Monitoring Transferable Work-load Projects for the optimization of duration and cost

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Abstract

Progress measurement, in an environment where remaining work can be transferable from one resource to another, is hard to perform due to the ambiguities and complexities involved in the nature of these projects. This paper discusses the environs of Transferable Work-load project, the realization of which is transferable among different departments of a same company or in different parts of the world. Project management and operational research literature is reviewed for discovering various planning, management, monitoring, and forecasting techniques applicable to such projects. This paper presents a problem related to pharmaceutical industry which involves the determination of the effectiveness of a given medical treatment, applied to patients in a given number of countries. In this problem patients are first recruited then their treatment starts. The great number of variables involved increases the complexity of this problem. The main objective of the problem is to analyze the effectiveness of a particular solution, for the recruitment of patients, in different situations such that a shorter project duration and in turn a lower project cost can be achieved.

Keywords:

Transferable Work-load; monitoring: progress measurement; forecasting; project management

1. Introduction

In projects where the work-load can be transferable between resources, it is common to encounter progress-related problems. These projects depend on more than one entity for their completion and these entities may be two departments in one Company or numerous partners in different parts of the world, depending upon the size of projects.

Project management continues to grow as a very important research field in Industrial Engineering and Operational Research. Fortunately it helps us in finding solutions to various problems as it deals with the complete organization of activities throughout the life cycle of project. But a project is prone to changes on the course of its completion as it is not an isolated process rather it very much depends on the evolution of its environment. That is why unusual and inexperienced environments and situations are always the biggest threats which bother Project Management. For encountering these uncertain dangers or Murphy's Law, proper planning, monitoring, and re-planning or forecasting are the weapons at our disposal, with objectives expressed in terms of cost, time or quality. Thus, the project starts with the establishment of performance indicators, then gathered information on its advancement is monitored. Project monitoring can simply be defined as "Knowing where we are" as defined in [1], as well as "Knowing where we will be" in terms of progress and performance. Once we know our status we can compare it with our plans to see where we should have been, and thus implying to use corrective or controlling actions or re-plan for the achievement of objectives.

Every project is unique at some level, which in turn requires specific methods for the resolution of problems that it encounters. The references of Project management such as IPMA[2], PMI[3] and APM[4]

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are general in nature i.e. they do not consider solving the problems that are specific to a certain type of projects, they rather define general processes of project management. This study relates to the monitoring of a transferable work-load project, i.e. a project in which work is transferable from one resource to another even if job processing has started. We are especially interested in projects related to pharmaceutical industry, for some of them typically correspond to this description of transferable work-load projects.

This paper has been organized in the following way: in section 2 we discuss the literature pertinent to our subject matter. Academic literature on project management treating this type of transferable work-load environs with monitoring and forecasting is very much limited especially in empirical studies. Then the background of our problem will be presented in section 3, i.e. a problem related to pharmaceutical industry in which patients are recruited in different countries for taking a given treatment. The planning involved and the estimation of initial budget is the topic of section 4. Section 5 will explain the application of reallocation of the patient's recruitment for the optimization of project duration, on the basis of the status of project progress. The results for a particular situation are discussed in section 6 with the emphasis on fundamentals that can improve the solution. The questions like "What are the lessons we learned?" and "How can this problem be extended for future research?" are addressed in section 7. This paper augments the theoretical and practical comprehension of projects with movable work-loads in related realms and also our findings propose extensions for further study.

2. Literature overview

In the majority of literature on Project management, the projects are considered as fundamentally similar therefore this literature is general or not specific. But there is an utmost need for the development of industrial specific project management techniques. Managing projects with transferable work-loads becomes an uneasy task if proper attention is not given to various variables in different processes of the project life-cycle. As described in PMBOK [2], project management is carried out by following five processes namely: project Initiating, planning, execution, monitoring and control, and closing. In this section the project management and operational research literature is explored for discovering the approaches that can be applied to these projects.

2.1. Project Planning:

As Larry Elder on his radio show, rightly quoted "*a goal without a plan is just a wish*", the real start of a project is with the commencement of the single most important and continuous process in the life-cycle of a project i.e. planning. Kerzner [3] defines planning as the development of a preordained plan in a forecasted environment. It is an iterative process done for reducing risks, better comprehension of the project's objectives and better monitoring and control. Planning can be strategic, tactical and operational depending upon the duration for which it is being done. Before entering into the phase of planning, the project has already passed through feasibility and benefit to cost analysis. It is interesting to know that about 50 percent of resources can be spent before execution begins for the completion of project with the required quality. It is also important that executives, project and line management should be in agreement on the plan for making it successful [3].

The information required for project planning includes: the Statement of Work (SOW), project specifications, milestone schedule and Work Breakdown Structure (WBS) [3]. Poor definition of the requirements and extreme optimism are the usual causes of the failure of a plan from the part of project manager [3]. For simple and small projects a technique called *mindmapping* can be employed for generating a WBS, which is always built as a group work. However for large projects it is impractical

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[2] International Project Management Association

[3] Project Management Institute

[4] Association for Project Management

to assemble the whole planning team for making a WBS, rather the lower levels of the WBS are completed by responsible departments [4].

After the establishment of the WBS, Network scheduling is done through PERT/CPM. Detailed or master schedules are also required for the doers as summary schedules are required for the planners. Creating a planned budget for the project becomes the last step in project planning, with execution as the next process in the life-cycle of the project. In the execution of many projects sometimes re-planning is required during monitoring and control due to a change in the objectives or other variables of the project. Re-planning is simply planning so it requires the same actions to be repeated.

2.2. Monitoring and control:

Knowing 'Where we stand?' is significant for better performance of a project, as it ensures timely completion of the project and within available resources, through the necessary modifications as the need of re-planning arises. In this section, in addition to Earned Value Analysis we will discuss some other methods of progress measurement, which will also evaluate the accuracy of our planning, such as Progress Plotting, Milestone and Resource Slip charts, as a solution to the third objective. Proper monitoring and control of a project guarantees the successful completion of the project, avoiding unnecessary delays. *Earned value analysis, curves* or *matrices* has served this purpose for years, as it is and its improvements are still considered to be an effective weapon in a project manager's arsenal as mentioned in [5].

As the probability of project's finishing in time is illegible from traditional PERT or GANTT charts therefore Schmidt [6] proposes *Progress Plot*, as a tool for monitoring and controlling of a project, differentiating between small and large problems on the course of the project. For this, first the PERT chart is created and then only the critical path CP is taken out of it. This plot is drawn with horizontal axis representing time while vertical axis representing progress as a percentage of Critical Path. Control lines are also used which are drawn to show a certain probability of completion of the project in time [6].

The accuracy of a PERT chart can be evaluated by a project manager by using *Milestone slip charts* as presented by Elphick [7] which is a progress evaluation tool incorporating a number of review stages on the course of the project at which re-estimations can be done taking into account the delays and problems in the history of the project. A *resource slip chart* can also be made which depicts lack, excess or underestimation of resources [7]. These progress measurement tools can be used for en-route projects, in order to preview the future with the help of the past experience. And thus re-planning is done if reorganization of work is indispensable for the timely completion of the project.

Various Performance indicators specific to a project also help a manager to evaluate his project's performance at any point in the life time of the project. Pillai *et al.* [5] propose a model for performance evaluation of R&D projects by identifying important project phases, key factors in these phases and then integrating these factors into an *integrated performance index.* Clemens *et al.* [8] present an interesting case study done at the Nike's European Operations department, in which a performance measurement system (PMS) is designed, by developing and monitoring various distributed performance indicators (PIs), for the improvement of the supply chain process of the sportswear manufacturing giant. Benchmarking can also be employed, as a method of comparing one entity with one which is considered to be the best to pick out the key performance indicators for improvement [9]. Rozenes *et al.* [10] discuss a multidimensional project control system for improving the performance of a project by minimizing the gap between planning and results.

Delay in progress arises due to various reasons such as redesign, rework, lack of resources, lack of updated information and conflicts. Assaf and Al-Hejji [11] discussed reasons of delay and conclude from a construction point of view that owners blame contractors and contractors in return blame owners for delay. Delays in responses from the clients are the major source of delay, so they should be given a great consideration since this can cause a serious duration issues if carelessly treated. This problem can be avoided if customers are included in project's design and planning phases. Numerous kinds of reports are also used for progress tracking, variance detecting and making corrections, for enhancing project control [4].

Many software packages also provide managers, options to monitor progress of their projects using the above methods along with GANTT Charts. The software packages on the market usually have various limitations and this is the frequently reported drawback, as very few project management software packages provide the capability of tracking shared resources as concluded through a survey by White and Fortune [12]. Also Configuration management (CM) has not met the wide industrial attention but CM techniques can also be employed for having up-to-date data throughout the project life cycle as inaccurate information leads to waste of time and efforts [13]. CM is indispensable for transferable work-load projects as any small errors can lead to grave failure of the project because the work can be transferred between different partners possibly at different geographical locations and the information at every location should be updated accurately.

2.3. Forecasting:

Forecasting is a very difficult process of projecting or previewing what will happen by a certain time because predicting the reaction of the environment is not easy. For predicting the future precisely, accurate knowledge of the system and its environment is indispensable i.e. the strengths and weaknesses of marketing, R&D, production, financing, man-power and management [3]. And in transferable work-load projects it is obviously difficult to predict precisely due to the number of variables involved, thus enforcing the manager to analyze the system closely for improved fore sighting.

Earned Value Management (EVM) is an early warning system which communicates problems in project progress and thus enables the managers to take corrective actions before the project gets out of control. Vandevoorde and Vanhoucke [14] have compared three different methods of duration forecasting and concluded that Earned Schedule (ES) is the most reliable throughout the project. Through Estimate at Completion (EAC) or the proposed Estimate of Duration at Completion (EDAC), a project schedule can also be forecasted as discussed in detail in [15].

As specified earlier, planning can be strategic, tactical or operational, so for strategic and tactical levels-planned projects it is difficult to forecast the status of the project as there is a high level of uncertainty involved, as future may vary year to year. But for operational level-planned project, forecasting can be done with high level of certainty as the variables are clearly definable. It is wise to consider more than one set of data for forecasting and also to critically examine the assumptions behind a forecast, as the professionals are generally too optimistic [3]. Academic literature is considerably less for this process in the life-cycle of the project.

3. Problem statement

The problem at hand is related to the pharmaceutical industry, which investigates the effectiveness of a given treatment. A given number of countries will test this treatment. The total number of patients to be treated will be divided among these countries, depending upon their populations, handling capacities and competences. This required number of patients to be treated, along with the budget and time available, proposes an interesting problem. This problem has a number of variables and assumptions, changing any of them induce a different result for this problem. The purpose of this study is to analyze the effectiveness of a solution in different situations such that an optimal arrangement between project budget and duration can be achieved.

The clinical development or working involves two stages, namely, Recruitment and Treatment of patients. The planning for the expected recruitment stage is generated by experience and previous studies i.e. the expected number of patients recruited per month. Depending upon this, scheduled budget is calculated since development costs are generated by different amounts paid to patients during the treatment. There are three phases in treatment as shown in fig. 1, each phase being defined by a part of the treatment process, duration and payment. Countries will be paid at every update depending upon the number of patients having completed a treatment phase since the last update. It is anticipated that a number of patients will quit without fully completing the treatment, this number being usually taken as a percentage of the total number of patients recruited and is defined by experience.

If we simulate the behavior of such a project, after completing the planning process, actual recruitment data can be generated for each defined period (project update) with some countries progress faster than scheduled whereas others recruit slower, and thus delay the end of the project. Now, the manager has to decide, for each update, what changes or corrective actions are expected to keep the project on track with the plan, or to minimize delay. The purpose of this problem is to come out with a better possible solution and thus every case is closely analyzed to be convinced over the effectiveness of a particular solution. The objective of this paper is to analyze how the system responds in different situations and thus optimize the project duration, possibly through periodic redistribution of the work still to be performed (*i.e.* remaining patients to recruit) between the different countries.

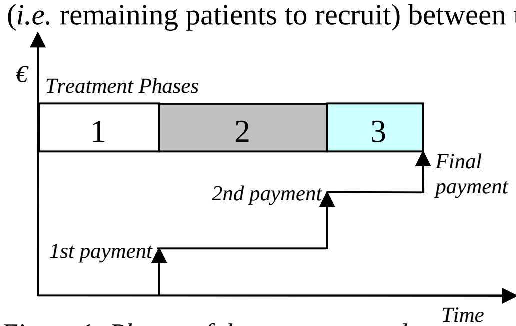

Figure 1: Phases of the treatment and payments

4. Planning and Budgeting

Traditionally, there are three periods in the execution of a project, conventionally presented as S-Curve, these periods correspond to learning, working and ending or closing periods as shown in fig. 2. Here the horizontal axis corresponds to time while the cumulate number of patients recruited (or treated) from the beginning is represented by the vertical axis. In the learning period, working is slow as knowledge is small but with time, both experience and momentum are gained so work accelerates. The ending period is a retarding period in which working is slowed down to end the work in the remaining time, which is Parkinson's Law i.e. "*Work expands to fill the time available*". The days during which working on the project is halted due to holidays or else can be shown with a horizontal line on the S-Curve.

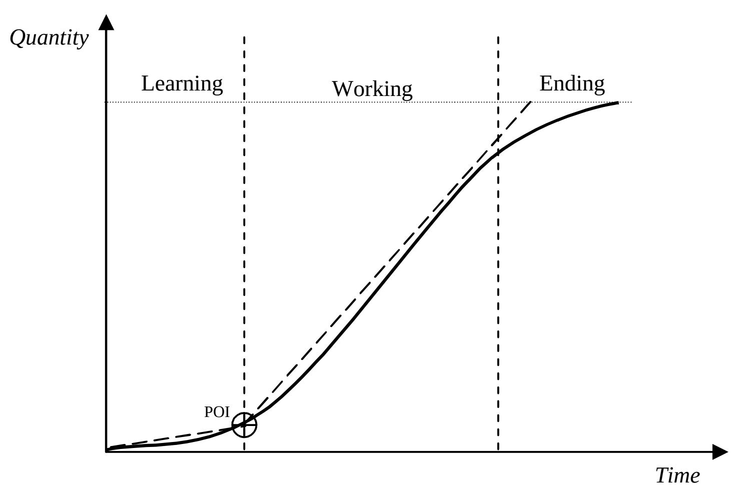

Figure 2: Conventional S-Curve (with straight dashed line)

For the sake of simplicity the ending period is not treated in this article and the curve is also replaced with straight lines as shown with the dashed curve in fig. 2. The point where the learning period ends and the working period start is known as "*Point of Inflexion* (POI)". As a first variable for our problem this POI can take two significations: as it depends upon the learning stage which either ends after recruiting a pre-specified number of patients (experience acquired) or recruiting for a pre-specified duration (job learning and mastering time) from the beginning of recruitment.

The straight dashed line in fig. 2 gives the advantage of ending the project before the due date for the S-Curve, but for making the situation closer to reality we could add another POI at the end of the working phase which is not treated in this paper and can be studied further in the continuation of this problem. Thus, before moving on POIs should be specified for each country. In this paper POI is taken as a pre-specified duration.

As the working capabilities and environments of countries are considerably dissimilar therefore their S-Curves will be dissimilar too. The *recruitment rate* (d) for each country will become the second variable and that is the reason for different S-Curves. There are two stages in this problem namely: recruitment and treatment of the patients. Planning is done for the recruitment of patients and completed with a schedule illustrating the expected number of patients to be recruited at every update till the total number of patients is achieved for each country. Scheduled budget is created with the help of the planned recruitment data. For generating a scheduled budget following information is produced: Recruitment dates (Rd), Durations (D) and Quitting dates (Qd). Recruitment dates for every patient is generated as a uniform random number between two dates within which the patient was recruited according to the planning. After that, the duration for the quitting patients is generated as a uniform random number while for others it is the duration of the treatment. Quitting dates are then calculated as a sum of the Recruitment date and Duration.

$$Qd = Rd + D$$

By experience it is anticipated that a number of patients represented as a percentage will be lost or they will leave the system before the completion of the treatment, thus added as another variable to our problem. The treatment stage comprises of three phases. Each phase has a particular part of treatment and cost. As the above data is generated, Phase boundaries are estimated for each patient i.e. at which date a patient has crossed each phase. These phases are determined so that a country can be paid at every update depending upon the phase a patient has completed since the last update. As all the above data is produced, scheduled budget will be developed with payments for each country on every update.

5. Monitoring and Control

As the planning process ends, actual recruitment data is produced from one update to another depending upon the performance of countries. Performance (P) can be defined as a percentage of the planned recruitments, so multiple cases are achievable by varying both the performance and the recruitment rate for each country. The manager has to decide at every update, what controlling actions are vital to keep the project within the planned project duration. For producing the data for actual scenario, POI is required, so should be provided. Now as the POI and the performance of a country is provided, the real recruitment data, i.e. the real number of patients recruited, can be generated till the next update. The manager can also define a recruitment rate for a country to produce real recruitment data till the next update, thus numerous states can be reached.

There are two approaches to this problem, namely: "*Without-Reallocation*" and "*With-Reallocation*". In the case of no reallocation, the total remaining time to complete the project will simply be the maximum remaining duration among all the countries. On the other hand, if the project allows reallocation of work, then the manager can re-estimate the total remaining time by sharing the number of remaining patients among countries, so that the project can be ended as soon as possible with little or no lateness and with every country ends work on the same date.

A "*Linear Hypothesis*" is used for the determination of "When the real POI will occur in time?" along with the rate of recruitment in the working period. It is based on the linearity of the learning and working periods of the planned and real curves, as shown in fig. 3, here planned learning period for a country ends at "$\boldsymbol{I^j}$" and the actual or real learning stage at "$\boldsymbol{I_R^j}$", $\boldsymbol{j}$ being the country number (omitted in the following for the sake of simplicity). Once crossed the planned learning period, the end point of real learning period can be forecasted by the *linear hypotheses*:

$$\frac{\boldsymbol{I_R}}{\boldsymbol{I}} = \frac{\boldsymbol{d_{R1}}}{\boldsymbol{d_1}} = \frac{\boldsymbol{d_{R2}}}{\boldsymbol{d_2}}$$

where,

Date when the planned learning period ends = I

Date when the real learning period ends = I_R

Recruitment Rate for the previewed learning period = d_1

Recruitment Rate for the previewed working period = d_2

Recruitment Rate for the real learning period = d_{R1}

Recruitment Rate for the real working period = d_{R2}

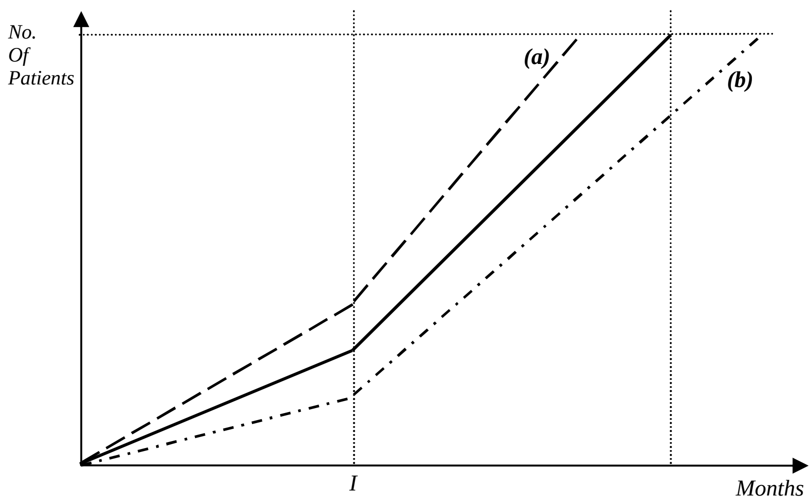

Figure 3: Behaviors of a country's performance along with the planned performance curve (solid line)

The performances or two behaviors of a country are shown in the fig. 3, which depicts one behavior of "working faster" then planned *(a)* and the other "slower" *(b)*, the planning being illustrated with the solid curve. Here it holds that *if we are not moving well in the start then we will not end well too*.

Once the real recruitment data is generated, the real or actual budget is calculated by following the steps defined for estimating the planned budget in the previous section. That is the determination of Recruitment dates (Rd), Durations (D), Quitting dates (Qd) and the phase boundaries for each patient. Depending upon the above data, real budget is estimated with payments for each country at every update. It is important to note here that we are also interested in finding when to use re-allocation. If with-reallocation was used, a certain amount of transfer cost (renegotiation and administrative spending) for each patient transferred can be charged, which could be considered as an extension to this problem. Another possibility can be of adding a new country to the project and thus transferring patients from slower countries to this new country. But for this situation it should be kept in mind that the new country will be in the learning period first and thus may not be beneficial. For this transfer additional charges can be applicable too. Hence a real budget should take into account every single detail defined above and be actuated at every update. So, there are multiple results possible depending upon the decisions of the management.

6. Simulation

6.1. Program

The program is built in Microsoft Excel with programming in Visual Basic. If a user opens the file of pharmaceutical problem, the screen will show the *Form1* as it is shown in fig. 4(A). The user will input information on this form for the generation of real recruitment data. As it can be seen from fig. 4(A) the user will have to input number of countries where the treatment will be provided and update after the required number of months. Then the user is provided with two options to choose from, for inserting the planned recruitment data, i.e. either the planned recruitment data is copied in this file of pharmaceutical problem or the data is in another excel file so its link along with relevant fields filled in by the user. This is followed by the cost of treatment where the user will provide the cost for each phase of treatment. As it is anticipated that a percentage of the users will leave before completing their treatment, this percentage will be then provided by the user depending upon experience. The check box at the bottom if not checked indicates that the user only wants to generate scheduled budget but if checked and the button at the bottom of the screen displaying "*Solve*" is pressed, it will generate scheduled budget and then continue on the way for creating real recruitment data, with *Form2* shown on the screen as in fig. 4(B).

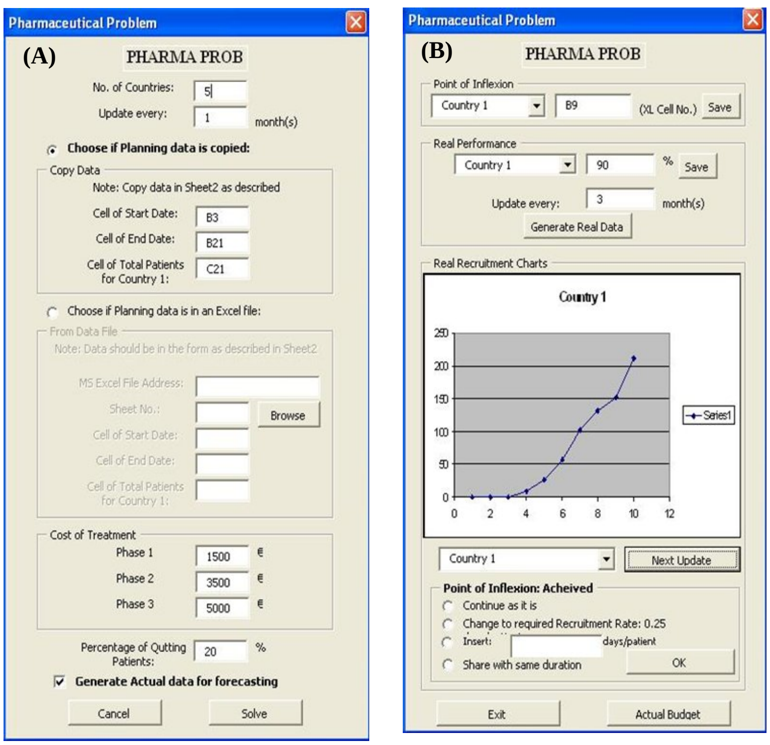

Figure 4: (A) Form 1; (B) Form2

For the generation of real or actual recruitment schedule with budget requires input on Form2 from the user. First the POI is inserted for each country selected from a drop down list. The real performance for each country is then filled for generating initial real recruitment data as a percentage of the planned recruitment data for each country. For example if 90% is inserted for country 1, it means that country1 starts with the recruitment of 90% of patients planned to be recruited till the first update. The number of months after which the progress should be updated is to be inserted next. The button in this frame displaying "*Generate Real Data*" will then be pressed for generating real recruitment data for starting the project with the performance provided for each country. The real recruitment chart for country1 will be displayed in the chart box, and for other countries can be seen by selecting them from the drop down list. The frame with the title of "*Point of inflexion: Achieved*" is disabled till the POI is achieved, once reached it will be automatically enabled and provide a number of options to the user for choosing the appropriate one to continue this real recruitment data generation till the next update. First option will not change anything and the real recruitment will be done according the performance already provided. The second option if selected will change the recruitment rate (as patients/day) to what is required for the country to recruit the total number of patients within project duration. Third option will provide a space for the user to provide the required recruitment rate. Last option is for sharing the remaining number of patients to be recruited among countries i.e. with-reallocation.

If one of the top three options is selected and the button that says "*Next Update*" is pressed, the data will be generated till the next update and so on till the end of the project. Then, the button "Actual budget" will estimate the actual cost update by update as explained in the previous section. On the other hand if the fourth option is selected for any country then linear programming will be carried out with the sharing of remaining number of patients for recruitment among all the countries, as some countries work slower than others, with the completion of recruitment on the same date. Then it will calculate the real or actual budget for the problem.

6.2. Analysis and results:

This problem, due to the presence of numerous variables, offers interesting insight for managing transferable-workload projects, with the emphasis on the respect of a standard procedure for the definition of variables or performance indicators. These variables if properly defined and vigilantly watched, can improve the results of the problem. One instance of the problem is shown in *Form1* in fig. 4(A) in which five countries are going to be involved in this project. Costs of the first, second and third phases are 1500€, 3500€ and 5000€ respectively. It is expected that 20% of patients will quit the system before their treatment completes. Table 1 shows the planned number of patients to be recruited at each country and in total 10004 patients. As the *Form2* comes up on the screen as shown in fig. 4(B), POI is inserted as the address to the corresponding cell of the date for each country. The initial real performances of the countries are inserted but if not mentioned for a country then the program will take it as 100% for that country.

Country 1	Country 2	Country 3	Country 4	Country 5	Total
1285	1909	2163	2195	2452	10004

Table 1: Planned distribution of patients to be recruited

Numerous instances of the problem are created by changing the values of different variables so that the results could be gathered for a number of situations. For every situation first results are gathered for without-reallocation and then with-reallocation is applied to the same situation, so that a comparison is achievable for the better comprehension of the problem. Table 2 shows the result for two instances which are created by varying the performance of countries. It is not surprising to note from the results of table 2 that with-reallocation comes out to be the champion approach for the optimization of project duration in a shared environment.

As we are also interested in finding out when to use reallocation to produce better results, reallocation is applied on the 1st update after the POI and the results were noted then reallocation is used on the 2nd update after POI for the same scenario and so on. Transfer costs are also added for the number of patients transferred.

Performance entered for	Without-Reallocation	With-Reallocation	Planned Duration
Country 1 & 3	**Duration**	**Duration**	
90% & 75%	730 days	669 days	547 days
Country 2, 4 & 5	**Duration**	**Duration**	
110, 120 & 70%	1551 days	539 days	

Table 2: Results of two instances of the problem

Fig 5 (ordinate : cost at completion, expressed in % of budgeted cost ; x-axis : actual duration, expressed in % of planned duration) shows the results, i.e. cost is getting closer to 100% i.e. planned cost as we apply reallocation in later updates with duration also getting close to what was planned. From this we can infer that reallocation if used in later stage of the project with 2/3 of the project duration passed will produce better compromise between duration and cost.

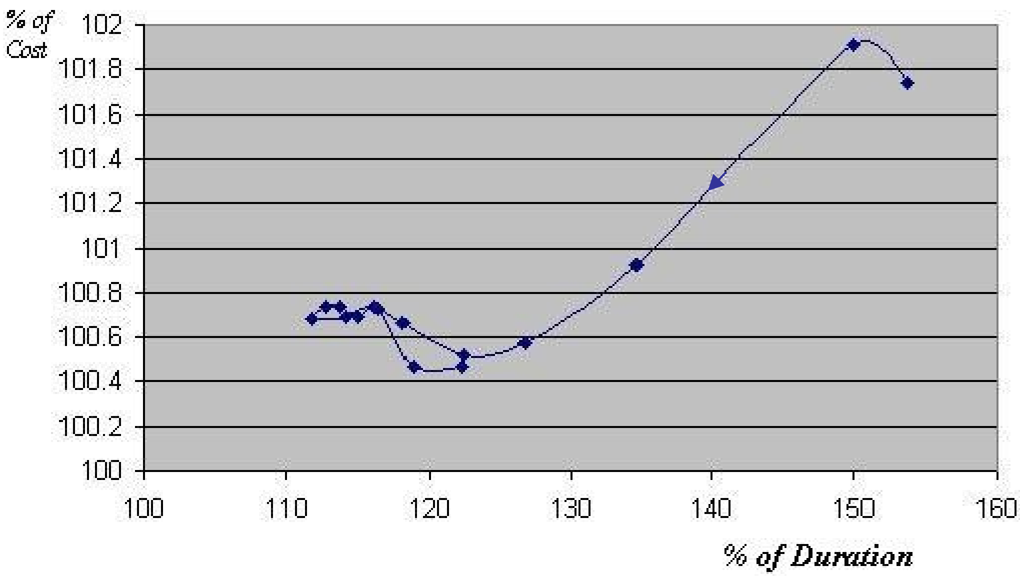

Figure 5: Reallocation applied from update to update

7. Conclusion

The basic objective of treating this problem was to find out what is the best solution i.e. the best acceptable compromise for project duration and cost. Not much attention has been given to this part of project's lifecycle, for projects with transferable work-loads, in literature. The experience we learned may not be generalized yet but may be helpful in the realization of similar goals. We have included the description of our approach to these projects so that its extension and improvement are possible. The progress of a project at a certain point in time is usually difficult to find out in a transferable-workload project scenario. For better controlling and monitoring a large project's progress, techniques are still required that expose our planning flaws. Then re-planning can be done if redistribution is required for completing the project in time or with minimal delay.

With the improved understanding due to this study, we suggest several avenues for its extension like: penalties for late project completion can be incorporated; transfer costs can be charged when recruitments are transferred to another country or to a new country; these costs can be fixed or with a different cost coefficient for each treatment phase the transferred patients are in. While more generalized propositions for further study may be: improving risk management techniques and their applications, taking into account that nowadays, the management of uncertainties is inseparable from project's progress to ensure timely completion of project. There is also a need for project or industry specific generation of management methods. Configuration management (CM) techniques may also be improved so that CM can easily be implemented so that delays due to configuration troubles can be minimized.

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