two days. There is no need for rescheduling activity C.

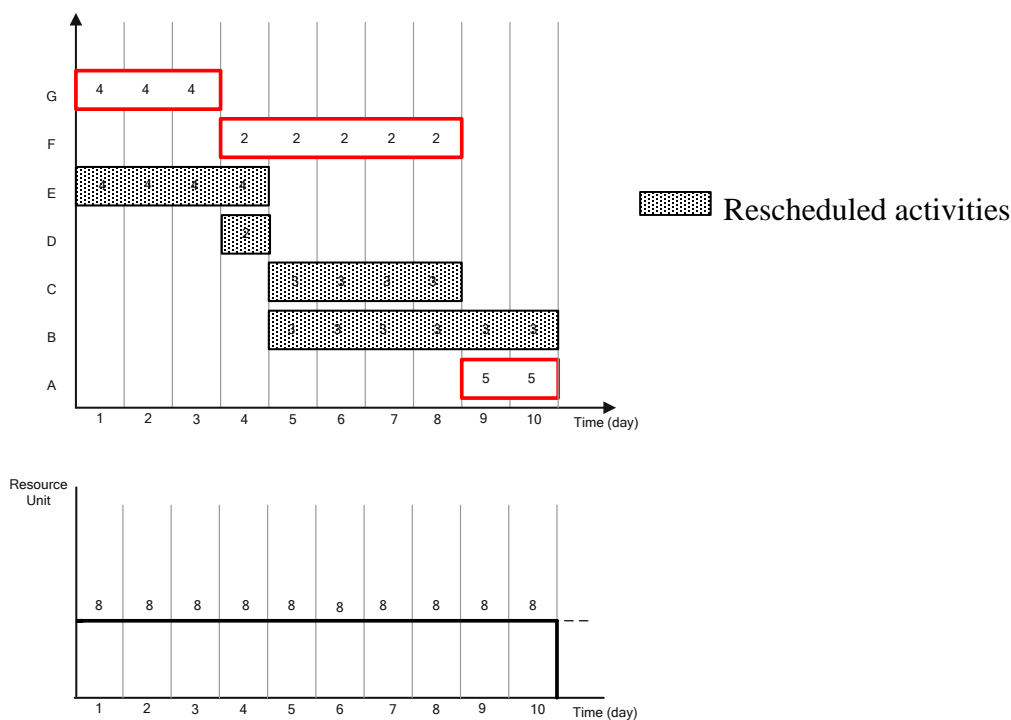


Figure 17: Resource levelling: final result

All activities and their resources are under the limit.

2.9.3.3 Resource allocation

Resource allocation, also known as resource constrained levelling, has to be used when resource requirements have to be below a certain limitation. It might happen that there is no feasible solution which satisfies the limitation if the project duration gained from the time analysis can not change. These procedures allow the lengthening of the duration of the project.

For the sake of simplicity it is assumed that there are no maximal types of precedence relationships in the network, which contains one start and one finish activity. Only one resource is limited and this limit does not change in time. In case of multiple limited resources or more start and finish activities, the algorithm will change slightly.

It has to be mentioned that the function describing the resource limitation can take any form, especially if it is used in the company level in multi project environment. Subtracting the resource requirements of a project from the company's resource pool will result in resource limitations that can change from day to day for the rest of the projects.

Table 5: Used notations during the allocation algorithm

| | |
|----|---|
| L | Resource limit |
| pp | Project duration (result of the allocation) |

A possible solution to the resource allocation problem can be using resource levelling to satisfy the resource limits. If the limits cannot be kept within the given project duration, then a fictive SF (p+1) relationship has to be added to the network between the start and finish activities. The application of this precedence relationship will increase the project duration by one day. Now, another levelling has to be performed for this increased project duration. If the resource requirements are still above the limits, the project duration has to be increased by another day and new levelling, must be performed. This procedure has to be continued until the result resource profile is below the limits.

2.9.3.3.1 Allocation algorithm

The above-mentioned procedure is rather time consuming, that is why a faster algorithm is going to be presented. It is similar to the algorithm used for the simple time analysis, but it is just being completed with resource handling step. It is on the observation that an activity can be arranged on the time scale if its predecessor activities are arranged, too. This implies that the algorithm has to be started with the start activity. Once an activity has been chosen, its start has to be calculated by its predecessors. Adding its resources to the resource histogram, it has to be examined if the resource histogram was below the resource limit or not. If not, the activity has to be shifted until the resource limits are satisfied.

```

Step 1.      Let  $ES_s = 0$ ;  $EF_s = ES_s + \tau_s$ ;  $SR_f = 0$  ( $f := 1 \dots \infty$ )
Step 2.
REPEAT
     $k := k + 1$ 
    REPEAT
        Take an activity  $i$  of which all the successors are calculated
        If there is no such activity, then GO TO step 3
         $ES_j = \max [ ES_i + SSz_{(ij)k};$ 
             $EF_i + FSz_{(ij)k};$ 
             $ES_i + SFz_{(ij)k} - \tau_j;$ 
             $EF_i - FFz_{(ij)k} - \tau_j ] \quad \forall [(ij)k] \in A$ 
         $EF_j = ES_j + \tau_j$ 
         $SR_f := SR_f + R_j$  ( $f := ES_j$  to  $EF_j$ )
        If  $SR_f > L$  then
            BEGIN
                Shift  $j$  in the time ahead until  $SR_f < L$  will satisfies for all  $f$ 
                If  $SR_f \leq L$  satisfies then  $ES_j = start$  of  $j$  and  $EF_j = ES_j + \tau_j$ 
            END
    UNTIL  $k=n$ 

Step 3.
If  $f < n$  THEN STOP! (There is a loop in the network) ELSE  $p = EF_i$ 
    
```

Figure 18: Allocation algorithm

Backward calculations based on the reverse order of forward calculations can be performed as well. The procedure has to be started from the time policy and the resource histogram (SR_f) gained from the forward calculations. An activity can be chosen if all the successor activities have been arranged for the latest start or finish times. Once an activity is chosen, it simply has to be shifted to the latest possible occurrence where the histogram is still below the limit. Knowing the latest and earliest times of activities, the critical activities can be defined. However, the latter does not make much sense. Different heuristic rules lead to different early and late activity times, as well as different project durations. It is hard to believe that an activity which has been indicated as critical according to some heuristic computations, will not be critical according to another heuristic calculations, where the project duration is shorter

than in the first case. Application of exact optimization methods can help a lot to solve these theoretical problems.

The resource limited scheduling problem depicted in the figure 19 illustrates the algorithm. The availability of the resource is limited to 4 men.

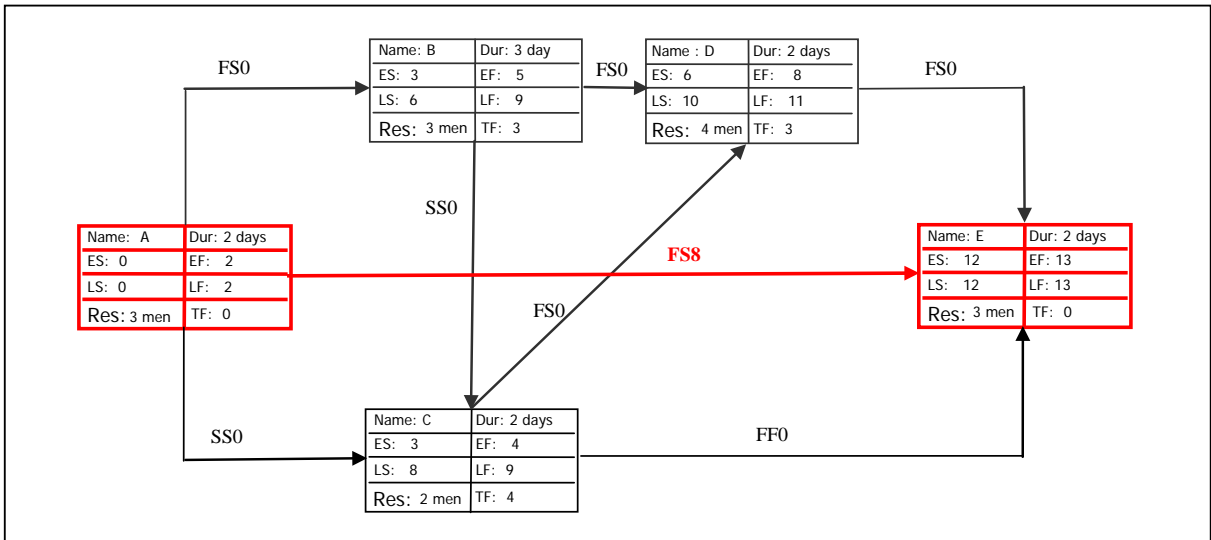


Figure 19: Time analysis of example project to illustrate the resource allocation

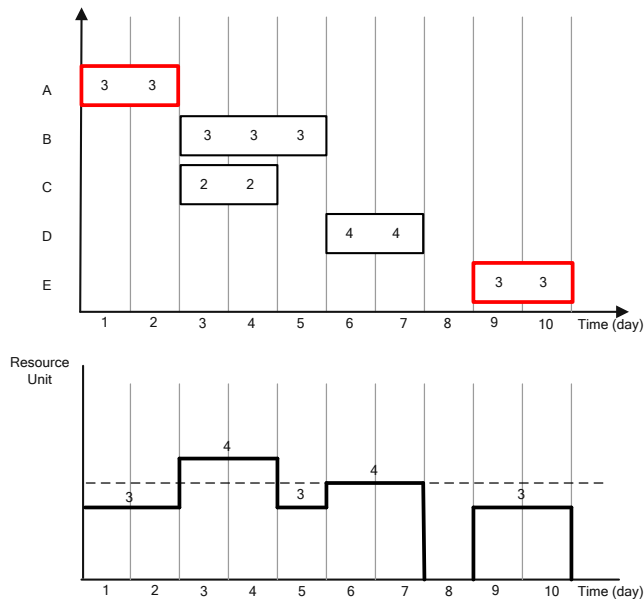


Figure 20: Results of time analysis and resource histogram

It can be seen that the resource limit makes this time policy non-feasible. The result of the resource allocation can be seen in the figure 20.

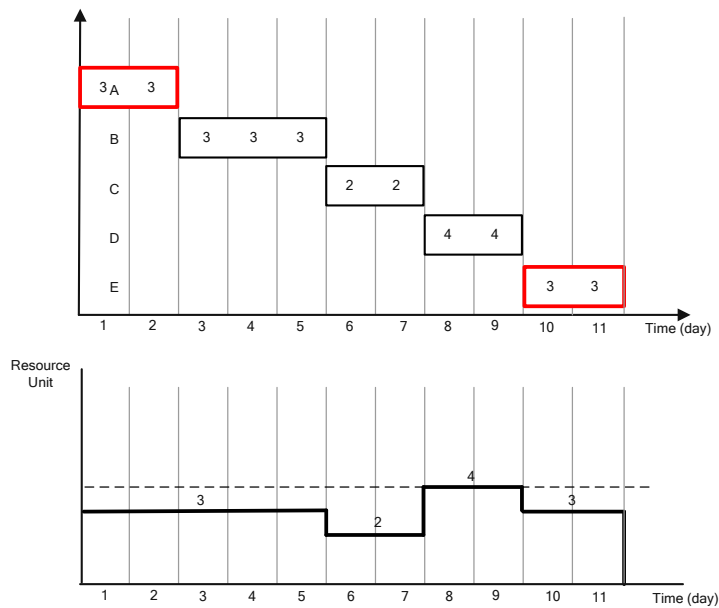


Figure 21: Results of resource allocation procedure

The calculation starts with scheduling activity A. The resource requirement of the activity has been added to the resource histogram. The only activity for which all predecessors are scheduled is activity B, therefore activity B is chosen for further computations. Based on its predecessors, it can be started on day 2 and finished on day 5. Activity C is the next in the queue. Based on its predecessors, it can be started on day 2, but a conflict arises when adding its resources to the histogram. To solve this resource conflict, its start has to be shifted to day 5 and it will be finished on day 7. Activity D can be chosen for further computations. According to the previous shift in the start and finish of activity C, activity D can start on day 7. Finally, activity E can start on day 9. The new project duration that satisfies the resource limitation is 11 days.

Remarks to the algorithm:

It is possible that more activities can be taken into account at the same time. In this case the scheduler can decide what activity should be next. The following rules can be applied for choosing among the activities:

- Choose the activity with the greatest resource demand.
- Choose the activity with the greatest total float.
- Choose the activity that has the minimum early start time.
- Choose the activity that has the maximum late start time.
- Choose the activity with the smallest priority.

It can never be known which rule gives the better solution. Rules that perform well in some cases can perform poor in others.

2.9.3.4 Aggregation

Aggregation is the simplest among the methods of scheduling the resources. It is a method of determining the total number of resource units required on a time basis throughout the life of the project. The most frequently used unit is a day.

The method of aggregation is created with a number of cells into which the resources are accumulated. This table will normally have one cell for every time unit of the project or period of interest, e.g. the next three months. Each activity of the network is then examined to see if it uses the resources which are of interest in this exercise. The resources required for this task are the same as in the case seen in the figure 14 and then added to the appropriate cells in the main table. At the end of the list of activities, the contents of the table can be printed in a variety of ways; as a table, as histogram, as bar chart or as a part of a management report.

Table 6 : The example illustrates the method

| EARLY START AGGREGATION | | | | | | | | | | |
|-------------------------|---|----|----|----|----|---|---|---|---|----|
| DAY | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| ACTIVITY | | | | | | | | | | |
| A | 4 | 4 | 4 | | | | | | | |
| B | | | | 5 | 5 | 5 | 5 | 5 | | |
| C | 4 | 4 | 4 | 4 | | | | | | |
| D | | 2 | | | | | | | | |
| E | | 3 | 3 | 3 | 3 | | | | | |
| F | | | 3 | 3 | 3 | 3 | 3 | 3 | | |
| G | | | | | | | | | 5 | 5 |
| TOTAL (ES) | 8 | 13 | 14 | 15 | 11 | 8 | 8 | 8 | 5 | 5 |

| LATE START AGGREGATION | | | | | | | | | | |
|------------------------|---|---|---|---|----|----|----|----|----|----|
| DAY | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| ACTIVITY | | | | | | | | | | |
| A | 4 | 4 | 4 | | | | | | | |
| B | | | | 5 | 5 | 5 | 5 | 5 | | |
| C | | | | | 4 | 4 | 4 | 4 | | |
| D | | | 2 | | | | | | | |
| E | | | | | | 3 | 3 | 3 | 3 | |
| F | | | | 3 | 3 | 3 | 3 | 3 | 3 | |
| G | | | | | | | | | 5 | 5 |
| TOTAL (LS) | 4 | 4 | 6 | 8 | 12 | 15 | 15 | 15 | 11 | 5 |

This is the basic principle of aggregation, the resource requirement being slotted into the cell with the corresponding times of activity. In most network calculations there are two sets of calculated time: the early times and the late times. The aggregations can be done with either of these sets and consequently an early start aggregation or a late start aggregation is obtained. Obtaining the two tables is useful for the project manager as an initial guide to the flexibility that exists in the project, as well as potential loading.

In the example seen in the table 6 there are two results; the first one being early start aggregation and the second one late start aggregation.

The movement of requirement from the beginning of the project towards the end is typical of many situations and is the key which other scheduling heuristic techniques use as an advantage.

2.9.3.5 Cumulation

The cumulation method provides a running accumulation of the resource requirements during the life of the project. The input of this process is the output of the aggregation calculation. In the cumulation the aggregation results are accumulated on a running basis. Using the example of the table 6 again we get:

Table 7: Table of results of cumulation calculation

| | | | | | | | | | | |
|----------------------------|---|----|----|----|----|----|----|----|----|----|
| EARLY START AGGREGATION | 8 | 13 | 14 | 15 | 11 | 8 | 8 | 8 | 5 | 5 |
| LATE START AGGREGATION | 4 | 4 | 6 | 8 | 12 | 15 | 15 | 15 | 11 | 5 |
| EARLY START CUMULATION | 8 | 21 | 35 | 50 | 61 | 69 | 77 | 85 | 90 | 95 |
| LATE START CUMULATION | 4 | 8 | 14 | 22 | 34 | 49 | 64 | 79 | 90 | 95 |

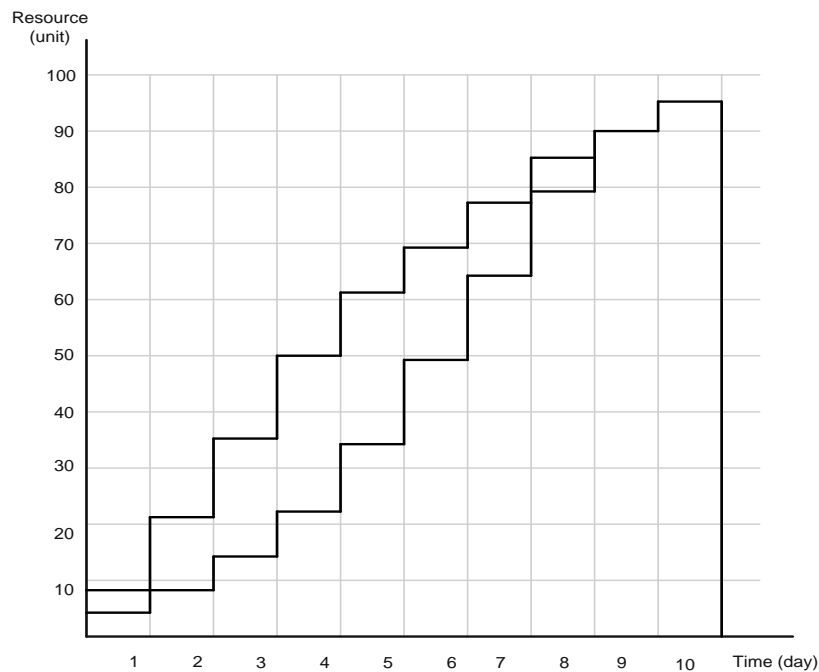


Figure 22: Graph of results of cumulation calculation

The result gives the project managers the total resource usage, which can be expected from the start of the project to any time in it. For example, by the seventh day in this simple case 77 units of resource will be required of the total 95 units.

It is even more useful, if both the early start and late start aggregation are cumulated. What the user is given are the bounds within which normal resource usage should move during the performance of the project. The normal use of this method is when working with costs, which are in effect a particular form of resource. As reports of progress are obtained, the manager can quickly determine if they are in the bounds of reasonableness by checking, whether the figure lies within the envelope of the cumulation. This is not a fool proof test, but it can give early warnings of possible catastrophes.

It is also used as an initial guide when management sets up a new team for a project. The gradient of the minimum slope straight line that lies within the envelope gives an indication of

the rate at which each resource will be used at the various stages of the project. In this simple example the eight phases of start-up, main progress and completion have different resource demands that can be seen by drawing eight lines in the envelope.

2.9.3.6 Smoothing

The objective of the smoothing method is to produce a feasible schedule within the time constraints with a uniform level of resource requirement or planned usage.

In the allocation routines it is very difficult to produce a schedule which is time limited and where the resource requirement does not suddenly explode into unacceptable dimensions. The smoothing procedure looks at the whole project and works within the time frames of the project that have been set by the user. There are four steps in the cycle which repeats until all activities have been scheduled.

- Schedule any critical activities
- Find the most important activity yet to be scheduled
- Find the best place to schedule this activity and do so
- Adjust the early and late times of the unscheduled activities to take account of this new scheduled activity

The overall attack of this procedure is to work within the float of activities in order to find a good place for them to be scheduled. Float can be added to all activities by increasing the duration of the project calculated by the time analysis. Since activities with no float on them cannot be moved, the first step is to schedule them in the time slots they need as defined by their start and finish times. The resources which are needed to accommodate this work are also recorded as in the aggregation process.

Once the decision has been made to work within the limits of the time frame and not to allow automatic extensions, there are three items which measure to some extent the importance of the activity, amount of work to be done (TW) and the float remaining (FR) or the flexibility in

choosing a time slot for this task to be scheduled. The latter two items are simple numeric calculations and so a computer program can easily produce a single number which can be formulated as:

$$F = \frac{TW}{FR} \tag{7}$$

The activity with the largest factor of this kind has either a lot of work or very little flexibility and is sifted from those that need to be scheduled. The complication of the conflicts caused by multiple resources will be touched on later.

Having selected an activity to schedule, it is necessary to find the best place to put it there. This is not as difficult as it seems, for the many managers when confronted with the situation of this partial schedule intuitively guess what to do. The best place is the one where the resources utilization to date is the lowest within the span of the early start and late finish times of this activity. This is shown in the figure 23.

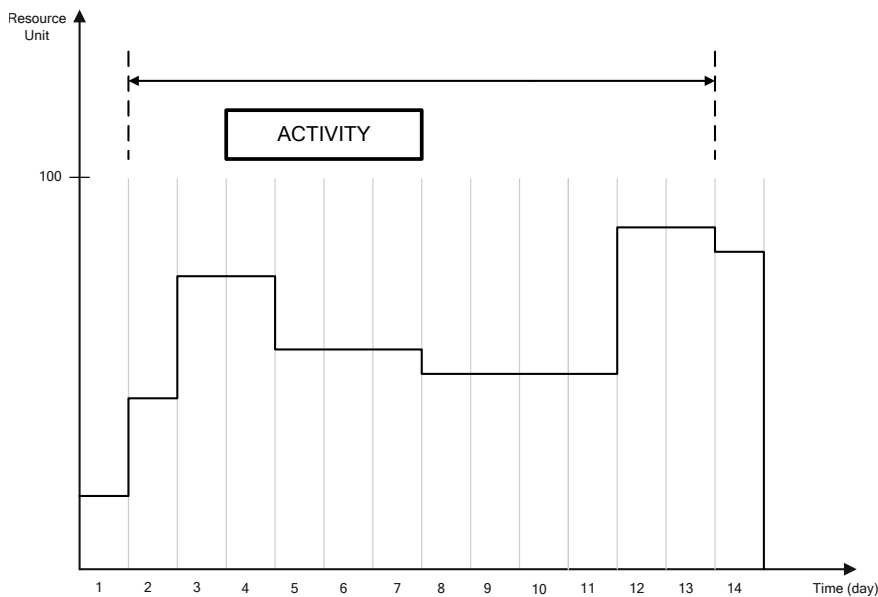


Figure 23: Scheduling and activity in smoothing

PM software cannot view the profile in the way that the project schedule does in order to deduce the slot in which to schedule the activity. The only automated approach is to try the activity in every feasible position and make a judgement on how good the result is. The simplest statistical test is to take the sum of the squares of the resource requirements in this time span for each possible schedule slot and compare them. The best, that is the lowest, or if two or more are the same, the earliest is then selected as the schedule for this particular activity. The effect of this sum of squares test is to force the procedure to avoid any peaks in the resource profile if possible and to prefer to fill in the valleys.

It is easy to create an image when there is only one resource to manipulate but in real life there can be many associated with the project. A method needs to be devised to separate conflicts that arise when resource A needs to be in one slot and resource B would prefer to be in a different one. The easiest way out is to use qualitative ranking of the resources. By this, some of the problems of relative importance to electricians and plumbers can be avoided. If this approach is adopted, then all tasks with the highest priority resource are scheduled before looking at any of the others.

This seems arbitrary, but it is not too far away from the way a person would work. It opens the door for easy production of alternative schedules when the administrator is insured of the key resource as far as the project is concerned. In general terms it will be the one doing the most work within the longest time span, but it may not be. It almost certainly will not be the best paid or the most costly resource. The other item of interest with this procedure, as compared to allocation methods, is that a prediction of the final resource level is not required.

2.10 Earned Valued Analysis

The earned value analysis (EVA) in its various forms is the most commonly used in one in the method of performance measurement controlling process. The Cash flow chart presented in chapter 4.6.2.3. is the base for EVA, which integrates scopes, cost (or resource) and schedule measures to help the project management team assess project performance. The earned value (EV) involves calculating three key values for each activity:

- The planned value (PV) is the portion of the approved cost estimate planned to be spent on the activity during a given period.
- The actual cost (AC) is the total of costs incurred in accomplishing work on the activity during a given period. The AC must correspond to whatever was budgeted for the PV and the EV (e.g. direct hours only, direct costs only, or all costs including indirect costs).
- The EV is the value of the work actually completed – the budgeted cost of work performed.

These three values are used in combination in order to provide measures of whether or not a working task is being accomplished as planned. The most commonly used measures are the cost variance (CV) and the schedule variance (SV).

$$CV = EV - AC \quad (8)$$

$$SV = EV - PC \quad (9)$$

These two values, the CV and the SV, can be converted to efficiency indicators to reflect the cost and schedule performance of any project. The cost performance index (CPI) is the most commonly used cost - efficiency indicator.

$$CPI = \frac{EV}{AC} \quad (10)$$

The cumulative (the sum of all individual EV budgets divided by the sum of all individual ACs) is widely used to forecast the project's costs at completion. Also, the schedule performance index (SPI) is sometimes used in conjunction with the CPI to forecast the project completion estimates.

$$SPI = \frac{EV}{PV} \quad (11)$$

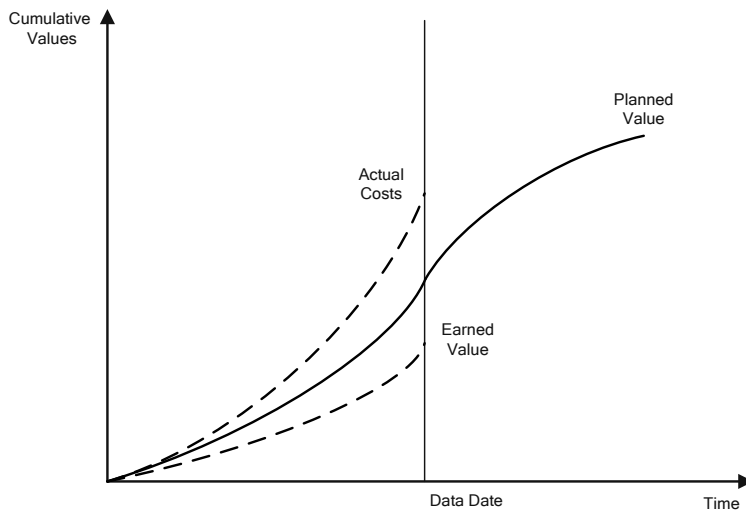


Figure 24: Illustrative graphic performance report

3 A CASE STUDY OF RESOURCE SCHEDULING

3.1 Introduction in a case study

The main objective of the Project Management Centre (PMC) at the Istanbul Technical University (ITU) is to gain international recognition as a centre of excellence in topics of project and construction management in both theoretical and practical applications through teaching, training, research and development and by providing the highest level of expert service to business practices. PMC also provides the construction management service for the needs of ITU.

After searching for the most suitable schedule, I decided to analyse the schedule of Molecular Biology Building (MBB). The schedule was prepared while attending a master programme. It was based on construction management at PMC in ITU, its author being Ebru Baykal, a master student in the academic year 2003/2004. All calculations, quantities and assigned resources in the schedule were prepared by Ebru and show the Turkish construction characteristics. The schedule is not particularly complex and the presentation of resource constrained scheduling tools and techniques it is clear.

3.2 Presentation on the Technical University's Molecular Biology Building in Maslak Campus

This centre was designed to be the heart of the bio-technology and gene projects of Turkey. The centre with its laboratories, research and development facilities, as well as technological equipment serves both to the ITU Molecular Biology and Genetic Department's educational activities and to the power of Turkish research and development in international technology interface.

The building was designed to have a specific character in campus. In addition, geometry, interior space use and details are kept on minimum, while contemporary needs are being

responded to. Integrated interior space design and transparent surface arrangements allow users to come together easily in order to have productive meetings.

On the ground floor there are coffee rooms, the library and service units. On the first floor there are classrooms, the computer lab and club rooms. On the second, third and fourth floor there are laboratories and on the fifth floor, there are administration and support units, as well as the end multi-purpose hall with suitable equipment to be used during various meetings and events.

In the basement there are labs and technical units. The basement, ground and first floor are visually connected by an interior space. The stairs and the elevator are placed parallel to the Büyükdere avenue and being three-dimensional, they surround the mass as a transparent shell. This shell in rectangular geometry serves both to separate the laboratory units and office units, as well as to define the area where the technical equipments is placed on the roof. The building is connected to the Arts and Sciences Faculty by means of a sub-level passage.

Table 8: Main data about MBB

| | |
|-----------------------------|--|
| Main function | Laboratories and Education |
| Design Project | Gülsün Sağlamer, Meltem Aksoy, Pelin Dursun Korkmaz |
| Investor | Istanbul Technical University |
| Static project | TEM Muhendislik Musavrlık Ltd. Sti. |
| Mechanic project | MECON Yapi Endustriyel Muh. Taah. ve Tic. Ltd. Sti |
| Electric project | ROTA-TEK Muhendislik Elektrik Ins. San. Tic. Ltd. Sti |
| Main contractor | Sibel Gurcu |
| Project management | ITU Project Management Centre, Attila Dikbas, Isilay Akkoyun |
| Construction Area | 3756 m ² |
| Main structure | Steel Frame |
| Date of design Completion | 1. 11.2003 |
| Date of construction start | 20.11.2003 |
| Date of construction finish | 1.8.2004 |
| Grant | Dr. Y. Müh. Orhan Öcalgiray |
| Costs of the project | 2 Million USD |



Figure 25: Photos of MBB

3.3 General information about the real case schedule of MBB using P3

The schedule has got 163 activities, 51 of which are lying on the critical path. There are 321 relationships between the activities, which are distributed as per the activity work breakdown structure. The list of activities can be seen in the appendix A. Appendix B shows the data of 80 different resources entered. The resources have been shown by labour values and have been

distributed to the relevant activities with normal distribution as per the activity distributions. The budget for the activities has also been distributed in the same manner.

The values of the resources and their unit costs show the united and weighed costs of the relevant activities with all the material costs and labour costs divided by the budgeted cost of the relevant item. This approach brings smart and condensed information regarding the activities, budgeted labour and budgeted costs, regardless of the material quantities and has been chosen as the general intention of the project management. This approach is used in order to sub contract the works on lump sum basis with a fixed price, have strict control of the labour at the site and the budgeted cost in the planning phase during the execution of the work.

3.4 Start and execution of the work

After site mobilization of the structural contractor, the earth works with excavation and back filling were started. After the earth works, structural works followed with formwork, reinforcement and concrete for foundation. Then structural and water insulation works for the basement started. The building of a full brick wall was planned to start right after the placement of protection concrete. After finishing the basement, steel structure works started with the erection of the first floor columns, the installation of main and sub beams and the montage of the trap slab surface. Then the installation of the connection plates could be executed.

The sequence of the steel structure works was planed floor by floor starting from the bottom to the top. When the main steel structure was built, the metal painting started as well as settings up the gypsum walls with aluminium facade. At the same time the site road works began with storm water installation and landscaping.

Finishing works began with laying down granite tiles for each floor, matt water based painting and the montage of doors and windows. The mechanical and electrical equipment installations and elevator installations were to be executed at this stage. The mechanical works comprised of the installation of sewer clean water, heating and the ventilation system. The electrical works were divided into weak and high current works. All building works were finished off with glazing.

3.4.1 Creating a work breakdown structure

After defining the scope of the project and creating a work breakdown structure (WBS) to define and organize the project elements, it is possible to clearly identify the deliverables and report and summarize schedule and cost data at different levels of detail. Graphically portrayed as a tree, a WBS is created by establishing a hierarchy of work to be accomplished, beginning with the end - product at the top and subdividing in successive levels down to the individual activity tasks at the bottom. A project cannot be controlled unless it is broken down into its tasks and coded for computer processing.

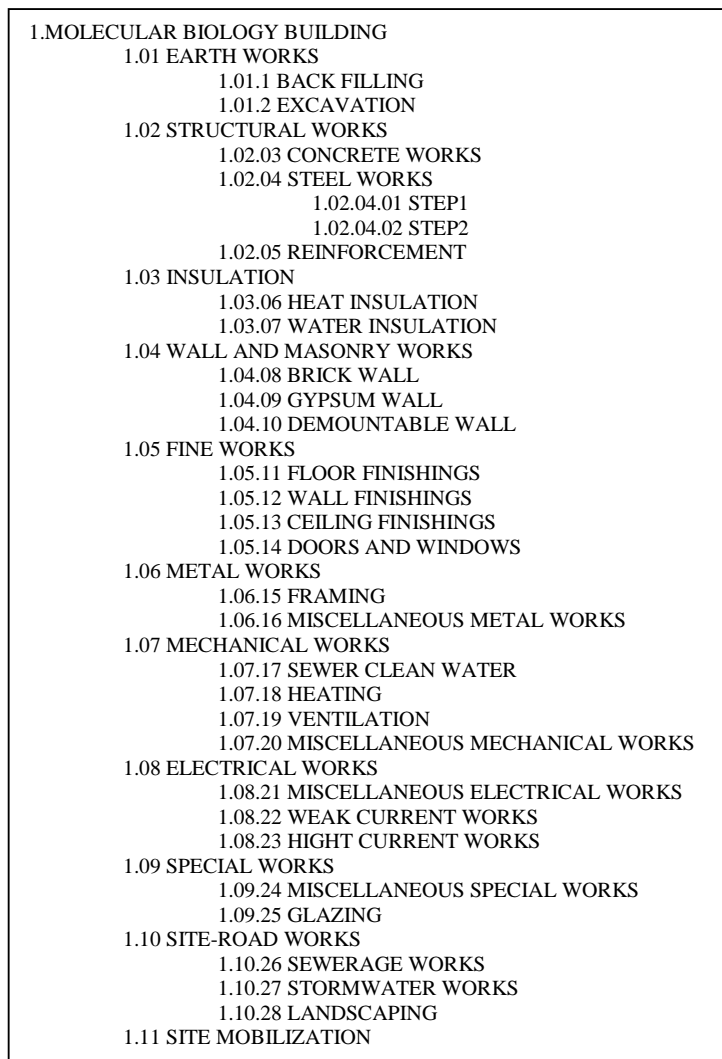


Figure 26: A Work breakdown structure for MBB' s schedule

3.5 Resource scheduling tools and techniques using P3 presented in MBB's schedule

3.5.1 Resource constrained scheduling using P3

Resource GW1 is used for erecting gypsum walls in the MBB's schedule. The activity Gypsum wall 10, with its identity number vWM01 and original duration of 30 days, has assigned GW1 resource. The total float of that activity is 7 days. If a group of workers, after the completion of constructing the 10 centimetre wide gypsum wall, starts with constructing a 20 centimetre wide gypsum wall, there will be no total float of Gypsum wall 10 activity. It means that the critical activity Gypsum wall 20 will use the resource GW1 30 days after its start. The resource constrained problem should be solved by dividing Gypsum wall 20 into two activities: Gypsum wall 20 and Gypsum wall 20A. Their durations are 30 days and 10 days. The resource GW1 is assigned to the new activity and additional relationship links are created: SF from Gypsum wall 10 and Gypsum wall 20. Successors of the new activity are the same as from activity Gypsum wall 20. The previous manual solution satisfies resource constrained requirements. Using levelling procedure in P3, it is possible to set and select splitting of activities.

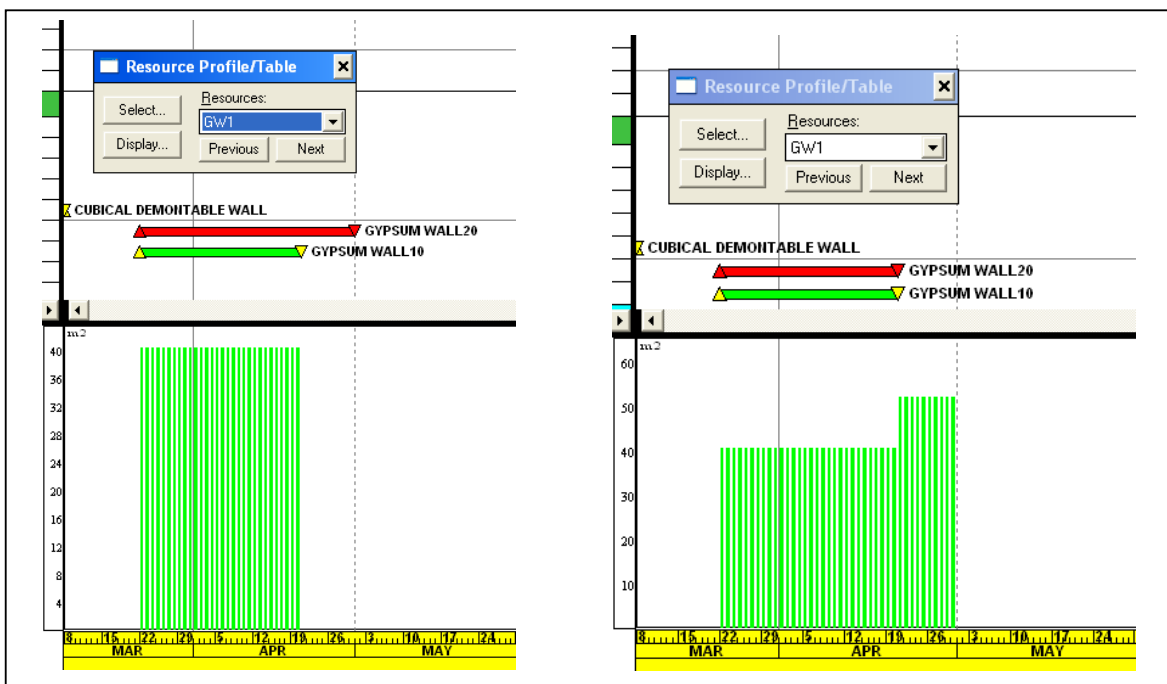


Figure 27: Activities before and after resource constrained requirements

3.5.2 Allocation in P3

P3 enables to develop a resource plan that integrates resources, costs and schedule to implement effective project control. Begin by building a dictionary of the resources necessary to complete the project; for each resource set availability limits, unit prices, and a calendar to define its standard work time and non-work time; then allocate resources to the activities that require them.

Using this information, P3 enables to produce resource reports and profiles. Analyze the resource allocation and adjust the project plan to avoid over allocation as well as the peaks and valleys of resource usage. The figure 28 presents a flow chart of a typical process of creating a resource driven schedule. After creating the list of resources required, the resources have to be allocated and measured.

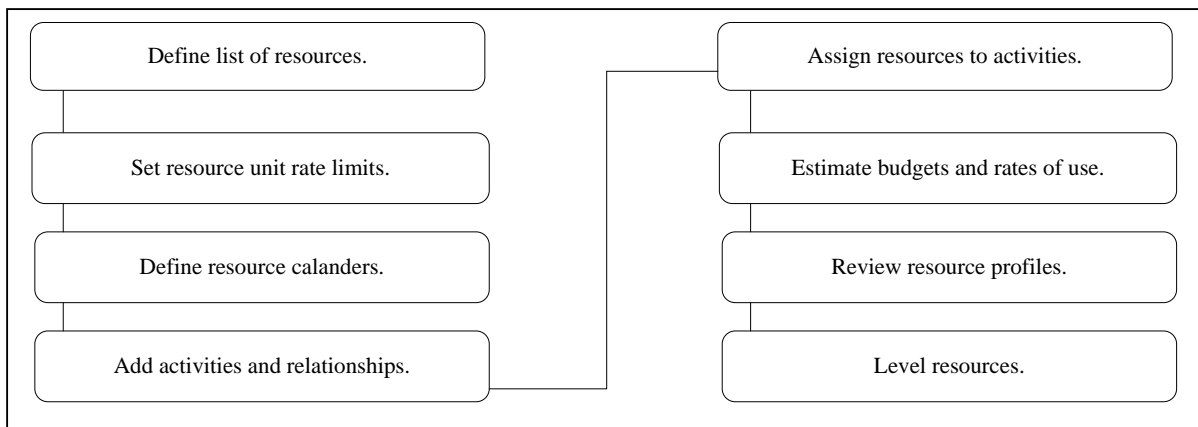


Figure 28: The process of using resources

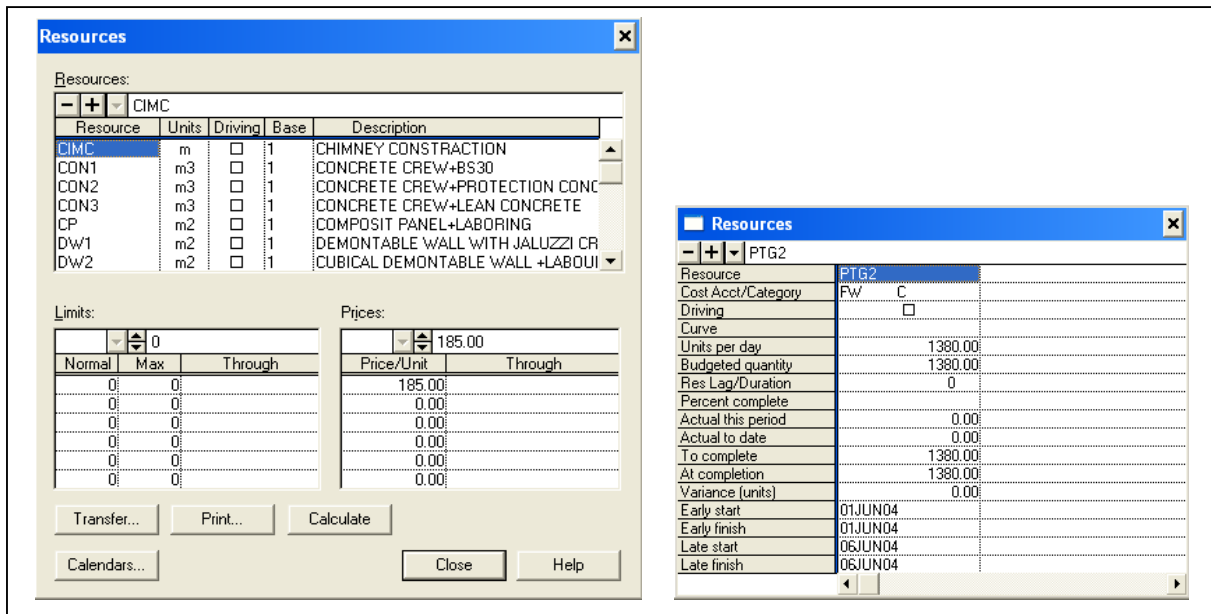


Figure 29: The windows in P3 for displaying resources, their requirements and resource measurement window

After assigning resources to activities, it is possible to see each resource profile of the whole project in P3.

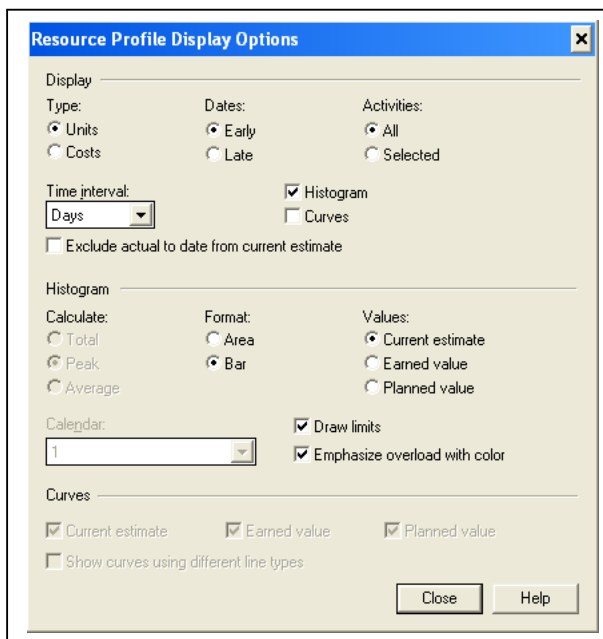


Figure 30: Resource profile display options in P3

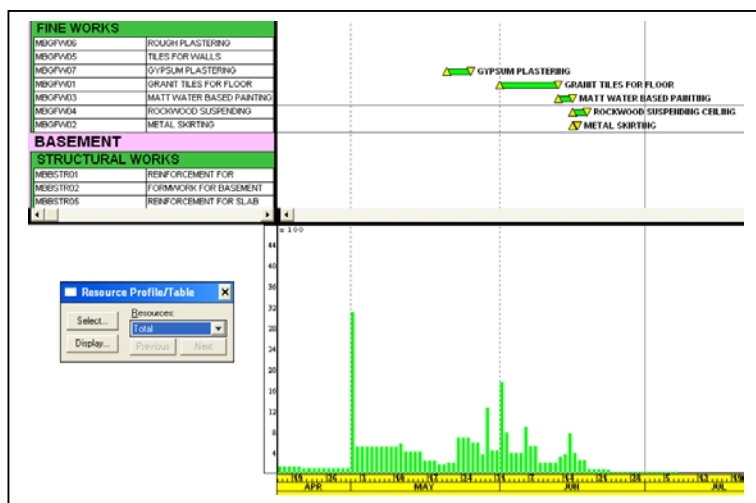


Figure 31: The resource profile in P3

3.5.3 Levelling in P3

Resource levelling is an automated process that delays the start of certain activities. During levelling, P3 compares the requirements of all scheduled activities to the maximum quantity available at the time of levelling. P3 delays an activity, if too few resources are available at any time during the activity's duration.

In P3, there is a possibility of selecting resources for levelling as well as specify the levelling priority for each activity. In addition to delaying activities until resources are available, P3 can decrease the overall duration of an independent activity during resource levelling. By using surplus available resources during any work period when they exist, P3 increases the units per time period of a resource, reducing the duration of that resource proportionately. This can reduce the overall duration of the overall activity.

During levelling, P3 can also make the work periods of a task or independent activity non contiguous. If it is allowed to split an activity, P3 can suspend work until sufficient resources become available on that activity.

The results of levelling can be seen in a bar chart. It is possible to set up a bar chart to show the following bars for activities: early bars (where they were scheduled after levelling),

unlevelled bars (where they were scheduled before levelling) and level delay bars and points (the amount of time they were delayed). P3 draws the level delay bar from the unlevelled start date to the levelled start date to illustrate the amount of delay; the level delay point is placed at the unlevelled start of the activity.

If there the automatic resource levelling function is turned on, P3 levels each time of scheduling the project or each time of modifying the data that affect levelling, such as when there is an addition, change or when a resource, calendar or relationship are deleted.

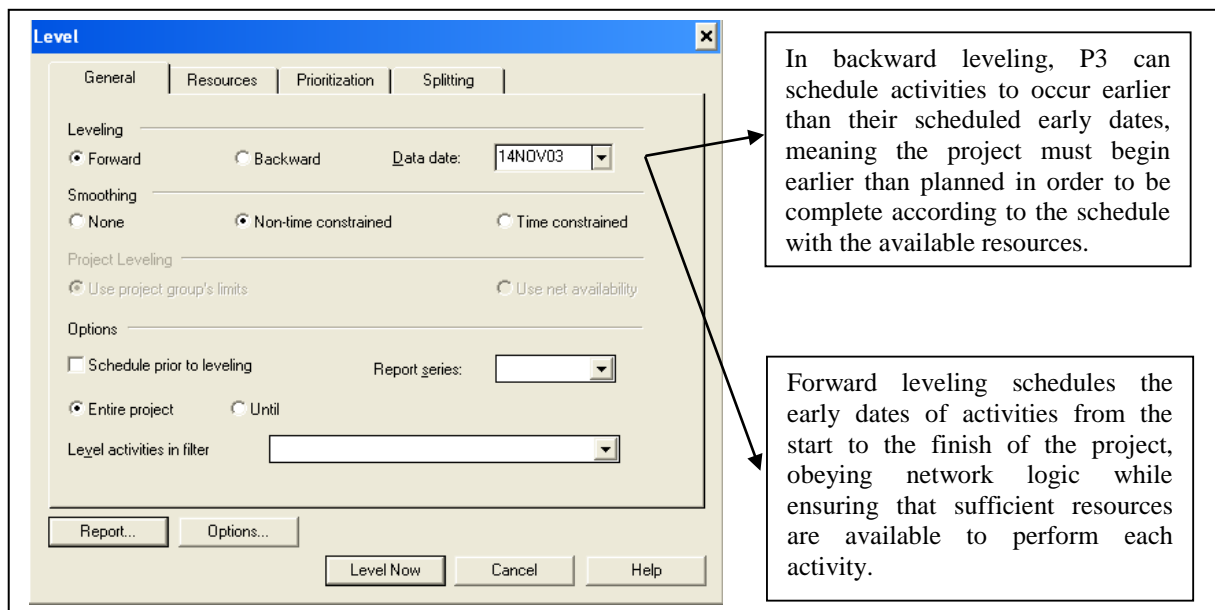


Figure 32: The window in P3 for levelling

Activities Gypsum Plastering, their identity numbers being: MBF3FW07, MBF1FW07 and MBBFW02, are using GPLS2 resource. It provides costs for material and plastering group. The total amount of work which has to be done is 2745 m², but because of the typical features of the plastering, the quantity of water based painting is limited from normal 160 m² to maximum 170 m² per day. Resource excess can be seen in the figure 33. It is possible to use levelling techniques in P3. The figure 34 present the successful result of levelling process.

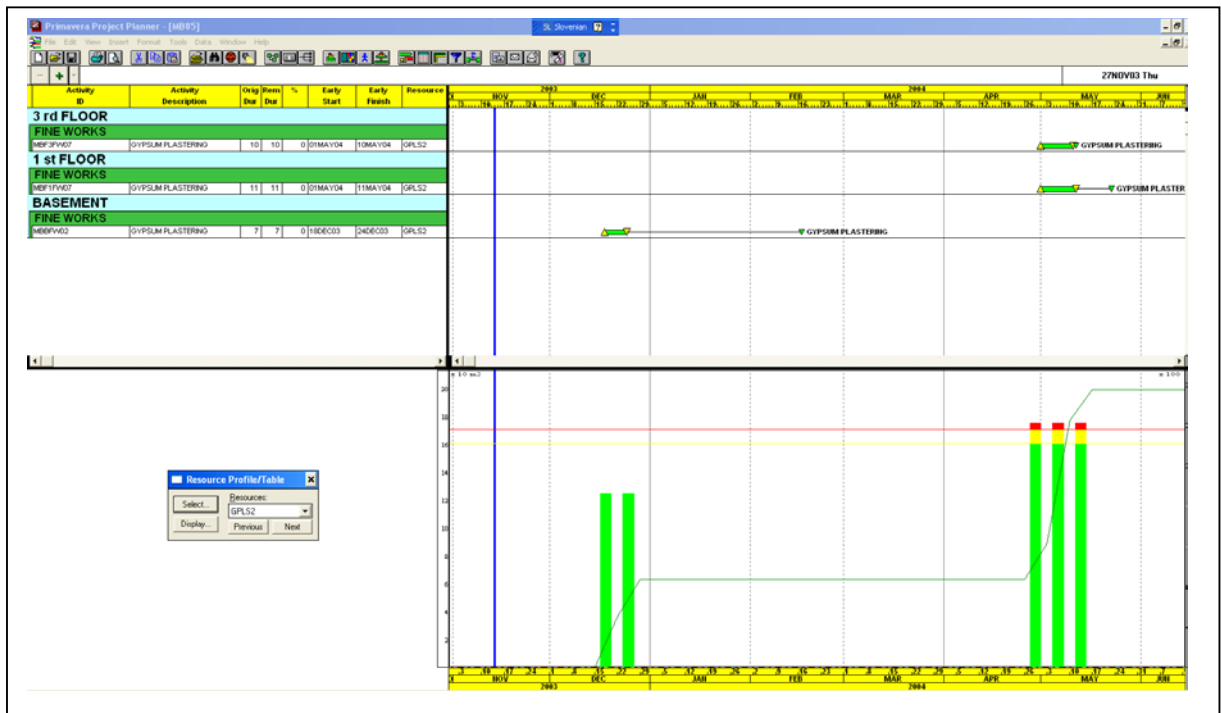


Figure 33: GPLS2 resource over limit

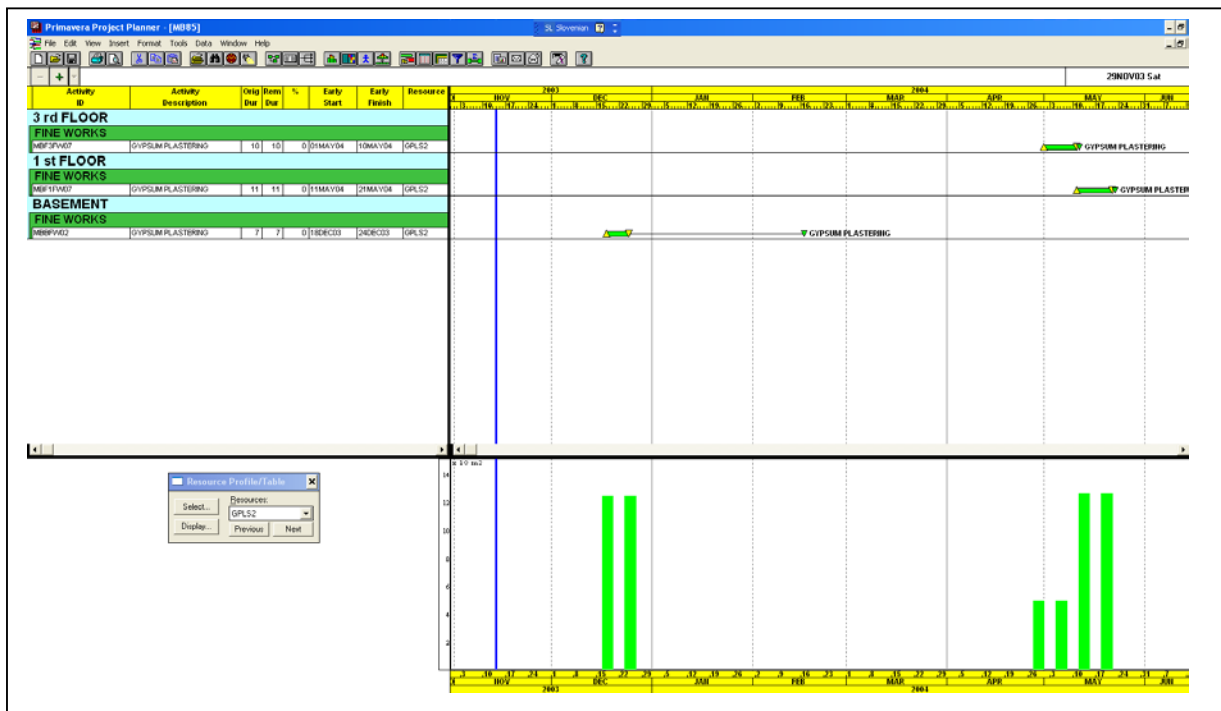


Figure 34: Result of levelling GPLS2 using P3

3.5.4 Smoothing in P3

During levelling, P3 refers to the normal and maximum availability limits in the Resource Dictionary. Sometimes the normal limit is insufficient to provide enough resource to schedule an activity. Without smoothing, P3 assumes the maximum availability of resources. Smoothing uses different assumptions about resource availability. By modelling incremental increases in availability, smoothing minimizes the peaks and valleys in the resource usage profile. This is often desirable: maintaining relatively constant resource levels can reduce costs.

Choosing none smoothing option when the normal and maximum limits of all resources are equal or nearly equal. Using this option, P3 tries to schedule an activity within its float span using the normal resource limit. Levelling without smoothing schedules activities as early as possible, using total float to delay others while keeping usage below the maximum limit. If there is an insufficient resource, P3 tries again, beginning at the early schedule date, using the maximum limit. This method may result in overestimation of the amount of resource being used.

For example, if an activity requires 6 units per time period of a resource that has normal and maximum limits of 5 and 15, respectively, P3 makes all 15 units available to the activity.

Choosing the non - time constrained option when the normal and maximum limits significantly differ. This method of levelling attempts to keep resource usage as close to the normal limits as possible, using positive float to delay and stagger activities rather than using the maximum quantity available and scheduling several activities to occur simultaneously. This technique can produce a smoother profile of resource use than levelling without smoothing.

P3 divides the range between normal and maximum into ten increments. If the activity cannot be scheduled assuming normal limits, P3 delays the activity for one work period (within its available positive float) and tries again. After exhausting the float, P3 begins the entire levelling process again on the original date, this time increasing the availability assumption by one increment (ten percent of the difference between the normal and maximum limits). P3

repeats this process, if necessary, until it reaches the maximum limit. If the activity still cannot be scheduled, P3 continues assuming the maximum limit and delays the activity for one work period at a time, repeating the process and causing negative total float if necessary.

Choosing the time constrained option when the project must finish on time, regardless of the resources required. P3 levels activities assuming double the normal and maximum resource limits, and proceeds as when using the none option; however, no activity is delayed beyond its late schedule dates. If P3 cannot schedule an activity within its available float, the activity occurs on its original schedule date and a warning message appears in the Resource Levelling Analysis Report. No changes are made to the Resource Dictionary, but P3 reflects the doubled maximum limits in the Resource Levelling Analysis Report.

3.6 Reports on the schedule using P3

P3 provides some very beneficial reports and graphics for cost analysis and forecasting, which enable the communication regarding detailed or summarized information about the projects between the scheduler, site and the project manager. To make the most suitable report, it is necessary to determine the content, format, order and the selection of activities, among other options. After determining individual reports or graphics, or a series of reports or graphics, it is possible to print them.

P3's wide variety of reports provides multi-dimensional views of the project. For a simple one-dimensional view of the schedule or the resource/cost data, choose schedule reports, resource/cost control reports, resource productivity/cost, price, and rates reports, earned value reports, tabular resource/cost reports, or resource/cost loading reports. The activity and resource/cost matrix reports add a second dimension because schedule data can be combined with resource/cost data in a cross tab report. Custom reports give the opportunity of expanding the presentation to a third dimension by including custom or calculated data, which are not included in the standard reports.

Generally speaking, projects contain many activities, a smaller number of resources and an even smaller number of cost accounts. Once the project is under the way, it is necessary to

modify the schedule to keep it current. Cost accounts help to track budgets and accumulated resource use, actual costs as well as the estimates of costs to complete. The main aim of using cost accounts is to review costs at a summarized or a detailed level for any group of activities in the project, e.g. when organizing layout by cost account and including cost data columns in the list of activities to review cost accounts at a detailed level. For example, one cost account may represent the efforts of an entire department containing 40 people working on 100 tasks. Developing a cost account structure enables each cost account's presentation of a unique project component. It is also possible to establish separate cost categories to classify resources into categories such as labour, material or equipment.

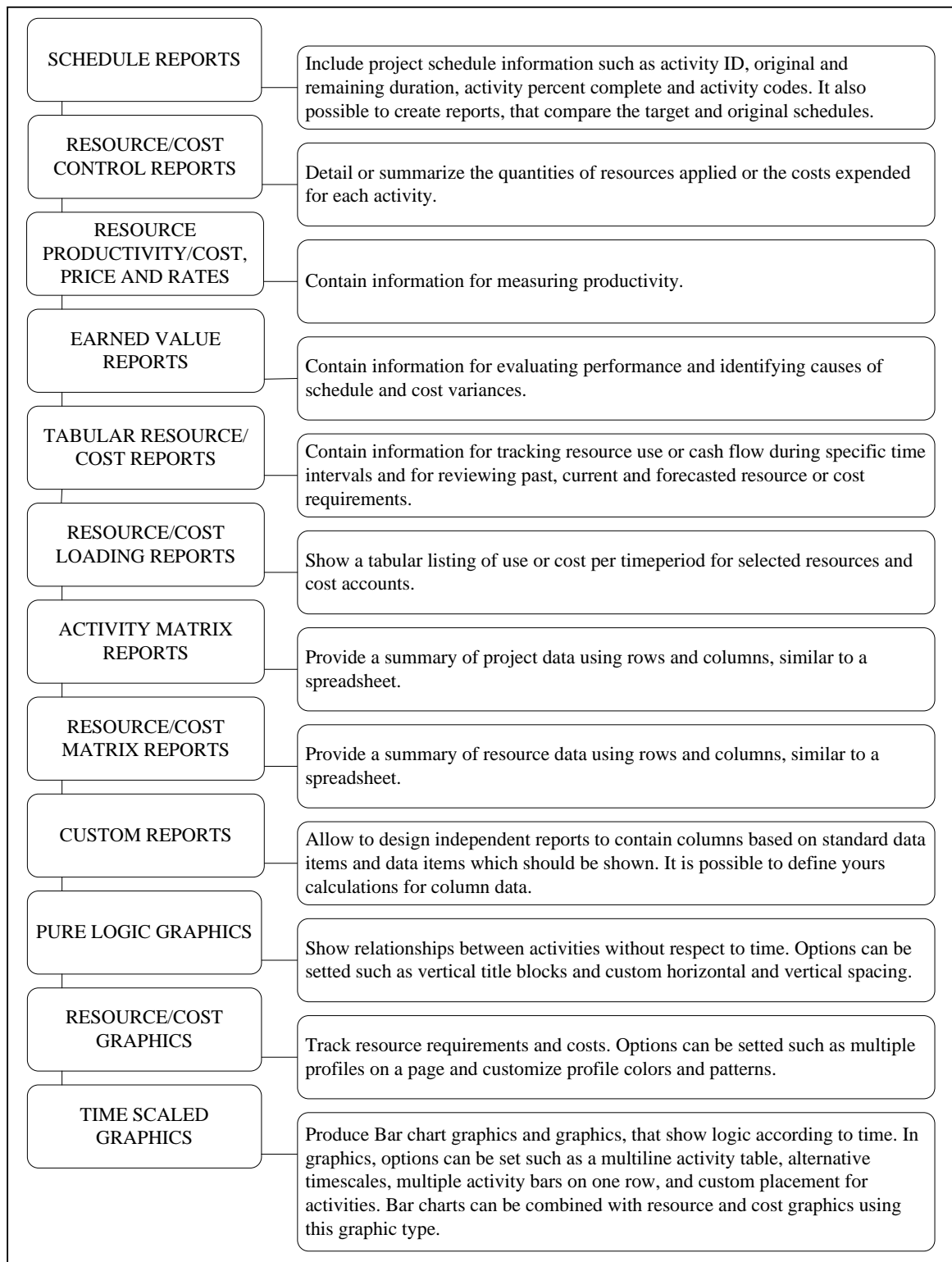


Figure 35: The scheme of different reports and graphics types using in P3

3.6.1 Reports on the MBB's schedule

3.6.1.1 Schedule report

Schedule report provides a tabular list of data showing activity identifications, descriptions, durations, float and early and late schedule dates. Customize the report to show additional data on separate lines (e.g. displaying budgets, resources, predecessor/successor activities and logs).

The screenshot shows a software window titled 'Primavera Look - [Untitled-Sheet 1 of 29]'. The main content is a schedule report for 'PRIMAVERA PROJECT PLANNER'. The report includes a header with project name, report date (30APROG 15:55), run number (151), start date (14NOV03), finish date (7JUL04), data date (14NOV03), and page number (1). The main body is a table with columns for Activity ID, Orig Dur, Rem Dur, Cal, #, Activity Description, Budget, Earned, Early Start, Early Finish, Late Start, Late Finish, and Total Float. The table lists various construction activities such as 'BEGINNING OF THE PROJECT', 'SITE MOBILIZATION', 'BEGINNING OF THE ISOLATION WORKS', etc., with their respective durations, budgets, and schedule dates.

| ACTIVITY ID | ORIG DUR | REM DUR | CAL | # | ACTIVITY DESCRIPTION | BUDGET | EARNED | EARLY START | EARLY FINISH | LATE START | LATE FINISH | TOTAL FLOAT |
|-------------|----------|---------|-----|---|--|----------|--------|-------------|--------------|------------|-------------|-------------|
| 1 | 0 | 0 | 1 | 0 | BEGINNING OF THE PROJECT | .00 | .00 | 14NOV03 | | 14NOV03 | | 0 |
| MOB01 | 7 | 7 | 1 | 0 | SITE MOBILIZATION | 518.00 | .00 | 14NOV03 | 20NOV03 | 14NOV03 | 20NOV03 | 0 |
| ISOLATION1 | 0 | 0 | 1 | 0 | BEGINNING OF THE ISOLATION WORKS | .00 | .00 | 12DEC03 | | 5FEB04 | | 55 |
| FINE WORK1 | 0 | 0 | 1 | 0 | BEGINNING OF THE FINE WORKS | .00 | .00 | 18DEC03 | | 1MAY04 | | 135 |
| MBBSTR04 | 7 | 7 | 1 | 0 | FORMWORK FOR SLAB | 18524.16 | .00 | 20DEC03 | 26DEC03 | 20DEC03 | 26DEC03 | 0 |
| WMASONRY1 | 0 | 0 | 1 | 0 | BEGINNING OF THE WALL AND MASONRY WORKS | .00 | .00 | 22DEC03 | | 8MAY04 | | 138 |
| ELECTRW1 | 1 | 1 | 1 | 0 | BEGINNING OF THE ELECTRICAL WORKS | .00 | .00 | 25DEC03 | 25DEC03 | 25JUN04 | 25JUN04 | 183 |
| MECHANICW1 | 0 | 0 | 1 | 0 | BEGINNING OF THE MECHANICAL WORKS | .00 | .00 | 28DEC03 | | 8JUL04 | | 193 |
| SPECIALW1 | 0 | 0 | 1 | 0 | BEGINNING OF THE SPECIAL WORKS | .00 | .00 | 25FEB04 | | 22MAY04 | | 87 |
| SW05 | 1 | 1 | 1 | 0 | METAL DOORS | 900.00 | .00 | 25FEB04 | 25FEB04 | 31MAY04 | 31MAY04 | 96 |
| SRW02 | 1 | 1 | 1 | 0 | STORM WATER WORKS | 1844.00 | .00 | 26FEB04 | 26FEB04 | 22JUN04 | 22JUN04 | 117 |
| SRW01 | 2 | 2 | 1 | 0 | SEWERAGE WORKS | 2926.20 | .00 | 26FEB04 | 27FEB04 | 21JUN04 | 22JUN04 | 116 |
| SRW03 | 15 | 15 | 1 | 0 | LAND SCAPING | 88.00 | .00 | 28FEB04 | 13MAR04 | 23JUN04 | 7JUL04 | 116 |
| ISOLATION2 | 0 | 0 | 1 | 0 | END OF THE ISOLATION WORKS | .00 | .00 | | 29FEB04 | | 7JUL04 | 129 |
| STRUCT.W2 | 0 | 0 | 1 | 0 | END OF THE STRUCTURAL WORKS | .00 | .00 | | 1MAR04 | | 30JUN04 | 121 |
| ELW13 | 7 | 7 | 1 | 0 | ELECTRICAL UTILITIES(saltlar vs panelar) | 36180.00 | .00 | 2MAR04 | 8MAR04 | 24MAY04 | 30MAY04 | 83 |

Figure 36: The schedule report of the MBB' s schedule

3.6.1.2 Resource/cost control report

Resource report organizes data by the resource quantity designed. Cost report shows the cost accounts and currency associated with the resources. Control reports provide detailed or summarized information about the quantities of resources for each activity or for the costs expended for each activity.

| RESOURCE | UNIT MEAS | BUDGET | PCT CMP | ACTUAL TO DATE | ACTUAL THIS PERIOD | ESTIMATE TO COMPLETE | FORECAST | VARIANCE |
|--|-----------|---------|---------|----------------|--------------------|----------------------|----------|----------|
| CC - CARPET+LABOURYNG | m2 | 174.00 | .0 | .00 | .00 | 174.00 | 174.00 | .00 |
| TOTAL CC | | | | | | | | |
| CIMC - CHIMNEY CONSTRUCTION | m | 30.00 | .0 | .00 | .00 | 30.00 | 30.00 | .00 |
| TOTAL CIMC | | | | | | | | |
| CON1 - CONCRETE CREW+BS30 | m3 | 1270.00 | .0 | .00 | .00 | 1270.00 | 1270.00 | .00 |
| TOTAL CON1 | | | | | | | | |
| CON2 - CONCRETE CREW+PROTECTION CONCRETE | m3 | 74.06 | .0 | .00 | .00 | 74.06 | 74.06 | .00 |
| TOTAL CON2 | | | | | | | | |
| CON3 - CONCRETE CREW+LEAN CONCRETE | m3 | 69.50 | .0 | .00 | .00 | 69.50 | 69.50 | .00 |
| TOTAL CON3 | | | | | | | | |
| CP - COMPOSIT PANEL+LABORING | m2 | 330.00 | .0 | .00 | .00 | 330.00 | 330.00 | .00 |
| TOTAL CP | | | | | | | | |
| DW1 - DEMONTABLE WALL WITH JALUZZI CREW | m2 | 136.40 | .0 | .00 | .00 | 136.40 | 136.40 | .00 |
| TOTAL DW1 | | | | | | | | |
| DW2 - CUBICAL DEMONTABLE WALL +LABOURING | m2 | 72.00 | .0 | .00 | .00 | 72.00 | 72.00 | .00 |
| TOTAL DW2 | | | | | | | | |
| EL01 - EL.ARH | UNIT | 1.00 | .0 | .00 | .00 | 1.00 | 1.00 | .00 |
| TOTAL EL01 | | | | | | | | |

Figure 37: The resource control report of the MBB' s schedule

3.6.1.3 Resource/cost loading report

Resource/cost loading report is the tabular list of using costs by time-period for selected resources and cost accounts; it includes subtotals and totals. Further example shows total monthly cost loading for all activities. After organizing the report by resource, cost account, cost category, activity code or project code, P3 first groups activities by the organizing item, such as resource or activity code value and then subdivides them by the code specified.

Control report shows values for the budget, actual to date, actual during period, estimate to complete and estimate at completion (forecast) and the variance between the budget and the forecast values.

| Primavera Look - [Untitled] | | | | | | | | | | | |
|--|-----------------------|--------------|--------------|----------|-------------|----------|----------|----------|----------|----------|----------|
| File Edit View Insert Format Table Window Help | | | | | | | | | | | |
| REPORT DATE 30APR06 RUII NO. 149 1410V03 FIN DATE 07JUL04 02:06 DATA DATE 1410V03 CL-03 | | | | | | | | | | | |
| ACT ID | DESC | TOTAL | NOV 2003 | DEC 2003 | JAN 2004 | FEB 2004 | MAR 2004 | APR 2004 | MAY 2004 | JUN 2004 | JUL 2004 |
| MOBILIZATION&START UP WORKS | | | | | | | | | | | |
| MOB01 | SITE MOBILIZATION | 518 | 518 | | | | | | | | |
| TOTAL | MOB | 518 | 518 | | | | | | | | |
| EARTH WORKS | | | | | | | | | | | |
| EW01 | EXCAVATION | 7904 | 7904 | | | | | | | | |
| EW02 | HAND EXCAVATION | 1488 | 1488 | | | | | | | | |
| EW03 | LINING WITH QUARRYST | 1020 | 1020 | | | | | | | | |
| EW04 | FILLING WITH GRANULA | 1408 | | | 1408 | | | | | | |
| EW05 | LINING DRENAJ PIPE | 8584 | | | 8584 | | | | | | |
| TOTAL | EW | 20404 | 10412 | | 9992 | | | | | | |
| STRUCTURAL WORKS | | | | | | | | | | | |
| MBBSTR01 | REINFORCEMENT FOR BA | 9908 | | 9908 | | | | | | | |
| MBBSTR02 | FORMWORK FOR BASEMEN | 8233 | | 8233 | | | | | | | |
| MBBSTR03 | CONCRETE FOR BASEMEN | 7640 | | 7640 | | | | | | | |
| MBBSTR04 | FORMWORK FOR SLAB | 19524 | | 19524 | | | | | | | |
| MBBSTR05 | REINFORCEMENT FOR SL | 21798 | | 21798 | | | | | | | |
| MBBSTR06 | BS30 CONCRETE FOR SL | 7640 | | 7640 | | | | | | | |
| MBF1STR01 | MAIN BEAMS INST ALLAT | 16800 | | | 16800 | | | | | | |
| MBF1STR02 | SUB BEAMS INST ALLATI | 11424 | | | 11424 | | | | | | |
| MBF1STR03 | MONTAGE OF THE TRAPE | 12768 | | | 12768 | | | | | | |
| MBF1STR04 | 2 LEVELS REINFORCEME | 3942 | | | 3942 | | | | | | |
| MBF1STR05 | 1st LEVEL SLAB CONCR | 7147 | | | 7147 | | | | | | |
| MBF2STR01 | ERECTION OF THE 2nd | 36960 | | | 36960 | | | | | | |
| MBF2STR02 | INSTALLATION OF THE | 2688 | | | 2688 | | | | | | |
| MBF2STR03 | INSTALLATION OF THE | 16800 | | | 16800 | | | | | | |
| MBF2STR04 | INSTALLATION OF THE | 11424 | | | 11424 | | | | | | |
| MBF2STR05 | MONTAGE OF THE TRAPE | 12768 | | | 12768 | | | | | | |
| MBF2STR06 | 2 LEVELS REINFORCEME | 4294 | | | 4294 | | | | | | |
| MBF2STR07 | 2nd FLOOR SLAB CONCR | 7886 | | | | 7886 | | | | | |
| MBF3STR01 | INSTALLATION OF THE | 16128 | | | 2304 | 13824 | | | | | |
| MBF3STR02 | INSTALLATION OF THE | 10080 | | | | 10080 | | | | | |
| MBF3STR03 | MONTAGE OF THE TRAPE | 12768 | | | | 12768 | | | | | |
| MBF3STR04 | 2 LEVEL REINFORCEMEN | 4294 | | | | 4294 | | | | | |
| MBF3STR05 | 3rd FLOOR SLAB CONCR | 7969 | | | | 7969 | | | | | |
| MBF4STR01 | INSTALLATION OF THE | 16800 | | | | 16800 | | | | | |
| MBF4STR02 | INSTALLATION OF THE | 11424 | | | | 11424 | | | | | |
| MBF4STR03 | MONTAGE OF THE TRAPE | 12768 | | | | 12768 | | | | | |
| MBF4STR04 | 2 LEVEL REINFORCEMEN | 4294 | | | | 4294 | | | | | |
| MBF4STR05 | 4th FLOOR SLAB CONC | 7969 | | | | 7969 | | | | | |
| MBF5STR01 | COLUMNS AND BEAMS | 20160 | | | | 20160 | | | | | |
| MBF5STR02 | MONTAGE OF THE TRAPE | 1344 | | | | 1344 | | | | | |
| MBF5STR03 | 2 LEVEL DOUBLE REINF | 352 | | | | 352 | | | | | |
| MBF5STR04 | SCREED | 2995 | | | | 2995 | | | | | |

Further reports are used after the start of construction, when the project management team controls and measures the costs, resources and duration of the project.

3.6.2.1 Resource productivity/cost, price and rates reports

Resource productivity or labour indicates the amount produced (output) per unit of resource used (input). For example, the surface of a wall painted per person - days of work. This measure of productivity helps to identify areas of a project that need performance

improvements and is thus used for comparing the actual rates to budgets and forecasts using the resource productivity report. The cost version (cost, price, and rates reports) displays data in a cost per resource quantity.

Assigning resources and cost accounts with categories to activities is needed to generate a productivity report. Cost accounts should be developed for grouping the resources (labour input and material output) for a particular work item. For example, suppose that the site manager wants to measure the productivity of an electrician's day in terms of the number of linear feet of electrical conduit installed. Specify a cost account that represents the installation of electrical conduit and assign it to the electrician and electrical conduit resources.

Consecutive range can be used for cost accounts within a work item. Using the same unit of measure for all labour resources within a cost account; identify each with a designator (such as L for Labour) in the cost category position in the Cost Accounts Dictionary. P3 calculates the labour input by collecting only specified cost accounts with an L in the cost category position.

3.6.2.2 Earned value reports

Earned value report is used to evaluate performance by identifying the causes of schedule and cost variances. Performance is measured on a cumulative basis according to units or costs; earned value is calculated as the product of the percent complete and the budget. To report variance values accurately, P3 requires a target plan as designate as Target 1. If it is specified for a resource, P3 uses the resource percent complete for the activity; otherwise, P3 uses the schedule percent complete.

It is also possible to base the budgeted amount upon the budgets from the current or target schedule. In the Earned value calculations dialog box in P3 the project management team can indicate which budget should be used to calculate the earned value and the planned value.

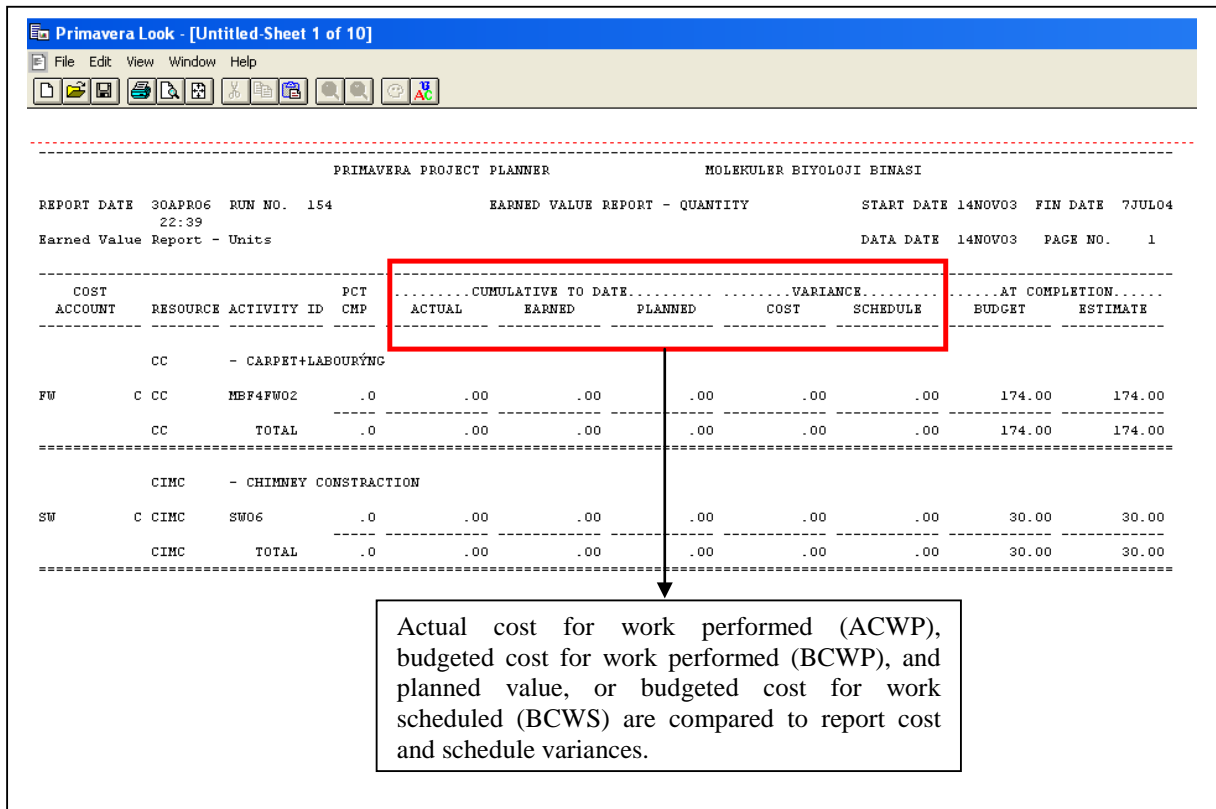


Figure 39: The earned value report

3.6.2.3 Reviewing cash flow report

After assigning budgets to the cost accounts it is possible to analyze cash flow for the entire project. P3 provides several ways of reviewing the budget with examining a time-phased spending plan using a cost table or profile. Three different curves can show the accumulated current estimate, earned value and scheduled budget costs.

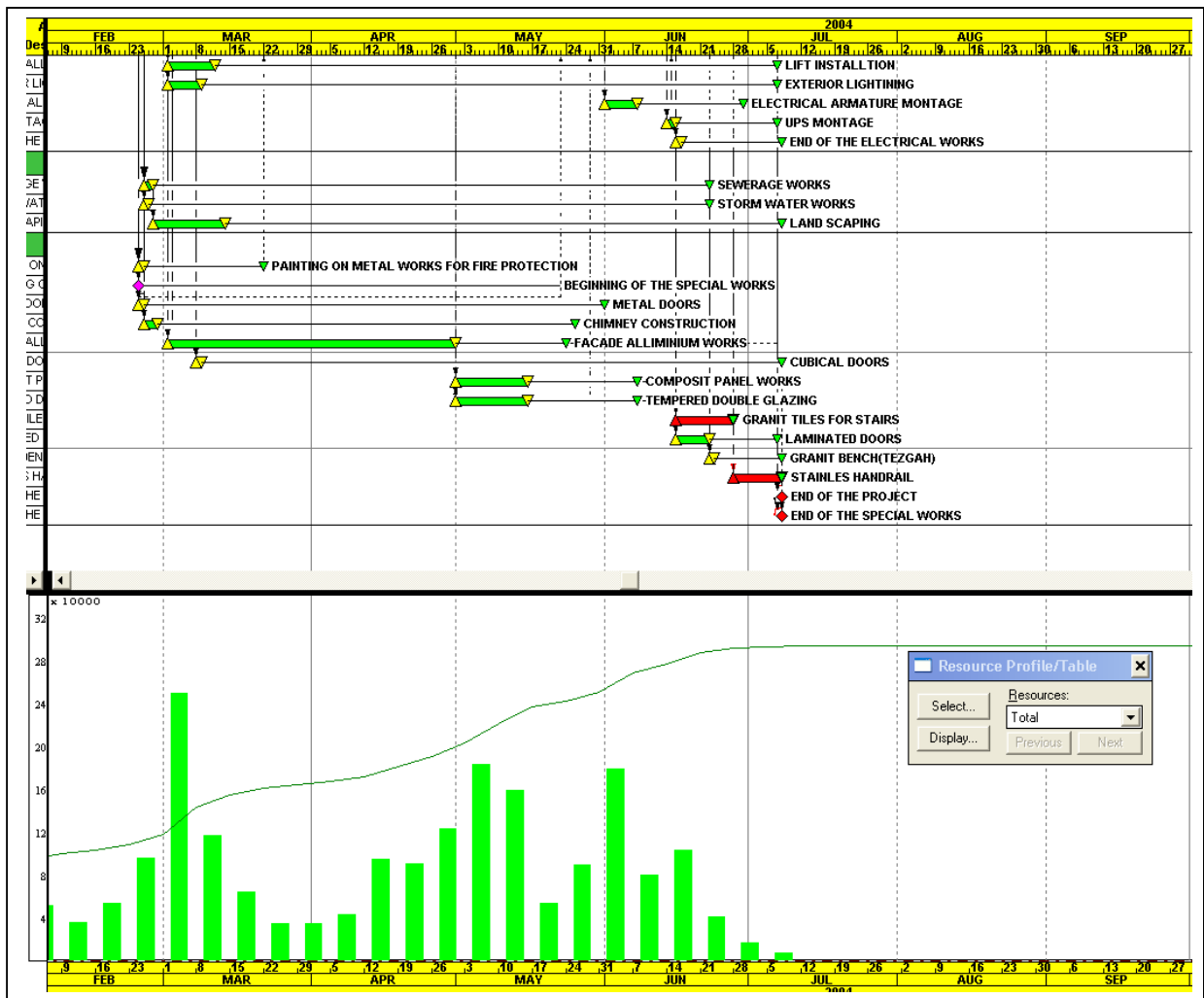


Figure 40: Cash flow diagram

3.6.2.4 Tabular Resource/Cost Reports

The tabular resource usage report is used to track resource use during specific time intervals. P3 shows up to three different schedules for comparing past, current and forecasted resource requirements. The format of the tabular cost report (cash-flow report) is similar to that of the tabular resource report. Both reports compare expenditure rates between periods based on early, late and Target 1 schedule dates and spread the actual to date values from the resource actual start to the data date.

If the period performance is stored, tabular reports spread resource quantities and costs evenly for each update period, as well as the quantities and costs for the current period from the last storage date to the data date. If the period performance is not stored, tabular reports spread resource quantities and costs evenly from the resource start through the data date. The report spreads the estimate to complete values evenly from the data date to the finish date.

The screenshot shows the Primavera Look interface with a menu bar (File, Edit, View, Window, Help) and a toolbar. The main window displays a report titled 'PRIMAVERA PROJECT PLANNER' for 'MOLEKULER BIYOLOJI BINASTI'. The report is a 'Tabular Resource Report-Monthly' with the following details:

- REPORT DATE: 1MAY06, RUN NO.: 156, 0:47
- TABULAR RESOURCE REPORT-MONTHLY
- START DATE: 14NOV03, FIN DATE: 7JUL04
- DATA DATE: 14NOV03, PAGE NO.: 1

The report table is as follows:

| PERIOD | ---AVAILABLE--- | | ---EARLY SCHEDULE--- | | ---LATE SCHEDULE--- | | ---TARGET 1 SCHEDULE--- | |
|--------|-----------------|--------------------|----------------------|----------------------|---------------------|------------|-------------------------|----------------|
| | BEGINNING | NORMAL | USAGE | CUMULATIVE | USAGE | CUMULATIVE | USAGE | CUMULATIVE |
| | CC | - CARPET+LABOURYNG | | UNIT OF MEASURE = m2 | | | | TARGET = EARLY |
| 1JUL96 | 0 | 0 | .00 | .00 | .00 | .00 | .00 | .00 |
| 1AUG96 | 0 | 0 | .00 | .00 | .00 | .00 | .00 | .00 |
| 1SEP96 | 0 | 0 | .00 | .00 | .00 | .00 | .00 | .00 |
| 1OCT96 | 0 | 0 | .00 | .00 | .00 | .00 | .00 | .00 |
| 1NOV96 | 0 | 0 | .00 | .00 | .00 | .00 | .00 | .00 |
| 1DEC96 | 0 | 0 | .00 | .00 | .00 | .00 | .00 | .00 |
| 1JAN97 | 0 | 0 | .00 | .00 | .00 | .00 | .00 | .00 |

Figure 41: The tabular resource report

3.6.2.5 Matrix reports

Matrix reports provide a two-dimensional view of the project data, similar to a cross-tab report. Display schedule data, quantity or cost information in columns and rows, grouped by activity codes and/or resources or cost accounts. For example, the amount of money spent by each department by project can be seen. P3 offers two types of matrix reports, activity and resource/cost. Activity matrix reports are used to report activity or resource data grouped by activity codes. Resource/cost matrix reports are used to review the data grouped by resource or cost account. P3 provides an extensive list of data items you can specify for an activity or resource/cost matrix report, such as activity identification, schedule dates, durations, resources, cost accounts and variances. These selections determine the values P3 displays in the report cells.

PRIMAVERA

REPORT DATE 01MAY06 RUII NO. 160
 14HOV03 FIII DATE 07JUL04
 01:07
 Budgeted Quantity and Cost for Engineers DATA DATE 14HOV03

Budget Quantity/Cost for Engineers

| Project Phase | DESCRIPTION | Field Engineer 2 | Automation Engineer | Operations Engineer | TOTAL |
|---------------|-----------------------------|------------------|---------------------|---------------------|----------|
| EW02 | HAND EXCAVATION | 155.00 | | | 155.00 |
| | | 1488.00 | | | 1488.00 |
| WM04 | BIMS20 | | | 246.25 | 246.25 |
| | | | | 3270.20 | 3270.20 |
| ELW01 | ELECTRICAL ARMATURE MONTAGE | | 1.00 | | 1.00 |
| | | | 54182.00 | | 54182.00 |
| | | 155.00 | 1.00 | 246.25 | 402.25 |
| | | 1488.00 | 54182.00 | 3270.20 | 58940.20 |

Figure 42: The matrix report

Once the project is underway, it is necessary to modify the schedule to keep it current.

3.7 Sharing project data in P3

Once a project is underway, the schedule and resource use must be updated at regular intervals. Each project is different: it may be needed to be updated daily, weekly or monthly, depending on the amount of time a project spans and how frequently forecasts should be adjusted.

To facilitate the communication of the vital project data within the corporate office or between offices worldwide, P3's E-mail capabilities can be used to send and receive project information. Update information can be collected and merged into the project, keeping it as current as possible. A backup of an entire project or project group can be sent in P3 to another member of the workgroup using ordinary e-mail system. P3 backs up the open project into one file with the project name and the extension.

Instead of sending an entire project or a project group through e-mail, specified activities from a project can also be sent. P3 allows to choose whether to send the activities in the current view, currently selected activities, or filtered activities, as well as to choose a Standard

or Custom status sheet. The Standard status sheet is a quick way of updating activity progress, while the Custom status sheet allows more flexibility in collecting information about the data items selected.

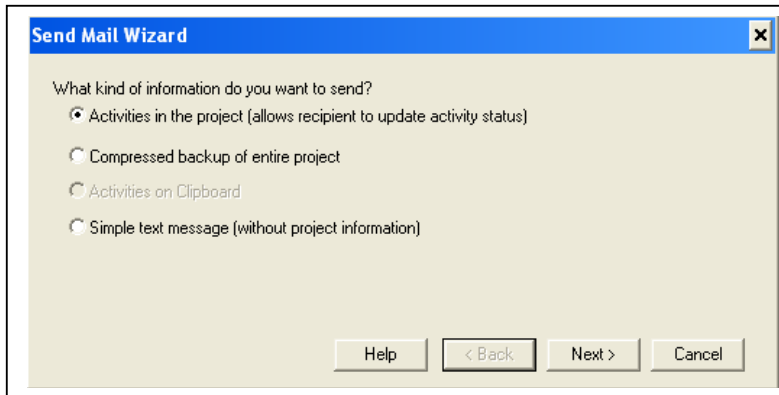


Figure 43: Send mail wizard in P3

Since most companies run multiple projects simultaneously, coordination is the key to achieving overall corporate objectives. Each project shares resources with other projects, its activities depending on the accomplishment of activities in other projects, and its information must be available to, as well as shared by participants and management. To facilitate the communicating project data within a company with offices spread locally or worldwide, it is possible to create layouts in P3, save them in HTML format and create P3 reports in HTML format using the Primavera Web Publishing Wizard, then placing them on a central server - office network or the Internet. By publishing project information on a central server, a user can maintain a single copy of the project layouts and reports, which the administrators, management, or individual project managers can access at any time. Using the World Wide Web to disseminate information also supplies the most current project information to remote managers.

P3's Web Publishing feature enables to publish project information on the World Wide Web or on an office intranet for others to access. The Primavera Web Publishing Wizard can guide user through the process of creating Web pages that contain the specified project information. Once the pages are completed, they can be transferred to the Internet or placed on company intranet server. Layouts can be saved in Hyper Text Markup Language (HTML) format in P3.

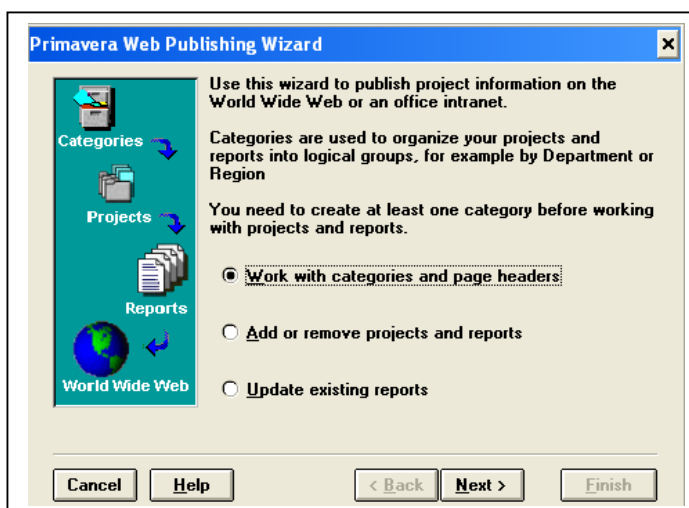


Figure 44: Primavera web publishing wizard

Creating a structure of HTML documents P3's Web Publishing Wizard creates a hierarchical structure of HTML pages based on the projects and reports specified. These pages contain hypertext links, or jumps to other pages in the structure, enabling to move between projects and reports and from page to page within a report. Only the structure must be set up once and then, as the projects progresses, the Wizard is used to add new reports, remove outdated reports, or update existing ones with the latest data. The first HTML page lists the project categories that have been defined, such as Development Projects, Construction Projects, Information System Projects, etc. a user can select a category to display the list of projects and overview information about each project it contains. A project can be selected from this list to see the reports that are available and displayed as an HTML page containing that information.

HTML is a platform independent language, which means that pages do not have to be viewed using the same type of computer that generated them. Once an HTML structure in P3 is created, anyone can use an Internet browser to review HTML documents, whether they are downloaded from the World Wide Web or an office intranet.

To create and maintain HTML reports using the Primavera Web Publishing Wizard, there are seven steps one has to follow, which can be seen in the figure 45.

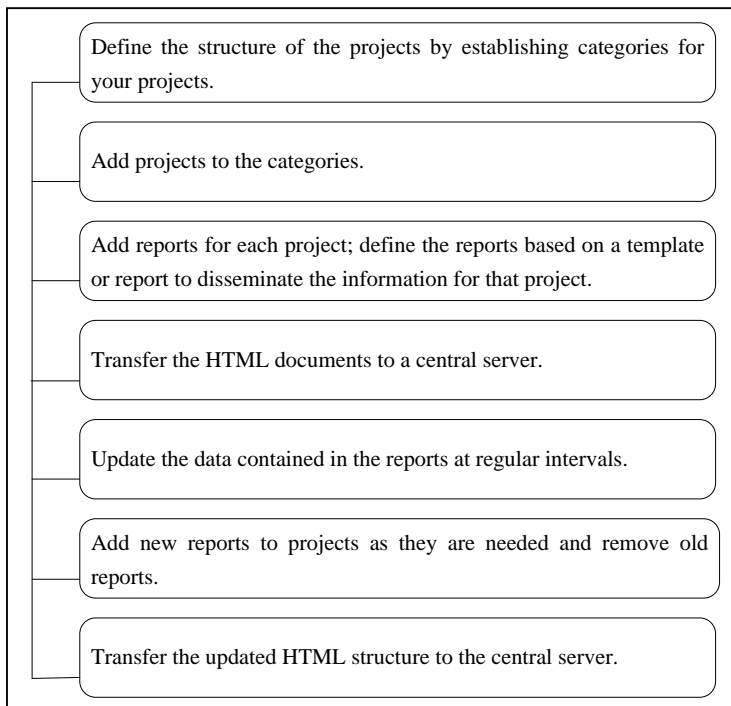


Figure 45: Steps in creating HTML reports using P3

The Primavera Web Publishing Wizard helps to create a structure of HTML documents based on the projects and reports defined. Using the Wizard enables you to keep and manage only one set of documents that others in the project team can access using standard Web browsers such as Microsoft Internet Explorer or Netscape Navigator.

3.8 Team members of the project

All team members are essential for a project's success. During the life of the project there are three major management fields: operational, field and partner management which include several processes: estimating, accounting, managing scope, schedule, costs and changes.

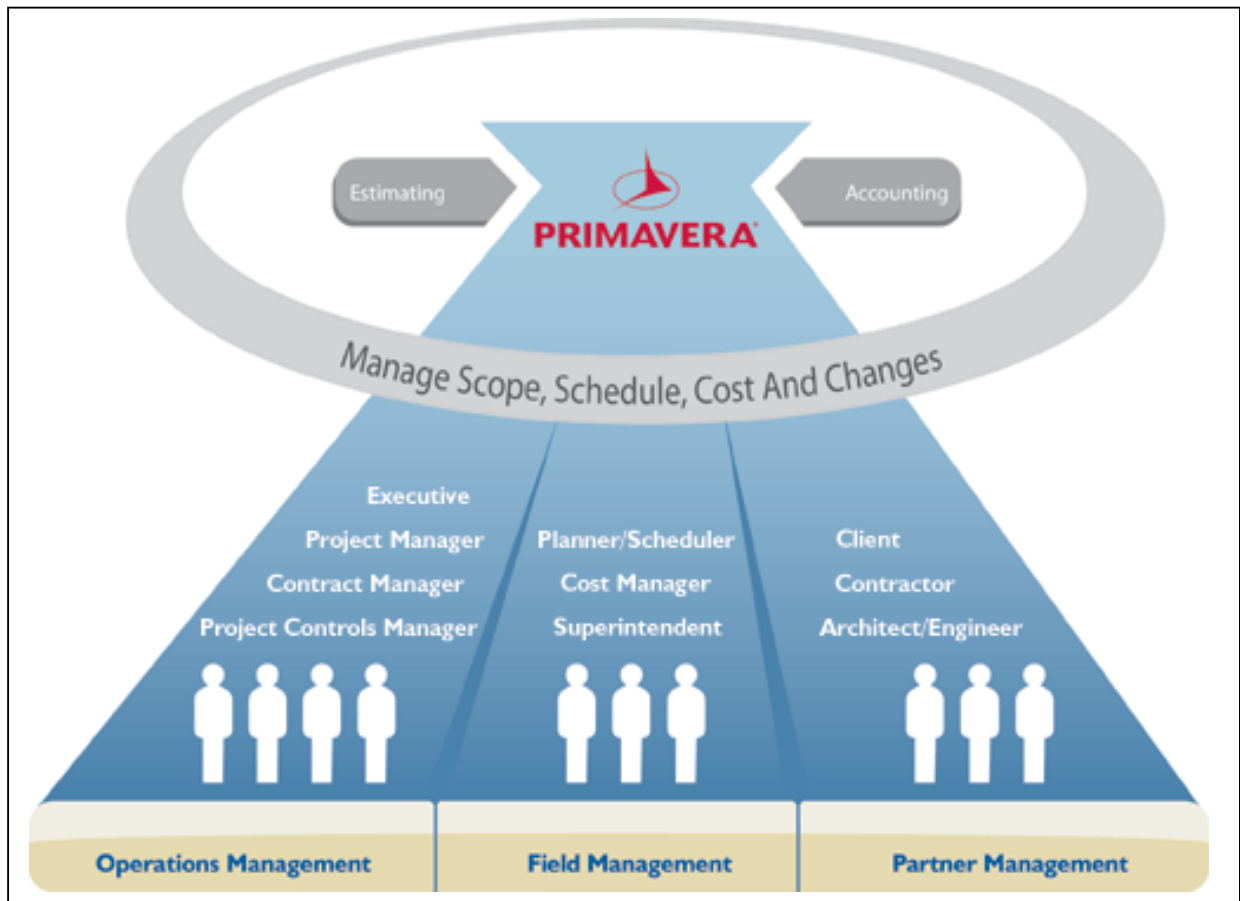


Figure 46: Scheme of the project's team members structure

Executive, Project manager, Project Controls manager and Scheduler have to deal with resource scheduling, updating project's information, controlling and estimating project data.

3.8.1 Scheduler

A scheduler has to manage the preparation and scheduling of construction work and the respective work crew. His workday is spent gathering and analyzing information to prepare reports on the progress of projects, ensuring that assignment and scheduling of work follows company policy and evaluating current procedures and recommends changes to improve the efficiency of planning and scheduling of projects.

Schedule projects quickly and easily:

- Identify all critical paths within a project by using CPM.
- Integrate schedules from engineering, architects, subcontractors and owners to create a master program schedule.
- Easily create attractive and fully customizable graphics including Gantt charts, Activity Network Diagrams, Time-scaled Logic Diagrams and Histograms.
- Quickly plan for the upcoming day, week or month to ensure everyone knows what they are responsible for.
- Control budgets, changes and estimates at completion to ensure a successful project delivery.
- Allocate resources to activities using distribution curves to accurately reflect how the work is performed.
- Improve collaboration by quickly emailing entire projects with the click of a button.
- Communicate status to general contractors, subcontractors, owners and other project team members via customizable industry standard reports.
- Coordinate labour, material, equipment and subcontractors to ensure on-schedule, on-budget completion.
- Quickly compare baseline budgets to the actual costs and work performed while maintaining independent versions of cost to complete estimations.
- Store actual cost, units, earned value and planned value by customizable financial period for comparison current and future trends.
- Create unlimited “what-if” scenarios to explore alternatives.
- Break activities down into smaller weighted steps and track the completion of the steps to determine the activity percent complete.
- Document risks and calculate risk exposure values and impacts on the project's schedule, costs and durations.
- Build thresholds for tolerable project performance and get notified when performance is outside of the acceptable performance window.
- Leverage best practices by using templates and completed projects to build new projects.

- Perform earned value analysis by using past performance to predict a more accurate cost to completion.

3.8.2 Executive

An executive plans and directs all aspects of organization's construction function. The majority of team is consumed by ensuring all projects are completed on time, within budget and according to pre-established specifications.

Executive Solution Capabilities:

- View current trends and forecasts for projects within a business unit or a profit & lost centre via a web based dashboard.
- Review, analyze and manage issues and risks across portfolios of projects and programs to ensure there are no surprises near the completion deadline.
- Manage by acceptance by using calculated key performance indicators and automated alerts. Quickly determine which projects or programs need help to get back on track.
- Drill into program and project details by viewing project dashboards that contain schedule performance, cost performance, earned value metrics, milestone dates and WBS summaries.
- Communicate with the project manager or project team by using P3's communication capabilities.
- Keep up to date by reading executive summaries about each project or program within a customized portfolio.
- Run reports about the projects from anywhere using the web and launching the report and get the data needed.

3.8.3 Project manager

The role of a project manager comprises overseeing and directing construction management. Project managers divide their time between communicating directly with contractors/designers about the costs of a project, staffing and scheduling as well as working to ensure plans adhere to contract specifications.

Project Manager Solution Capabilities:

- Access to web-based project management functions (such as WBS and activity creation and maintenance) ensures that projects are completed on-time and on-budget.
- Complete Issue and Risk management functions to ensure project status is understood and tough decisions are made in a timely manner.
- Robust resource management capabilities help the project manager to understand resource allocation and schedules to ensure the best fit for the project.
- Customized project workspaces store documents, discussion threads, approvals and other important project information in a central repository for easy access.
- Auditable approval workflows track subjects, documents and changes that are important to a project's success.
- Detailed time reports, expense reports, budgets and financial information ensure that real-world data is available to make important decisions.
- Reporting and program dashboards ensure that data is collected and shared, so that project managers and their stakeholders are not surprised by project trends.

3.8.4 Project controls manager

A project controls manager (PCM) develops and manages the project controls effort, including estimating, scheduling, and cost analysis, for all projects within the company. PCMs provide guidance and specialized assistance to projects for the resolution of difficult and complex problems.

Project Controls Manager Solution Capabilities:

- Set the standards for organizations by determining global coding structures that all projects must adhere to.
- View summary information about projects via a web based or personalized dashboard.
- Drill into project details, like WBS, activities, resource assignments and issues to resolve problems.

4 CONCLUSION AND RECOMMENDATIONS

The purpose of project management is to achieve the goals and objectives of a project through a planned expenditure of resources that meet the project's quality, costs, time and safety requirements. A construction companies are in business in order to be successful and make money. When producing a successful project, financial risks can thus be controlled and minimized.

Modern project management is based on the concept of the office of a project manager using the computerized CPM network, as well as the use of bar charts as a visual tool for presenting schedule results. The planner prepares a resource loaded and cost loaded CPM schedule, which is then converted into a list of time-phased budgets. The sum of the budget equals the value of the contract. The schedule leads to the required project completion date.

The levelling and allocation techniques present an important role during the scheduling process and are widely used. When it comes to P3, it is possible to choose either automatic or manual levelling procedure. Choosing smoothing method for maintaining relatively constant resource levels can reduce the costs.

Cost estimating and budgeting is driven by definitions of functions and elements, the breakdown of work into tasks and packages and the assignment of packages to particular individuals and organizations. The process leads to more accurate cost pictures at each transition point. Control requires that the project scope be maintained throughout each stage. Tabular reports are very useful as a communication tool. Only by tracking and comparing the actual usage of resources to the baseline budget, the contractor can determine the physical progress and earned value. Management must gauge the progress gained for the amount of resources expended to determine if the project is over or under the baseline budget.

The use of sensible solutions for today's project management professional program P3 provides keeping the project under the constant review, taking action when necessary to correct the situation and measuring what was done against what should have been done. It is also very helpful when it comes to proactively defining problem areas of the project. With the schedule which contains resources, costs and main data about the project, measuring,

monitoring and managing during the project life should be easier and more successful. After costs and resources are assigned and updated, it is possible to see cash flows, earned values and all needed reports for analyzing the time and resources, including associated costs and revenues. P3 helps to obtain early warning of project risk, improve the insight into project performance, forecast project health at completion and to collaborate with the project team. Update information about the project can be collected and merged into the project, keeping it as current as possible. To facilitate the communicating project data within a company, it is necessary to publish the project data on the company's intranet or world wide web.

Good project management implies exact project control. All projects have two primary control documents: the estimate and the schedule. The project managers have to evaluate and analyse data as well, as they have to be familiar with controlling and evaluating techniques, using modern PM software.

The preparation of a very detailed schedule is not needed when it comes to small and non complex projects, due to the fact that the development of the schedule also presents a substantial amount of cost.

Every company uses different planning techniques for managing with all kinds of projects and is of course aware of the existence of modern PM software tools. However, planning sectors in construction industry are lag behind in exploiting advanced scheduling software tools. Planning sectors meet the scheduling problems on a daily basis, so it is essential that they acquire some theoretical background about resource scheduling techniques and methods, otherwise modern software tools cannot be used efficiently by everyone on the project team: planning, site and project managers. The main goal of scheduling is for the planning sector to develop the optimal schedule, because producing an ideal one is almost impossible, as well as unrealistic.

From my point of view, the companies which do not use PM software tools efficiently have to increase their investments in training and educating their employed project teams, as well as in establishing information technology systems that will support and help PM teams.

5 POVZETEK

5.1 UVOD

Projektno planiranje in programiranje je nujno za uspešni projektni gradbeni management, za izvajanje kontrole nad viri, časom in rapoložljivim proračunom. Razlogi za planiranje so naslednji:

- Podpora kontroliranju pogodb za izvedbo gradbenih projektov,
- Vzpostavitev realnih norm,
- Vzdrževanje plana pod stalnim nadzorom in urgiranje s pomočjo sodobne programske opreme, ko je to potrebno.

Metoda kritične poti je pogosto uporabljena v procesu planiranja, kontrole in izvedbe gradbenih projektov. V fazi planiranja večina planerjev tako v Sloveniji, kot v Turčiji uporablja samo časovno planiranje, ki temelji na planerjevih preteklih izkušnjah. Nujno je potrebno definirati in v projektni plan vključiti razpoložljive vire in ostale potrebne informacije o projektu, uporabiti tehnike in metode za planiranje virov, metode obvladovanja prislužne vrednosti za kontrolo projekta ter uporabiti vse zmožnosti, ki jih ponujajo sodobna programska oprema. V diplomskem delu je predstavljeno področje projektne managementa, ki služi kot osnova za planiranje, hkrati z metodami in tehnikami za planiranje z omejenimi viri. Na realnem primeru projektne plana so prikazane tudi uporabe navedenih tehnik s profesionalnim programom za planiranje Primavera Project Planner verzija 3.1.

5.2 PROJEKTNI MANAGEMENT

5.2.1 Organizacija projekta in procesi planiranja

Organizacija projekta temelji predvsem na tipu pogodbe. V svojem delu sem izbral najbolj razširjeno obliko pogodbe na pavšalni znesek. Proces planiranja projekta je sestavljen iz:

- Proces izdelave ponudbe do podpisa pogodbe
- Proces od podpisa pogodbe do začetka izvedbe del
- Proces planiranja tekom gradnje

Ko glavni izvajalec pridobi posel, časovni plan gradnje razvije v glavni projektni plan, v katerem so prikazane dejavnosti in časovni potek le-teh z definirami in vključenimi viri, ki predstavljajo količine in cene materiala, delovne sile in ostalo zahtevano opremo. Za izdelavo plana je potrebno definirati in smiselno razporediti vse dejavnosti.. Istočasno morajo biti znane metode vodenja, kontrole projekta in merjenja količin tekom izvedbe.

5.2.2 Metoda kritične poti

Metoda kritične poti je analitična tehnika, ki v dejavnostni mreži določi kritično pot. Tiste dejavnosti, ki ležijo na najdaljši kritični poti, ne smejo imeti nobenih zamud. Princip dejavnostne mreže za metodo kritične poti uporabljajo tudi programi za planiranje. V diplomskem delu je predstavljen osnovni princip metode, dejanski primeri z uporabo P3 ter prednosti in slabosti metode kritične poti in predstavitvenih diagramov.

5.2.3 Ocenjevanje trajanja dejavnosti

Določitev trajanja dejavnosti poteka v času priprave plana. Pogosto ocenitev opravi najbolj izkušena oseba iz določenega področja, ki se poslužuje verjetnostnih ali determinističnih tehnik za določitev trajanja dejavnosti.

5.2.4 Planiranje virov

5.2.4.1 Rezervni čas posamezne dejavnosti in metoda kritične poti z omejenimi viri

Dejavnost, ki ne leži na kritični poti ima rezervni čas, ki omogoča, da se dejavnost začne kasneje, kot je njen predviden zgodnji čas, oziroma lahko traja dlje kot njen zgodnji konec.

Po določitvi in razporeditvi virov posameznim dejavnostim točne informacije o rezervnih časih izgubijo legitimno veljavo. Projektni plan in metoda kritične poti z vstavljenimi viri nista realna, saj so v praksi viri realno omejeni. Predstavljen je algoritem metode kritične poti z omejenimi viri, ki tovrstne ovire odstrani. Planerji take pomankljivosti rešujejo z uvedbo nepravih dejavnosti in dodatnimi medsebojnimi relacijami.

5.2.4.2 Metode in tehnike za planiranje virov

Zahtevane omejitve virov, ki so dodeljeni posameznim aktivnostim, vplivajo na trajanje dejavnosti. Z optimalno razporeditvijo, planiranjem dejavnosti in zadostitev mej virov lahko ustvarimo učinkovitejši projekt in zmanjšamo njegove stroške.

5.2.4.2.1 Izravnavanje virov

Procedura izravnavanja virov temelji na ideji prerazporeditve dejavnosti znotraj zahtevanih časovnih omejitev za zadostitev mej virov oz. odpravljanje morebitnih vrhov. Predstavljen je enostaven algoritem s primerom, ki prikazuje navedeni proces in rešitev.

5.2.4.2.2 Razporejanje virov

Razporejanje virov je metoda, kjer morajo biti viri pod zahtevanimi mejami in kjer je mogoče časovno podaljšanje trajanje projekta. Razporejanje je možno preko izbire prioritete kriterija. Predstavljen je enostaven algoritem s primerom, ki prikazuje navedeni proces in rešitev.

5.2.4.2.3 Kopičenje virov

Je najenostavnejša metoda izmed metod planiranja virov, ki omogoča prikaz vseh virov na zahtevano časovno enoto v obliki tabele ali histograma in je zelo uporabna za prikaz virov tekom projekta.

5.2.4.2.4 Zbiranje virov

Vhodni podatki za metodo zbiranja virov so končni podatki metode kopičenja virov. Rezultat je grafična predstavitev, ki projektному vodji ponuja prikaz izbora vseh virov, ki so potrebni skozi celoten projekt. Metoda omogoča nadzor nad možnostjo prevelike porabe virov.

5.2.4.2.5 Glajenje

Cilj te metode je izdelava plana znotraj časovnih omejitev s konstantno porabo virov. Glajenje upošteva celoten projekt in deluje znotraj časovnih okvirov, kjer za posamezno dejavnost iščemo najboljše mesto v planu - točko med zgodnjim začetkom in poznim koncem dejavnosti, ko je poraba virov do tistega časa najmanjša. Za merilo uporabimo statični moment v histogramu virov, nato te momente primerjamo med seboj za različne uvrstitve,

najboljši razpored pa je tisti, ki daje najmanjše momente. Bistvo je, da se izognemo viškemu porabi virov in zapolnimo vrzeli.

5.2.4.2.6 Metoda obvladovanja prislužne vrednosti

Metoda prislužne vrednosti je najbolj razširjena metoda procesa kontrole projektov. Graf denarnega toka je osnova za analizo, saj lahko razberemo učinek projekta. Standardna »S« krivulja nam poda planirane vrednosti stroškov, dejanske vrednosti ter proračunske vrednosti opravljenih dejavnosti. Indikator učinkovitosti plana in stroškovni indikator nam podata učinkovitost.

5.3 ŠTUDIJ PRIMERA PLANIRANJA VIROV

5.3.1 Projektni plan Molekularne biološke zgradbe

Podan je primer realnega projektne plana za Molekularno biološko zgradbo Istanbul Technical University, izdelan s programom Primavera Project Planner verzija 3.1. To je profesionalni program za planiranje in vodenje projektov in je primeren za obdelavo zelo velikega števila dejavnosti. Viri so dodeljeni posameznim aktivnostim in njihovo trajanje je določeno preko kvantitativne metode določitve trajanja dejavnosti.

5.3.2 Izdelava strukture izvedbe del

Izdelava strukture izvedbe del oz. razdelitev projekta v posamezne segmente je nujna za računalniško obdelavo in nadaljno kontrolo projekta. Podan je primer drevesne strukture za realen primer plana.

5.3.3 Tehnike planiranja virov z uporabo P3 uporabljene v planu MBB

5.3.3.1 Planiranje z omejenimi viri z uporabo P3

Konkretno so predstavljene dodatne zahteve in omejitve virov ter ustrezna rešitev s tvorbo nove dejavnosti in novih relacij med dejavnostmi za zadostitev zahtev.

5.3.3.2 Razporejanje virov z uporabo P3

P3 omogoča izdelavo plana, ki vključuje stroške in vire za razvoj učinkovite projektne kontrole. Prikazan je postopek uporabe s pomočjo P3.

5.3.3.3 Izravnanje virov z uporabo P3

Izravnavanje virov je avtomatiziran proces, ki se najprej loti vrhov na tistem delu projektne mreže, ki je vzrok za uravnavanje. Nato program na novo razporedi dejavnosti znotraj rezervnih časov. Prikazan je realen primer z rešitvijo in metoda izravnavanja virov v programskem okolju P3.

5.3.3.4 Glajenje virov z uporabo P3

V procesu izravnavanja virov je mogoče v P3 izbrati možnost glajenja, ki v profilu virov odpravi vrhove in doline. Približno konstanten profil lahko zniža stroške. Razložene so opcije načina glajenja glede na zahtevane časovne omejitve.

5.3.4 Poročila plana Molekularne biološke zgradbe z uporabo P3

P3 ponuja veliko različnih poročil za stroškovne analize in napovedi. Poročila služijo komunikaciji in deljenju informacij med projektnim timom. Predstavljena so poročila, ki so na voljo po izdelanem planu in tekom izvedbe, če plan vsebuje vse zahtevane podatke. Obravnavana in predstavljena so poročila plana, poročilo kontrole virov in stroškov, nosilna poročila virov in stroškov, poročila o produktivnosti, stroških in ocenah, poročila o denarnem toku, tabelarična poročila o virih in stroških ter matrična poročila.

5.3.5 Deljenje podatkov o projektu z uporabo P3

Tekom izvedbe projekta morajo biti podatki o virih in ostale informacije o projektu tekoče posodobljene. Predstavljene so rešitve, ki jih P3 ponuja za pošiljanje posameznih informacij med udeleženci projekta in hranjenje le teh na spletu ali lokalnem serverju.

5.3.6 Udeleženci projekta

Vsi udeleženci projekta so zelo pomembni za njegov končni uspeh. Predstavljeni so tisti, ki so najbolj odgovorni za planiranje, delo z viri in vodenje projekta ter njihove naloge in metode dela s pomočjo P3.

5.4 ZAKLJUČKI IN PRIPOROČILA

Uporaba sodobne programske upreme omogoča nadzor nad projektom, reagiranje ko je le-to potrebno in ocenjevanje samega poteka izvedbe. Če so v projektni plan vključeni viri, stroški in ostale potrebne informacije, je vodenje, nadzor in ocenjevanje projekta lažje, učinkovitejše

in bolj uspešno. Projektni timi morajo biti seznanjeni z metodami planiranja virov in metodami projektne kontrole; učinkovitejša uporaba sodobne programske opreme za planiranje in vodenje projektov mora postati norma.

APPENDICES

Appendix A: List of activities and their data

| Activity ID | Activity description | Original duration | Remaining duration | Percent complete | Early start | Early finish | Resource | Budgeted cost |
|-------------------------|--|-------------------|--------------------|------------------|-------------|--------------|----------|---------------|
| 5.th FLOOR | | | | | | | | |
| STRUCTURAL WORKS | | | | | | | | |
| MBF5STR01 | COLUMNS AND BEAMS | 4 | 4 | 0 | 21.feb.04 | 24.feb.04 | SSTR1 | 20,160.00 |
| MBF5STR02 | MONTAGE OF THE TRAPES SLAB SURFACE | 1 | 1 | 0 | 25.feb.04 | 25.feb.04 | SSTR1 | 1,344.00 |
| MBF5STR03 | 2 LEVELLED DOUBLE REINFORCEMENT GRID | 1 | 1 | 0 | 26.feb.04 | 26.feb.04 | RG | 352.00 |
| MBF5STR04 | SCREED | 1 | 1 | 0 | 27.feb.04 | 27.feb.04 | SCR | 2,994.60 |
| MBF5STR05 | PROTECTION CONCRETE | 1 | 1 | 0 | 1.mar.04 | 1.mar.04 | CON2 | 2,084.25 |
| STRUCT.W2 | END OF STRUCTURAL WORKS | 0 | 0 | 0 | | 1.mar.04 | | 0.00 |
| INSULATION | | | | | | | | |
| MBF5ISO02 | LEING MEBRAN | 1 | 1 | 0 | 28.feb.04 | 28.feb.04 | ISO2 | 10,008.00 |
| MBF5ISO01 | FORMBOARD FOR 5 TH FLOOR | 1 | 1 | 0 | 29.feb.04 | 29.feb.04 | ISO1 | 4,235.22 |
| ISOLATION2 | END OF THE INSULATION WORKS | 0 | 0 | 0 | | 29.feb.04 | | 0.00 |
| FINE WORKS | | | | | | | | |
| MBF5FW03 | ROUGH PLASTERING | 2 | 2 | 0 | 29.feb.04 | 1.mar.04 | RPLS2 | 210.84 |
| MBF5FW04 | GRATON | 3 | 3 | 0 | 2.mar.04 | 4.mar.04 | GR | 33,618.64 |
| MBF5FW01 | GRANIT TILES FOR FLOOR | 1 | 1 | 0 | 12MAY04 | 12MAY04 | GTL2 | 422.18 |
| MBF5FW02 | ROCKWOOD SUSPENDING CEILING | 1 | 1 | 0 | 29MAY04 | 29MAY04 | RSC2 | 606.10 |
| 4.th FLOOR | | | | | | | | |
| STRUCTURAL WORKS | | | | | | | | |
| MBF4STR01 | INSTALLATION OF THE MAIN BEAMS | 7 | 7 | 0 | 9.feb.04 | 15.feb.04 | SSTR2 | 16,800.00 |
| MBF4STR02 | INSTALLATION OF THE SUB BEAMS | 6 | 6 | 0 | 10.feb.04 | 15.feb.04 | SSTR1 | 11,424.00 |
| MBF4STR03 | MONTAGE OF THE TRAPES SLAB SURFACE | 3 | 3 | 0 | 16.feb.04 | 18.feb.04 | SSTR1 | 12,768.00 |
| MBF4STR04 | 2 LEVEL REINFORCEMENT GRID | 1 | 1 | 0 | 19.feb.04 | 19.feb.04 | G | 4,294.00 |
| MBF4STR05 | 4 th FLOOR SLAB CONCRETE | 1 | 1 | 0 | 20.feb.04 | 20.feb.04 | CON1 | 7,968.55 |
| FINE WORKS | | | | | | | | |
| MBF4FW07 | ROUGH PLASTERING | 1 | 1 | 0 | 28.feb.04 | 28.feb.04 | RPLS2 | 159.03 |
| MBF4FW05 | TILES FOR WALLS | 2 | 2 | 0 | 29.feb.04 | 1.mar.04 | TIL1 | 1,538.50 |
| MBF4FW08 | GYPSUM PLASTERING | 11 | 11 | 0 | 01MAY04 | 11MAY04 | GPLS1 | 10,638.60 |
| MBF4FW01 | GRANIT TILES FOR FLOOR | 7 | 7 | 0 | 12MAY04 | 18MAY04 | GTL1 | 27,562.58 |
| MBF4FW04 | MATT WATER BASED PAINTING | 6 | 6 | 0 | 23MAY04 | 28MAY04 | PTG1 | 8,850.60 |
| MBF4FW06 | ROCKWOOD SUSPENDING CEILING | 3 | 3 | 0 | 29MAY04 | 31MAY04 | RSC1 | 9,348.00 |
| MBF4FW03 | METAL SKIRTING | 1 | 1 | 0 | 29MAY04 | 29MAY04 | MS1 | 4,320.00 |
| MBF4FW02 | CARPET COVERING | 1 | 1 | 0 | 8.jun.04 | 8.jun.04 | CC | 2,871.00 |
| 3.th FLOOR | | | | | | | | |
| STRUCTURAL WORKS | | | | | | | | |
| MBF3STR01 | INSTALLATION OF THE MAIN BEAMS | 7 | 7 | 0 | 31.jan.04 | 6.feb.04 | SSTR2 | 16,128.00 |
| MBF3STR02 | INSTALLATION OF THE SUB BEAMS | 3 | 3 | 0 | 1.feb.04 | 3.feb.04 | SSTR1 | 10,080.00 |
| MBF3STR03 | MONTAGE OF THE TRAPES SLAB SURFACE | 2 | 2 | 0 | 4.feb.04 | 5.feb.04 | SSTR1 | 12,768.00 |
| MBF3STR04 | 2 LEVEL REINFORCEMENT GRID FOR 3 ND FLOOR | 1 | 1 | 0 | 6.feb.04 | 6.feb.04 | RG | 4,294.00 |
| MBF3STR05 | 3rd FLOOR SLAB CONCRETE | 1 | 1 | 0 | 7.feb.04 | 7.feb.04 | CON1 | 7,968.55 |
| FINE WORKS | | | | | | | | |
| MBF3FW06 | ROUGH PLASTERING | 1 | 1 | 0 | 27.feb.04 | 27.feb.04 | RPLS1 | 159.03 |
| MBF3FW04 | TILES FOR WALLS | 1 | 1 | 0 | 2.mar.04 | 2.mar.04 | TIL2 | 641.04 |
| MBF3FW07 | GYPSUM PLASTERING | 10 | 10 | 0 | 01MAY04 | 10MAY04 | GPLS2 | 3,523.59 |
| MBF3FW01 | GRANIT TILES FOR FLOOR | 11 | 11 | 0 | 12MAY04 | 22MAY04 | GTL1 | 40,899.08 |
| MBF3FW03 | MATT WATER BASED PAINTING | 5 | 5 | 0 | 23MAY04 | 27MAY04 | PTG2 | 6,921.35 |
| MBF3FW05 | ROCKWOOD SUSPENDING CEILING | 3 | 3 | 0 | 29MAY04 | 31MAY04 | RSC2 | 8,920.50 |
| MBF3FW02 | METAL SKIRTING | 1 | 1 | 0 | 29MAY04 | 29MAY04 | MS2 | 5,400.00 |
| 2.th FLOOR | | | | | | | | |
| STRUCTURAL WORKS | | | | | | | | |
| MBF2STR01 | ERECTION OF THE 2nd STEP COLUMNS | 3 | 3 | 0 | 20.jan.04 | 22.jan.04 | SSTR2 | 36,960.00 |
| MBF2STR02 | INSTALLATION OF THE CONNECTION PLATES | 1 | 1 | 0 | 23.jan.04 | 23.jan.04 | SSTR2 | 2,688.00 |
| MBF2STR03 | INSTALLATION OF THE MAIN BEAMS | 7 | 7 | 0 | 24.jan.04 | 30.jan.04 | SSTR2 | 16,800.00 |
| MBF2STR04 | INSTALLATION OF THE SUB BEAMS | 3 | 3 | 0 | 26.jan.04 | 28.jan.04 | SSTR1 | 11,424.00 |
| MBF2STR05 | MONTAGE OF THE TRAPES SLAB SURFACE FOR 2nd FLOOR | 2 | 2 | 0 | 29.jan.04 | 30.jan.04 | SSTR1 | 12,768.00 |
| MBF2STR06 | 2 LEVELS REINFORCEMENT GRID FOR 2st FLOOR | 1 | 1 | 0 | 31.jan.04 | 31.jan.04 | RG | 4,294.00 |
| MBF2STR07 | 2nd FLOOR SLAB CONCRETE | 1 | 1 | 0 | 1.feb.04 | 1.feb.04 | CON1 | 7,886.40 |
| FINE WORKS | | | | | | | | |
| MBF2FW05 | ROUGH PLASTERING | 1 | 1 | 0 | 27.feb.04 | 27.feb.04 | RPLS2 | 159.03 |
| MBF2FW06 | GYPSUM PLASTERING | 10 | 10 | 0 | 11MAY04 | 20MAY04 | GPLS1 | 8,480.11 |

| | | | | | | | | |
|------------|---|----|----|---|-----------|-----------|--------|-----------|
| MBF2FW01 | GRANIT TILES FOR FLOOR | 11 | 11 | 0 | 21MAY04 | 31MAY04 | GTL2 | 38,328.28 |
| MBF2FW03 | MATT WATER BASED PAINTING | 5 | 5 | 0 | 1.jun.04 | 5.jun.04 | PTG1 | 7,054.88 |
| MBF2FW04 | ROCKWOOD SUSPENDING CEILING | 3 | 3 | 0 | 6.jun.04 | 8.jun.04 | RSC1 | 9,659.60 |
| MBF2FW02 | METAL SKIRTING | 1 | 1 | 0 | 6.jun.04 | 6.jun.04 | GTL1 | 32,417.70 |
| | 1.th FLOOR | | | | | | | |
| | STRUCTURAL WORKS | | | | | | | |
| MBF1STR01 | MAIN BEAMS INSTALLATION OF THE FIRST FLOOR | 4 | 4 | 0 | 12.jan.04 | 15.jan.04 | SSTR1 | 16,800.00 |
| MBF1STR02 | SUB BEAMS INSTALLATION OF THE 1st LEVEL | 3 | 3 | 0 | 13.jan.04 | 15.jan.04 | SSTR2 | 11,424.00 |
| MBF1STR03 | MONTAGE OF THE TRAPES SLAB SURFACE FOR 1st FLOOR | 2 | 2 | 0 | 16.jan.04 | 17.jan.04 | SSTR2 | 12,768.00 |
| MBF1STR04 | 2 LEVELS REINFORCEMENT GRID FOR 1st FLOOR | 1 | 1 | 0 | 18.jan.04 | 18.jan.04 | RG | 3,942.00 |
| MBF1STR05 | 1st LEVEL SLAB CONCRETE | 1 | 1 | 0 | 19.jan.04 | 19.jan.04 | CON1 | 7,147.05 |
| | FINE WORKS | | | | | | | |
| MBF1FW06 | ROUGH PLASTERING | 1 | 1 | 0 | 26.feb.04 | 26.feb.04 | RPLS2 | 160.19 |
| MBF1FW04 | TILES FOR WALLS | 2 | 2 | 0 | 3.mar.04 | 4.mar.04 | TIL1 | 846.71 |
| MBF1FW07 | GYPSUM PLASTERING | 11 | 11 | 0 | 01MAY04 | 11MAY04 | GPLS2 | 9,858.34 |
| MBF1FW01 | GRANIT TILES FOR FLOOR | 9 | 9 | 0 | 23MAY04 | 31MAY04 | GTL1 | 35,395.61 |
| MBF1FW03 | MATT WATER BASED PAINTING | 1 | 1 | 0 | 1.jun.04 | 1.jun.04 | PTG2 | 8,197.20 |
| MBF1FW02 | METAL SKIRTING | 1 | 1 | 0 | 2.jun.04 | 2.jun.04 | MS2 | 4,920.00 |
| MBF1FW05 | ROCKWOOD SUSPENDING CEILING | 3 | 3 | 0 | 6.jun.04 | 8.jun.04 | RSC1 | 8,911.00 |
| | GROUND FLOOR | | | | | | | |
| | STRUCTURAL WORKS | | | | | | | |
| MBGSTR01 | INSTALLATION OF THE ANKRAJ PLAQUES | 2 | 2 | 0 | 4.jan.04 | 5.jan.04 | SSTR2 | 4,704.00 |
| MBGSTR02 | ERECTION OF THE 1st STEP COLUMNS | 3 | 3 | 0 | 6.jan.04 | 8.jan.04 | SSTR1 | 36,960.00 |
| MBGSTR03 | INSTALLATION OF THE MAIN BEAMS | 4 | 4 | 0 | 8.jan.04 | 11.jan.04 | SSTR2 | 16,800.00 |
| MBGSTR04 | INSTALLATION OF THE SUB BEAMS | 3 | 3 | 0 | 9.jan.04 | 11.jan.04 | SSTR1 | 11,424.00 |
| MBGSTR05 | MONTAGE OF THE TRAPES SLAB SURFACE | 1 | 1 | 0 | 12.jan.04 | 12.jan.04 | SSTR2 | 12,768.00 |
| MBGSTR06 | 2 LEVELS REINFORCEMENT GRID FOR GROUND FLOOR | 1 | 1 | 0 | 13.jan.04 | 13.jan.04 | RG | 3,942.00 |
| MBGSTR07 | GROUND LEVEL SLAB CONCRETE | 1 | 1 | 0 | 14.jan.04 | 14.jan.04 | CON1 | 7,147.05 |
| | FINE WORKS | | | | | | | |
| MBGFW06 | ROUGH PLASTERING | 1 | 1 | 0 | 26.feb.04 | 26.feb.04 | RPLS1 | 159.03 |
| MBGFW05 | TILES FOR WALLS | 2 | 2 | 0 | 3.mar.04 | 4.mar.04 | TIL2 | 846.71 |
| MBGFW07 | GYPSUM PLASTERING | 5 | 5 | 0 | 21MAY04 | 25MAY04 | GPLS1 | 3,207.65 |
| MBGFW01 | GRANIT TILES FOR FLOOR | 12 | 12 | 0 | 1.jun.04 | 12.jun.04 | GTL2 | 39,730.53 |
| MBGFW03 | MATT WATER BASED PAINTING | 3 | 3 | 0 | 13.jun.04 | 15.jun.04 | PTG1 | 2,668.55 |
| MBGFW04 | ROCKWOOD SUSPENDING CEILING | 3 | 3 | 0 | 16.jun.04 | 18.jun.04 | RSC1 | 9,667.20 |
| MBGFW02 | METAL SKIRTING | 1 | 1 | 0 | 16.jun.04 | 16.jun.04 | MS1 | 1,669.56 |
| | BASEMENT | | | | | | | |
| | STRUCTURAL WORKS | | | | | | | |
| MBBSTR01 | REINFORCEMENT OF BASEMENT CURTAIN WALLS,COLUMN | 5 | 5 | 0 | 11.dec.03 | 15.dec.03 | REIN 1 | 9,908.10 |
| MBBSTR02 | FORMWORK FOR BASEMENT CURTAIN WALLS,COLUMNS | 6 | 6 | 0 | 12.dec.03 | 17.dec.03 | FRM1 | 8,232.96 |
| MBBSTR05 | REINFORCEMENT OF SLAB | 5 | 5 | 0 | 16.dec.03 | 20.dec.03 | REIN 1 | 21,797.82 |
| MBBSTR03 | CONCRETE FOR BASEMENT FOR CURTAIN WALLS,COLUMNS | 1 | 1 | 0 | 18.dec.03 | 18.dec.03 | CON1 | 7,639.95 |
| MBBSTR04 | FORMWORK FOR SLAB | 7 | 7 | 0 | 20.dec.03 | 26.dec.03 | FRM1 | 18,524.16 |
| MBBSTR06 | BS30 CONCRETE FOR SLAB | 1 | 1 | 0 | 27.dec.03 | 27.dec.03 | CON1 | 7,639.95 |
| | INSULATION | | | | | | | |
| MBBISO01 | APPLYING EPC FOR WATER INSULATION TO WALLS | 1 | 1 | 0 | 17.jan.04 | 17.jan.04 | ISO5 | 8,832.00 |
| MBBISO02 | WATER INSULATION FOR CURTAIN WALLS WITH FORMBOARD | 1 | 1 | 0 | 17.jan.04 | 17.jan.04 | ISO4 | 8,832.00 |
| | FINE WORKS | | | | | | | |
| MBBFW02 | GYPSUM PLASTERING | 7 | 7 | 0 | 18.dec.03 | 24.dec.03 | GPLS2 | 6,219.65 |
| FINE WORK1 | BEGINNING OF THE FINE WORKS | 0 | 0 | 0 | 18.dec.03 | | | 0.00 |
| MBBFW01 | ROUGH PLASTERING | 2 | 2 | 0 | 18.dec.03 | 19.dec.03 | RPLS1 | 425.80 |
| MBBFW03 | TILES FOR WALLS | 3 | 3 | 0 | 5.mar.04 | 7.mar.04 | TIL1 | 2,117.57 |
| MBBFW04 | GRANIT TILES FOR FLOOR | 6 | 6 | 0 | 1.jun.04 | 6.jun.04 | GTL1 | 40,112.00 |
| MBBFW06 | MATT WATER BASED PAINTING | 7 | 7 | 0 | 7.jun.04 | 13.jun.04 | PTG2 | 5,174.33 |
| MBBFW07 | ROCKWOOD SUSPENDING CEILING | 2 | 2 | 0 | 14.jun.04 | 15.jun.04 | RSC2 | 7,628.50 |
| MBBFW05 | METAL SKIRTING | 1 | 1 | 0 | 15.jun.04 | 15.jun.04 | MS2 | 4,918.80 |
| FINE WORK2 | END OF THE FINE WORKS | 0 | 0 | 0 | | 18.jun.04 | | 0.00 |
| | FOUNDATION | | | | | | | |
| | STRUCTURAL WORKS | | | | | | | |
| MBFSTR01 | LEAN CONCRETE | 1 | 1 | 0 | 30.nov.03 | 30.nov.03 | CON3 | 4,415.34 |
| STRUCT.W1 | BEGINNING OF STRUCTURAL WORKS | 0 | 0 | 0 | 30.nov.03 | | | 0.00 |
| MBFSTR02 | FORMWORK FOR FOUNDATION | 10 | 10 | 0 | 1.dec.03 | 10.dec.03 | FRM1 | 21,440.00 |
| MBFSTR03 | REINFORCEMENT FOR FOUNDATION | 7 | 7 | 0 | 4.dec.03 | 10.dec.03 | REIN 1 | 74,310.75 |
| MBFSTR04 | BS30 CONCRETE FOR FOUNDATION | 1 | 1 | 0 | 11.dec.03 | 11.dec.03 | CON1 | 50,933.00 |
| MBFSTR05 | PROTECTION CONCRETE | 1 | 1 | 0 | 14.dec.03 | 14.dec.03 | CON2 | 2,326.02 |
| | INSULATION | | | | | | | |
| ISOLATION1 | BEGINNING OF THE INSULATION WORKS | 0 | 0 | 0 | 12.dec.03 | | | 0.00 |
| MBFISO01 | LYING MEBRANE+APPLYING EPC | 1 | 1 | 0 | 13.dec.03 | 13.dec.03 | ISO3 | 9,117.72 |

| | | | | | | | | | |
|------------|---|----|----|---|-----------|-----------|-------------|--|------------|
| | MOBILIZATION & START UP WORKS | | | | | | | | |
| 1 | BEGINNING OF THE PROJECT | 0 | 0 | 0 | 14.nov.03 | | | | 0.00 |
| MOB01 | SITE MOBILIZATION | 7 | 7 | 0 | 14.nov.03 | 20.nov.03 | GENER1 | | 518.00 |
| | EARTH WORKS | | | | | | | | |
| EARTHWORK1 | BEGINNING OF EARTH WORKS | 0 | 0 | 0 | 14.nov.03 | | | | 0.00 |
| EW01 | EXCAVATION | 8 | 8 | 0 | 21.nov.03 | 28.nov.03 | EW1 | | 7,904.26 |
| EW02 | HAND EXCAVATION | 7 | 7 | 0 | 21.nov.03 | 27.nov.03 | HAND EXC | | 1,488.00 |
| EW03 | LINING WITH QUARRYSTONE | 1 | 1 | 0 | 29.nov.03 | 29.nov.03 | EW2 | | 1,019.82 |
| EW05 | LIEING DRENAJ PIPE | 1 | 1 | 0 | 18.jan.04 | 18.jan.04 | GENER1 | | 8,584.00 |
| EARTHWORK2 | END OF EARTH WORKS | 0 | 0 | 0 | | 18.jan.04 | | | 0.00 |
| EW04 | FILLING WITH GRANULAR MATERIAL | 3 | 3 | 0 | 19.jan.04 | 21.jan.04 | EW3 | | 1,408.32 |
| | WALL & MASONRY WO | | | | | | | | |
| WM05 | FULL BRICK WALL | 7 | 7 | 0 | 15.dec.03 | 21.dec.03 | WM1 | | 4,399.67 |
| WMASONRY1 | BEGINNING OF THE WALL AND MASONRY WORKS | 0 | 0 | 0 | 22.dec.03 | | | | 0.00 |
| WM03 | BIMS10 | 5 | 5 | 0 | 21.feb.04 | 25.feb.04 | WM2 | | 2,061.40 |
| WM04 | BIMS20 | 4 | 4 | 0 | 21.feb.04 | 24.feb.04 | WM3 | | 3,270.20 |
| WM06 | CUBICAL DEMONTABLE WALL | 0 | 0 | 0 | 8.mar.04 | 7.mar.04 | DW2 | | 0.00 |
| WM02 | GYPSUM WALL20 | 40 | 40 | 0 | 22.mar.04 | 30.apr.04 | GW2 | | 38,001.36 |
| WM01 | GYPSUM WALL10 | 30 | 30 | 0 | 22.mar.04 | 20.apr.04 | GW1 | | 21,648.26 |
| WM07 | DEMOUNTABLE WALL WITH JALUZZI | 7 | 7 | 0 | 7.jun.04 | 13.jun.04 | DW1 | | 30,690.00 |
| WMASONRY2 | END OF THE WALL AND MASONRY WORKS | 0 | 0 | 0 | | 13.jun.04 | | | 0.00 |
| | METAL WORKS | | | | | | | | |
| MTW02 | METAL SUB FRAMING 20*40 | 30 | 30 | 0 | 21.feb.04 | 21.mar.04 | MSF | | 101,600.00 |
| MTW01 | METAL DOOR FRAMING | 1 | 1 | 0 | 01MAY04 | 01MAY04 | MEF | | 6,462.50 |
| | MECHANICAL WORKS | | | | | | | | |
| MW03 | CILLER SYSTEM | 7 | 7 | 0 | 28.dec.03 | 3.jan.04 | MEC3 | | 265,350.00 |
| MW04 | MISCELLANEOUS MECHANICAL WORKS | 60 | 60 | 0 | 28.dec.03 | 25.feb.04 | MEC4 | | 63,362.00 |
| MECHANICW1 | BEGINNING OF THE MECHANICAL WORKS | 0 | 0 | 0 | 28.dec.03 | | | | 0.00 |
| MW06 | LAB.TECH | 20 | 20 | 0 | 2.mar.04 | 21.mar.04 | MEC6 | | 44,101.00 |
| MW05 | FIRE PROTECTION SYSTEM | 10 | 10 | 0 | 3.mar.04 | 12.mar.04 | MEC5 | | 12,038.00 |
| MW01 | VENTILATION | 30 | 30 | 0 | 11.apr.04 | 10MAY04 | MEC1 | | 198,600.00 |
| MW02 | HEATING CENTRAL | 20 | 20 | 0 | 11.apr.04 | 30.apr.04 | MEC2 | | 39,749.00 |
| MECHANICW2 | END OF MECHANICAL WORKS | 0 | 0 | 0 | | 10MAY04 | | | 0.00 |
| MW07 | AUTOMATIC CONT | 7 | 7 | 0 | 16.jun.04 | 22.jun.04 | MEC7 | | 59,800.00 |
| | ELECTRICAL WORKS | | | | | | | | |
| ELW03 | GALVANIZING ELECTIRAL CHANNELS | 4 | 4 | 0 | 25.dec.03 | 28.dec.03 | EL03 | | 37,768.00 |
| ELECTRW1 | BEGINNING OF ELECTRICAL WORKS | 1 | 1 | 0 | 25.dec.03 | 25.dec.03 | | | 0.00 |
| ELW05 | MAIN CABLING | 10 | 10 | 0 | 29.dec.03 | 7.jan.04 | EL05 | | 37,878.00 |
| ELW06 | GROUNDING | 2 | 2 | 0 | 29.dec.03 | 30.dec.03 | EL06 | | 6,264.00 |
| ELW04 | DATA NETWORK CABLING | 2 | 2 | 0 | 29.dec.03 | 30.dec.03 | EL04 | | 21,515.00 |
| ELW07 | PHONE CABLING | 2 | 2 | 0 | 2.jan.04 | 3.jan.04 | EL07 | | 13,300.00 |
| ELW12 | ELECTRICAL PIPING(PVC BORU VE AKSESUARLARI) | 10 | 10 | 0 | 21.feb.04 | 1.mar.04 | EL12 | | 6,477.00 |
| ELW13 | ELECTRICAL UTILITIES(saltlar ve panolar) | 7 | 7 | 0 | 2.mar.04 | 8.mar.04 | EL13 | | 36,180.00 |
| ELW08 | GENERATOR INSTALLATION | 7 | 7 | 0 | 2.mar.04 | 8.mar.04 | EL08 | | 42,451.00 |
| ELW02 | INTERIOR LIGHTING(sortiler) | 15 | 15 | 0 | 2.mar.04 | 16.mar.04 | EL02 | | 21,934.00 |
| ELW10 | LIFT INSTALLATION | 10 | 10 | 0 | 2.mar.04 | 11.mar.04 | EL10 | | 22,148.00 |
| ELW11 | EXTERIOR LIGHTS | 7 | 7 | 0 | 2.mar.04 | 8.mar.04 | EL11 | | 65,084.00 |
| ELW01 | ELECTRICAL ARMATURE MONTAGE | 7 | 7 | 0 | 1.jun.04 | 7.jun.04 | EL01 | | 54,182.00 |
| ELW09 | UPS MONTAGE | 2 | 2 | 0 | 14.jun.04 | 15.jun.04 | EL09 | | 6,505.00 |
| ELECTRW2 | END OF ELECTRICAL WORKS | 1 | 1 | 0 | 16.jun.04 | 16.jun.04 | | | 0.00 |
| | SITE ROAD WORKS | | | | | | | | |
| SRW01 | SEWERAGE WORKS | 2 | 2 | 0 | 26.feb.04 | 27.feb.04 | SW, MH | | 2,926.20 |
| SRW02 | STORM WATER WORKS | 1 | 1 | 0 | 26.feb.04 | 26.feb.04 | SWW, MH | | 1,844.00 |
| SRW03 | LANDSCAPING | 15 | 15 | 0 | 28.feb.04 | 13.mar.04 | GENER3 | | 88.00 |
| | SPECIAL WORKS | | | | | | | | |
| SW08 | PAINTING ON METAL WORKS FOR FIRE PROTECTION | 1 | 1 | 0 | 25.feb.04 | 25.feb.04 | FP | | 18,750.00 |
| SPECIALW1 | BEGINNING OF SPECIAL WORKS | 0 | 0 | 0 | 25.feb.04 | | | | 0.00 |
| SW05 | METAL DOORS | 1 | 1 | 0 | 25.feb.04 | 25.feb.04 | MDF | | 900.00 |
| SW06 | CHIMNEY CONSTRUCTION | 3 | 3 | 0 | 26.feb.04 | 28.feb.04 | CIMC | | 5,550.00 |
| SW01 | ALUMINIUM FACADE WORKS | 60 | 60 | 0 | 2.mar.04 | 30.apr.04 | FW1 | | 188,653.50 |
| SW02 | CUBICAL DOORS | 1 | 1 | 0 | 8.mar.04 | 8.mar.04 | DW2 | | 9,720.00 |
| SW10 | COMPOSIT PANEL WORKS | 15 | 15 | 0 | 01MAY04 | 15MAY04 | CP | | 39,600.00 |
| SW11 | TEMPERED DOUBLE GLAZING | 15 | 15 | 0 | 01MAY04 | 15MAY04 | TDG | | 219,060.00 |
| SW03 | GRANITE TILES FOR STAIRS | 12 | 12 | 0 | 16.jun.04 | 27.jun.04 | GTFS | | 15,548.11 |
| SW04 | LAMINATED DOORS | 7 | 7 | 0 | 16.jun.04 | 22.jun.04 | LD | | 30,498.82 |
| SW09 | GRANITE BENCH(TEZGAH) | 1 | 1 | 0 | 23.jun.04 | 23.jun.04 | GB | | 5,554.98 |
| SW07 | STAINLESS HANDRAIL | 10 | 10 | 0 | 28.jun.04 | 7.jul.04 | SHR | | 23,220.00 |
| 2 | END OF THE PROJECT | 0 | 0 | 0 | | 7.jul.04 | | | 0.00 |

Appendix B: The legend of added and used resources in the schedule

| Sign of resource | Resource description | Unit | price (YTL/unit) | Sign of resource | Resource description | Unit | price (YTL/unit) |
|------------------|------------------------------------|------|------------------|------------------|----------------------------------|-------|------------------|
| CC | CARPET + LABOURING | M2 | 16 | HAND EXC | HAND EXCAVATION CREW | M3 | 9,6 |
| CIMC | CHIMNEY CONSTRUCTION | M | 185 | ISO1 | FORMBOARD | M2 | 8,37 |
| CON1 | CONCRETE CREW+BS30 | M3 | 82,15 | ISO2 | MEBRAN SERIMI | M2 | 18 |
| CON2 | CONCRETE CREW+PROTECTION CONCRETE | M3 | 59,55 | ISO3 | LEING MEMBRANE+EPC+LABOURING | M2 | 16,34 |
| CON3 | CONCRETE CREW+LEAN CONCRETE | M3 | 63,53 | ISO4 | FORMBOARD+BRICK+LABOURING | M2 | 23 |
| CP | COMPOSIT PANEL+LABOURING | M2 | 120 | ISO5 | EPC+LABOURING | M2 | 23 |
| DW1 | DEMOUNTABLE WALL WITH JALUZZI CREW | M2 | 225 | LD | LAMINATED DOORS+LABOURING | M2 | 90,06 |
| DW2 | CUBICAL DEMOUNTABLE WALL+LABOURING | M2 | 135 | MDF | METAL DOOR+LABOURING | UNIT | 150 |
| ELO1 | ELECTRICAL ALARM | UNIT | 54.182,00 | MEC 1 | VENTILATION | GROUP | 198.600,00 |
| ELO2 | INTERIOR LIGHTS | UNIT | 21.934,00 | MEC 2 | HEATING SYSTEM | GROUP | 39.749,00 |
| ELO3 | GALVANIC ELECTRICAL | UNIT | 37.768,00 | MEC 3 | CILLER SYSTEM | GROUP | 265.350,00 |
| ELO4 | DATA | UNIT | 21.515,00 | MEC 4 | MECHANICAL WORKS | GROUP | 63.362,00 |
| ELO5 | MAIN CAB | UNIT | 37.878,00 | MEC 5 | FIRE PROTECTION | GROUP | 12.038,00 |
| ELO6 | GROUNDING | UNIT | 6.264,00 | MEC 6 | LAB | GROUP | 44.101,00 |
| ELO7 | PHONE | UNIT | 13.300,00 | MEC 7 | OTOM | GROUP | 59.800,00 |
| ELO8 | GENERATOR | UNIT | 42.451,00 | MEF | METAL FRAMING | KG | 2,5 |
| ELO9 | UPS | UNIT | 6.503,00 | MH | MANHOLE | UNIT | 850 |
| EL10 | LIFT | UNIT | 22.148,00 | MS1 | METAL SKIRTING | MTL | 12 |
| EL11 | EX | UNIT | 65.084,00 | MS2 | METAL SKIRTING | MTL | 12 |
| EL12 | EL.PIPE | UNIT | 6.477,00 | MSF | METAL SUB FRAMING | KG | 2,54 |
| EL13 | EL.UT | UNIT | 3.618,00 | PTG1 | PAINTING CREW1 | M2 | 5,49 |
| EW1 | EXCAVATION+LABOURING | M3 | 1,82 | PTG2 | PAINTING CREW2 | M2 | 5,49 |
| EW2 | QUARRY STONE+LABOURING | M3 | 7,39 | REIN 1 | REINFORCEMENT CREW1 | TN | 990,81 |
| EW3 | GRANULLAR MATERIAL+LABOURING | M3 | 4,89 | RG | REINFORCEMENT GRID+3MEN | KG | 1 |
| EW4 | PIPE COST+LABOURING | M | 18,92 | RPLS1 | ROUGH PLASTERING CREW1 | M2 | 5,02 |
| FP | FIRE PROTECTION PAINT+LABOURING | M2 | 37,5 | RPLS2 | ROUGH PLASTERING CREW2 | M2 | 5,02 |
| FRM1 | FORMWORK | M2 | 10,72 | RSC 1 | ROCKWOOD SUSPENDING CEILING 1 | M2 | 19 |
| FW1 | FACADE ALUMINIUM WORK+LABOURING | M2 | 79,5 | RSC 2 | ROCKWOOD SUSPENDING CEILING 2 | M2 | 19 |
| GB | GRANITE BENCH+LABOURING | M | 145,8 | SCR | SCREED CREW | M3 | 69 |
| GENER1 | GENERAL WORKS CREW (5 MAN) | DAY | 74 | SHR | STAINLESS HANDRAIL+LABORING | MTL | 135 |
| GENER2 | GENERAL WORKS CREW (2 MAN) | TON | 29 | SSTR1 | STEEL STRUCTURE CREW1 | TON | 672 |
| GENER3 | GENERAL WOES CREW (6 MEN) | DAY | 88 | SSTR2 | STEEL STRUCTURE CREW2 | TON | 672 |
| GPLS1 | GYPSUM PLASTERING | M2 | 7,14 | SW | SEWERAGE WORKS | M | 12,54 |
| GPLS2 | GYPSUM PLASTERING | M2 | 7,14 | SWW | STORMWTARE WORKS | M | 7,2 |
| GR | GRATON+LABOURING | M2 | 66,44 | TDG | TEMPERED DOUBLE GLAZING+LABORING | M2 | 90 |
| GTFS | GRANIT TILES+LABOURING | M | 79,98 | TIL1 | TILING FOR WALLS | M2 | 26,71 |
| GTL1 | GRANIT TILES CREW 1 | M2 | 75,39 | TIL2 | TILING FOR WALLS | M2 | 26,71 |
| GTL2 | GRANIT TILES CREW 2 | M2 | 75,39 | WM1 | MASONRY CREW FOR BRICK | M2 | 8,4 |
| GW1 | GYPSUM WALL 10 CREW1 | M2 | 17,9 | WM2 | MASONRY CREW FOR BIMS10 | M2 | 9,37 |
| GW2 | GYPSUM WALL 20 CREW2 | M2 | 24,36 | WM3 | MASONRY CREW FOR BIMS20 | M2 | 13,28 |

Appendix C: Schedule of MBB

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