# Case Studies for the Planning and Monitoring of Unit- and Fixed-price Contracts Using Project Scheduling Software

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## ABSTRACT

Scheduling software used for construction projects is generally designed to plan and monitor activities and resources. These types of software allocate resources to the different activities, and allow for resource levelling, costing and cash flow calculations. These features are well-adapted to subcontractors who manage their own human and material resources, and allocate them to the activities of one or a multitude of projects. General contractors and consultants do not generally have full control over project resources, and therefore, most software does not directly address their needs for monitoring unit- or fixed-price contracts. In addition, subcontractors' schedule structures do not necessarily follow the logic of the Bill of Quantities which makes it more difficult to monitor financial progress and cash flow. This paper exposes the problems and limitations associated with the existing scheduling software, and presents three scheduling solutions using MS-Project and Excel individually or in combination. These methods have been applied to several case studies in irrigation and fisheries mega-infrastructure projects in Morocco and Burkina Faso. The methodology and proposed solutions are validated through their applications on these mega-projects.

## BACKGROUND

Most activities for construction building projects are performed by subcontractors who are responsible for the implementation of the majority of these activities using their own teams, equipment, and materials. Subcontractors are also responsible for preparing the construction schedule according to their own specialties and the day-to-day activity planning. To do so, they allocate the resources necessary for the completion of these activities.

Scheduling methods are generally based on critical path methods, abbreviated as CPM. These methods establish the logic between the project activities based on the networks traditionally known as Activity On Arrow (or AON) (Ford and Fulkerson, 1957), or the Precedence Diagram Method, PDM (Roy, 1962 Fondahl 1962). Resources are then allocated to these networks. Leung 2004 cites that scheduling methods deal with the allocation of scarce resources to tasks over time. Scheduling software is based on these methods by establishing logic between activities, and by allocating resources to the scheduled activities, allowing for resource levelling and costing. Using this process, the software is well-adapted for scheduling subcontractor specialities.

General contractors and consultants do not generally have full control over project resources. Their principles tasks concern the monitoring of unit- or fixed-price contracts. To plan their projects, general contractors must coordinate the activities of subcontractors and suppliers, and deliverables, but not resources. They need also to manage:

- Limited work locations in order to avoid conflict in space allocation;
- Horizontal and vertical circulation on site to avoid congestion;
- Procurements, inventories, waste management and recycling activities;
- Payment requests, change orders and cash flow calculations.

Despite this, most scheduling methods and software do not directly address these needs. Their operating logic is based on the establishment of the logic and constraints between activities in order to optimize and level the available resources. A survey of the construction industry relative to the use of CPM scheduling for construction projects (Galloway 2006), specifies that nearly 40% of contractors have indicated that their primary concern about CPM scheduling is the abuse of construction logic. In addition, subcontractors schedule structures do not necessarily follow the logic of the Bill of Quantities, which makes it more difficult to monitor the financial progress of the project and the cash flow calculation.

Subcontractors and General Contractors also do not share the same goals. The former is concerned with the effective use of its own resources, which can be described as a horizontal allocation of limited resources towards the different projects in which the subcontractor is involved. For subcontractors, this horizontal allocation dictates the individual project objectives, while the latter aims to coordinate various stakeholders, or vertical allocations, in order to respect schedules and budgets for individual projects.

General contractors must be able to communicate and share visual information understandably. While Neil and Knack (1984) indicate that effective communication among all project participants can stimulate cooperation and productivity, unfortunately, Bowden et al. (2006) identifies the dissatisfaction on the issue of available communication systems and practices in project planning.

In order to achieve that, scheduling software must allow resource allocation and management as well as facilitate the coordination between the contractor, the subcontractors and the suppliers. They must be able to implement schedules based on the Bill of Quantities by managing schedule and budget progressions using quantities, unit prices, different expenses and lump sum costs. It should permit general contractors to track payment progress and change orders with their subcontractors as well as with their clients, and allow them to follow income, expenses and cash flow. Planning concerns not only construction activities, but also: i) procurements, inventories, waste management and recycling processes; ii) site circulation, work locations and space management; iii) quality assurance, health and safety, and environment and social activities.

## OBJECTIVE OF THIS PAPER

As noted above, general contractors need to manage: i) limited work locations; ii) horizontal and vertical circulation; iii) procurements, inventories, waste

management and recycling activities; and iv) payment requests, change orders and cash flow calculations.

The objective of this paper is to address a solution to the fourth element mentioned above: payment requests, change orders and cash flow calculation. The paper present feasible solutions to the problem, namely, how to enable general contractors and consultants to efficiently manage lump sum and unit price projects, and which features are needed to allow scheduling software to address these needs for managing different types of contracts. We believe that scheduling software must enable different stakeholders to plan their projects according to their needs.

## CASE STUDIES

This paper presents three scheduling solutions using MS-Project and Excel individually or in combination to enable general contractors and consultants to plan and follow unit-price contracts efficiently. In these three methods, the activities structure follows the same structure as the Bill of Quantities of the project tender. Further details of these activities can be demonstrated if necessary.

**A scheduling solution using MS-Project.**  The first method uses MS-Project as a support for the project schedule. The methodology uses the Gantt Diagram Display to plan the project activities according to the structure of the Bill of Quantities (see Figure 1).
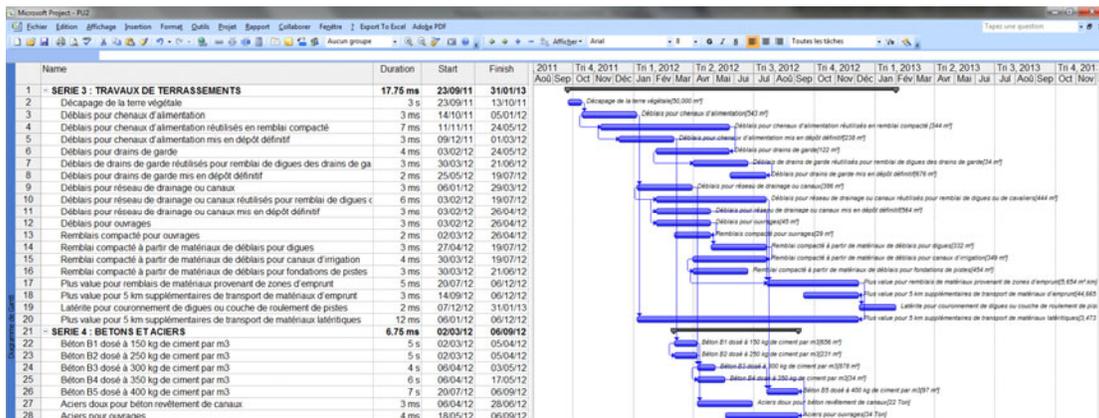


**Figure 1.        Gantt Diagram Display**

The planner must fill in the Resources Table with the same activities. These activities will then be represented in the project resources table. The type of resources must be adjusted to "Material" and the "Material Labels" must show the same unit indicated in the Bill of Quantities. The "Resources Rate" column is used to indicate the activity Unit Price. Obviously, for clarity reason, the planner could rename this column "Unit Price", as in Figure 2.

**Figure 2.** **The Resources Table shows the project activities.**

Ultimately, the "Resource Usage" display (see Figure 3), will show payment progress. The planner will assign the "Work" field to the caption "Quantity"; the "Standard Rate" field will be renamed "Unit Price" and the field "Cost" will be renamed "Total".

The monthly amount will be calculated automatically by MS-Project. It may also be entered manually by the user.



**Figure 3.** **The Resource Usage Display shows payment progress.**

Although this solution meets the needs of the General Contractor, it has some shortcomings, such as: i) the duplication of entries; and ii) the fact that the "Resource Usage" display does not show the summation amounts of the payment progress.

**A scheduling solution using VBA-Excel.** The second method uses VBA-Excel to schedule the project activities. The project is planned according to the structure of the Bill of Quantities, Figure 4. The ordinate axis shows this structure.

**Figure 4.     A scheduling solutions using VBA-Excel**

The file consists of four (4) vertical sections:
- The first section shows the activity data (quantities, unit prices, etc.).
- The other three (3) sections show the time-scaled distribution of: i) the planning of activity quantities by month; ii) the revised and actual distribution of the activity quantities by month, and iii) the percentages of progress.

Each month, the planner revises the quantity amounts (or the progress percentage) performed. The VBA-Excel, as per the example shown in Figure 5, detect the fields inputted manually and the fields to be calculated, and prepare the payment requests, the progress, and the performance curves Figure 6.

```
Sub AvancementRevise()
    Dim i As Integer
    Dim Distance As Integer, Nbr As Integer, Count As Integer, Courbes As String, Montant As Single, Total As Single, Cumulatif As Single

    Dim DatesCell As Range, NomsCell As Range, TypesCell As Range, CoutReviseCell As Range, CumulatifCell As Range, ReviseCumulatifCell As Range, ODC1erLigneCell As Range

    With frm_Demandes
        Set DatesCell = .Range("Dates")
        Set NomsCell = .Range("Noms")
        Set TypesCell = .Range("Types")
        Set CoutReviseCell = .Range("CoutRevise")
        Set CumulatifCell = .Range("Cumulatif")
        Set ReviseCumulatifCell = .Range("ReviseCumulatif")
        Set ODC1erLigneCell = .Range("ODC1erLigne")

        'calculer le nbr de ligne de difference entre DP et ODC
        Distance = ODC1erLigneCell.Row - NomsCell.Row

        'effacer la ligne revisé
        For Each DatesCell In .Range("Dates")
            .Cells(ReviseCumulatifCell.Row, DatesCell.Column).Value = ""
        Next DatesCell

        For Each NomsCell In .Range("Noms")
            Courbes = Cells(NomsCell.Row, TypesCell.Column).Value
            Total = (.Cells(NomsCell.Row, CoutReviseCell.Column).Value _
                   - .Cells(NomsCell.Row, CumulatifCell.Column).Value)
            Cumulatif = 0

            'Caculer le nombre de mois prévue pour terminer chaque lot
            i = 0
            Nbr = 0
            For Each DatesCell In .Range("Dates")
            Select Case .Cells(NomsCell.Row, DatesCell.Column)
              Case 1E-90 To 0.01
                  i = i + 1
                  Nbr = Nbr + 1
              Case Is > 0.01
                  Nbr = Nbr + 1
              End Select
            Next DatesCell

            'calculer le montant révisé
            Count = 0
            For Each DatesCell In .Range("Dates")
            Count = Count + 1

            If .Cells(NomsCell.Row, DatesCell.Column) > 0 Then
                If .Cells(NomsCell.Row, DatesCell.Column) > 1 Then
                    Montant = .Cells(NomsCell.Row, DatesCell.Column).Value
                    .Cells(ReviseCumulatifCell.Row, DatesCell.Column).Value _
                    = .Cells(ReviseCumulatifCell.Row, DatesCell.Column).Value _
                    + Montant '_
```

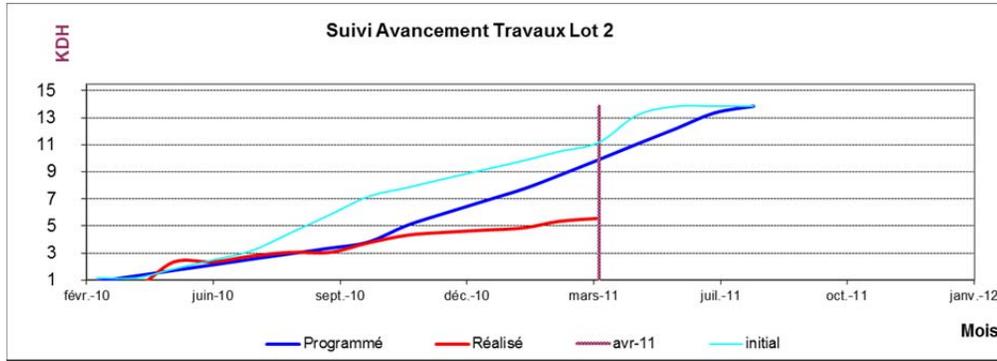**Figure 5.     Example of the Excel VBA macros**

**Figure 6.** **Progress curves**

**A scheduling solutions using a combination of VBA MS-Project and Excel.** The third method uses a process that combines MS-Project and Excel. Both applications were programed using VBA in order to allow the information transfer from the MS-Project file to the Excel File and to process the information on the Excel file. While this methodology is more adapted to the general contractor schedule, its limitation is that the MS-Project file (Figure 7) and both of the principal sheets in the Excel file (Figure 9; Figure 10) should be structured in the same manner according to the structure of the Bill of Quantities.
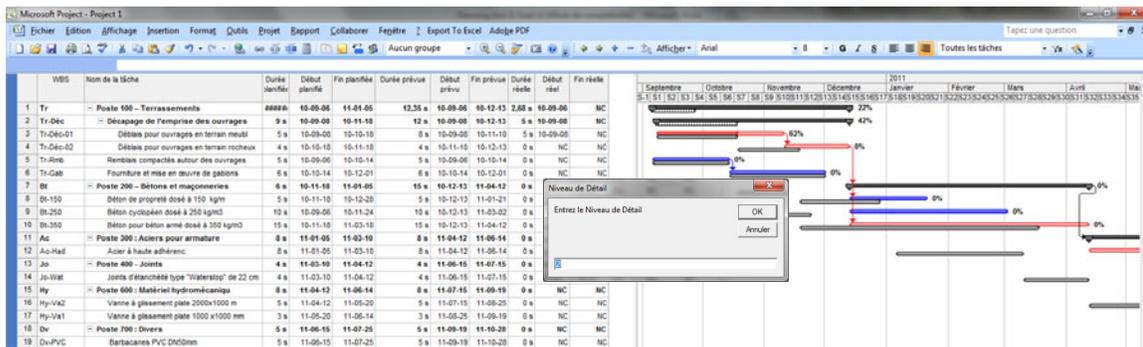


**Figure 7.** **General contractors schedule using MS-Project**

The planner starts by scheduling the project activity duration and logic, and identifying the initial planning using the traditional processes proposed by MS-Project as in Figure 7. It is not necessary for the planner to add resources or costs to this schedule. The same MS-Project schedule will be used later for monitoring progress.

Once planning is complete, the planner can transfer the data to Excel via the new menu "Export to Excel" created using VBA MS-Project (see the menu in Figure 7), to Excel as in Figure 8.

By using the "Update" button on the Excel file (here labeled "Mise à jour", see Figure 8), the planner can update the Excel file (see Figure 9). The progress of each task will be allocated to each activity depending on the duration and the date of its start and end.
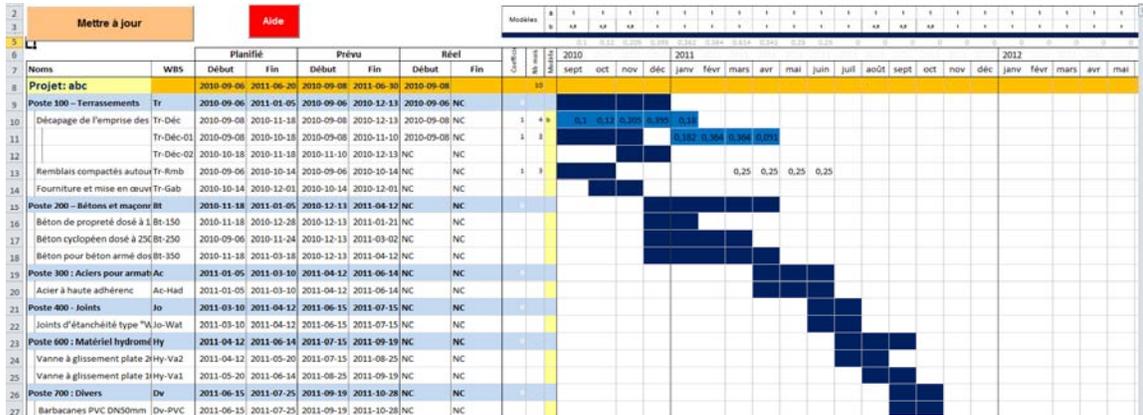
**Figure 8.          Transfering the data to Excel.**
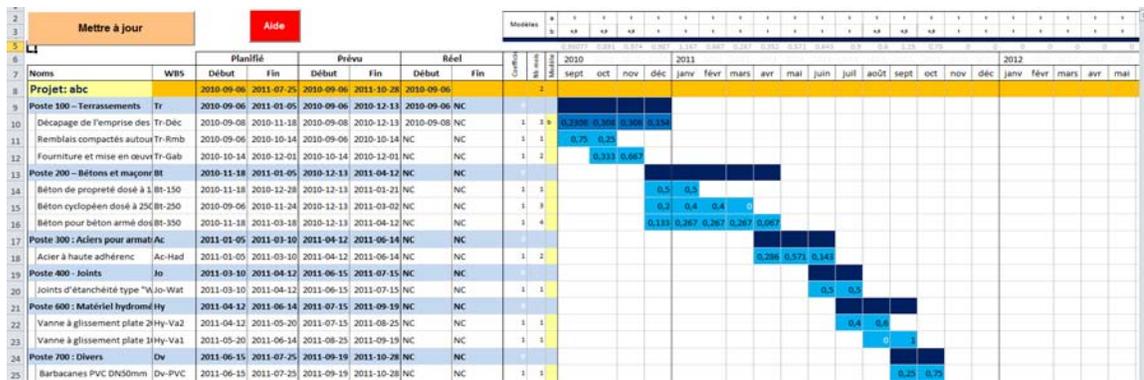


**Figure 9.          Updating the schedule date on the Excel file.**

Each month, the planner should adjust the percentages of progress manually according to the project's actual and projected progress. On the tracking sheet, Figure 10, the planner can activate the updated values using the corresponding button.
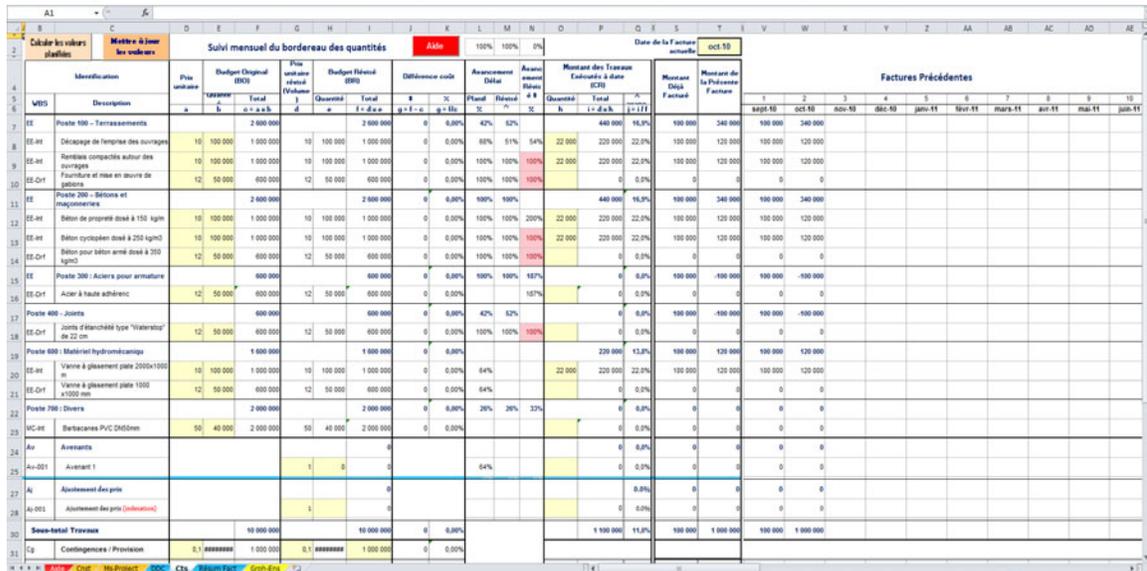


**Figure 10.          The project tracking table.**

These three methods have been applied to different infrastructure projects. These case studies concerns infrastructure projects, specifically, irrigation and fisheries mega-projects in Morocco and Burkina Faso. The methodology and proposed solutions are validated through their applications on these mega-projects.

## CONCLUSION

This paper exposes the problems and limitations associated with the existing scheduling software currently used to plan the project schedule according to the needs of both the general contractor and consultant.

The actual paper presents three scheduling solutions using MS-Project and Excel individually or in combination to enable general contractors and consultants to plan and follow unit price contracts efficiently. Within these three methods, the activities structure follows the same structure as the Bill of Quantities of the project tender. Further details of these activities can be demonstrated if necessary. These methods have been applied to infrastructure projects, specifically, irrigation and fisheries mega-projects in Morocco and Burkina Faso.

These three (3) applications partially solve the general contractor's needs and could serve for scheduling and following Unit Price and Lump Sum contracts. The methodology and proposed solutions are validated through their applications on these mega-projects.

Certainly each of these solutions has its own limitations. However, the objective of this research does not concern software development, but rather the demonstration of new methodologies that scheduling software should consider in order to provide more flexible applications that meet the diverse needs of different stakeholders.

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