Progress in Large-shared Projects: Method for Forecasting and Optimizing Project Duration in a Distributed Project

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Abstract - **In large-shared projects, it is still difficult to measure progress due to the complexities involved, because the realization is shared among departments of a company or among companies in the world. Project management and operations research literature is reviewed for discovering various techniques applicable. Widely used tools for progress measurement and forecasting, such as Earned Value Analysis, Progress Plot, Milestone and Resource slip charts, concurrent engineering, can be employed. This paper is based on a problem of pharmaceutical industry where the effectiveness of a certain medical treatment is examined on patients in a number of countries. The number of variables involved increase the complexity of this problem. The main objective is to analyze the effectiveness of a solution in different situations during the project such that a better project duration and a lower cost can be achieved. Our findings suggest that reallocation of patients among countries produces better results in terms of progress.**

Keywords - **Forecasting, large projects, progress measurement, project management, shared projects**

I. INTRODUCTION

In shared or global projects, it is still difficult to measure progress. Shared projects are those projects in which some work packages can indifferently be developed to depend upon more than one entity for their completion; entities may be two departments in one company or numerous partners in different parts of the world. Every project is unique at some level, which in turn requires specific methods for solving its problems. The references of Project management such as IPMA, PMI, and APM are general in nature i.e. defining general processes of project management. There is a great need for research in developing skills, methods, tools and techniques for understanding and managing various processes of large-shared projects.

In a nut shell, this work will present the implementation of a method for minimizing project duration with the help of progress measurement and redistribution of the remaining work to be done. The global objective is to respond to the following questions: *How to manage effectively large shared projects? What are the tools to aid us in their management? How to measure progress in this shared environment? And, How to re-plan and forecast on the basis of the past progress?*

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II. RESEARCH CONTEXT

Managing large-shared projects 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 [1], 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.

A. Large-Shared projects:

Large in respect of: *number of decisions to make, number of tasks to handle, number of participants to coordinate, significant cost, size of information to handle, and substantial risks involved;*

And shared such that: *they depend on more than one entity for their completion which may be two departments in a company or numerous collaborators in different parts of the world; moreover, we assume that the project (or major parts of it) can be indifferently distributed to one or another resource.*

In large-shared projects there is a difference of organizational culture, strategies, background and may be time zones, to name a few, between various partners. For the development of theoretical foundation an interesting assessment, is presented in [2], of the influence of the shared environment on the work to be done and, coordinating and controlling activities, by analyzing four different configurations.

The performance in this environment depends upon the working, adaptability and flexibility of partners because objectives are well defined but there are many factors (e.g. Division of Work DOW) not fully defined in the beginning. Egginton [3] addresses some of the major problems faced by projects of multi-national or multi-company nature and proposes effective measures to treat them. Bachy and Hameri [4] discusses the importance of creating an effective project management plan, implemented in the early stages of a large project, which sets the basis for cost and schedule control through WBS for a R&D project.

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B. Project Organization:

Industries for becoming competitive to their rivals employ the technique of Concurrent Engineering (CE) or Simultaneous Engineering or Design for Manufacture and Assembly (DFMA), various names for the similar thinking. CE is *an integration effort of all aspects of product development, by performing sequential activities in parallel* [5]. Even the suppliers and customers may also join manufacturers as partners for the realization of a CE project, thus everyone working for the same goal as one unit [6], so making it an effective approach for the management and organization of large-shared projects.

Also [7] rightly defines Project Management as Guerilla warfare, so a well equipped, multi-skilled team is essential for better organization. Four fundamentals of CE can be [8]: 1. Design for Manufacture (DFM); 2. Establish Cross-functional Teams; 3. Customer oriented design; and 4. Time to market.

C. Project Planning:

Kerzner [9] 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 planning starts, the project has already passed through feasibility and benefit to cost analysis [9]. Project planning requires: the Statement of Work (SOW), project specifications, milestone schedule and Work Breakdown Structure (WBS) [9].

Wysocky and McGary [10] define WBS as the hierarchical or tree type decomposition of work, requirements and services required for the realization of project objectives. 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 becomes the last step in project planning, with execution as the next process. PERT/CPM are the main planning systems for large projects but as they consider all activities to be independent so if any problem arises they assume the cause to be the current activity which is not true in reality as most activities are dependent in large projects[11].

D. Monitoring and Control:

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. In Earned Value Management (EVM) theory, Schedule Variance, Cost Variance and Estimate at Completion (EAC) as an estimate of cost or duration at the completion of the project, are used for control [9]. It is also necessary to avoid the "90% rule" for better control as defined in [7] i.e. everything (schedule and budget) moves according to plan up to 90%; but from here on for some time progress stops but spending continues.

As the probability of project's finishing in time is illegible from traditional PERT or GANTT charts therefore Schmidt [12] proposes Progress Plot, which is drawn with horizontal axis representing time while vertical axis representing progress as a percentage of Critical Path while control lines are used which are drawn to show probability of completion in time [12].

The accuracy of a PERT chart can be evaluated by using Milestone slip charts as presented by Elphick [13] 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. Sometimes it is necessary to reactivate an activity or to revert back to an earlier stage, if a problem occurs. If these loops become a norm, due to the complex nature of large projects, then progress measurement will become difficult and probabilistic as defined in [11] where Markov analysis is done for a recursive model urging to develop more sensible planning and monitoring systems.

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. [14] proposes a model for performance evaluation of R&D projects whereas Clemens et al. [15] presents an interesting case study done at the Nike's European Operations department for establishing a PMS (Performance Management System). For distributed projects a performance metrics is also discussed in [16] based on three dimensions, describing valid measures for all the contributors, integrated in a Balanced Scorecard.

E. Forecasting:

Forecasting is a difficult process of previewing what will happen by a certain time. For predicting the future precisely, accurate knowledge of system and its environment is indispensable i.e. strengths and weaknesses of management, R&D, production, financing, man-power and marketing [9]. And in large-shared projects it is evidently difficult to predict precisely as large number of variables are involved.

Earned Value Management (EVM) is an early warning system which communicates problems in project progress and enables the managers to take corrective actions before the project gets out of control. Through Estimate at Completion (EAC) or Estimate of Duration at Completion (EDAC), a project schedule can be forecasted [17]. It is wise to consider multiple set of data for forecasting and to examine the assumptions behind a forecast, as the professionals are generally too optimistic [9]. Literature is considerably less on this process.

III. PROBLEM STATEMENT

The problem at hand is related to the pharmaceutical industry, which involves the determination of the effectiveness of a certain treatment. The total number of patients to be treated will be divided among a number of countries, depending upon their population, handling capacity and competence. This required number of patients to be treated along with the budget and time available proposes an interesting problem. There are a number of variables or assumptions, changing any of them produce a different result.

The 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. There are three phases of the treatment, each phase comprises of a defined number of months, a certain part of the treatment and a different defined cost. Countries will be paid at every update depending upon the treatment phase completed by each patient. Scheduled budget is then calculated. As planning process is over, actual recruitment data are generated, multiple cases are possible by varying the rate of working for each country in the form of some countries working fast while others recruiting slowly and thus creating lateness in the project. The objective of this paper is to analyze how the system responds in different situations and thus optimizing project duration, by re-distributing work.

A. Planning and Budgeting:

There are three periods in the execution of a project as known by conventional S-Curve, namely: learning, working and ending periods as in fig. 1. In learning period, working is slow as knowledge is little but with time both experience and momentum are gained. 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"[18]. Ending period is not treated here and the curve is also replaced with straight lines as shown with the dashed lines in fig. 1. The point where the learning period of recruitment ends and the working period start is known as "Point of Inflexion (POI)".

As first variable of our problem POI can take two values as it depends on the learning stage which either ends after recruiting a pre-specified number of patients or recruiting for a pre-specified duration. In this paper POI is taken as a pre-specified duration. The recruitment rate (for the learning and working periods that are d_1 and d_2 respectively) is the second variable. By experience it is anticipated that a number of patients represented as a percentage will be lost or will leave the system before the treatment ends, thus added as another variable. Scheduled budget is created with the help of the planned recruitment data.

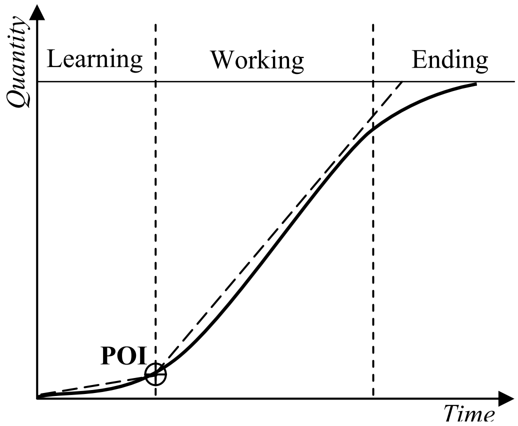

Fig. 1. Conventional S-Curve (replaced with dashed lines).

For generating a scheduled budget, with each country paid on each update, following data is produced: Recruitment dates (Rd), Durations (D) and Quitting dates (Qd). Rd is generated as a uniform random number between two dates within which the patient was recruited in Plan. Then, D for the quitting patients is generated as a uniform random number while for others it is the duration of treatment. Qd are then calculated (Qd = Rd + D).

B. Monitoring and Control:

As the planning process ends, actual recruitment data is produced for one update to another depending upon the performance (P) which is taken 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 indispensable to keep the project within planned project duration. POI is also required, so should be provided.

There are two approaches to this problem, namely: without-reallocation and with-reallocation. In without-reallocation, project duration will be of the country having the maximum duration. If planned finishing date for a country is represented by T_{fj} (*j* is the number of country) and real finishing date by T_{fj}', then total real duration of project in without-reallocation will be similarly:

$$T_f' = \max_j \{T_{fj}'\}$$

On the other hand, in with-reallocation the project duration will be optimized by sharing the remaining number of patients among all the countries and thus each country completes work on the same date. Linear programming is used for the reallocation with minimizing the total re-estimated duration of the project as the objective. Number of remaining patients to be recruited and the remaining duration will be taken as variables. Constraints would be the total number of patients and also the total re-estimated duration should be less than or equal to the largest total re-estimated duration.

For the determination of "When the real POI will occur in time?" and the rate of recruitment in the working period, a "Linear Hypothesis" is used which is a relationship between the real and planned states of the project. It is also equivalent to SPI (Schedule Performance index), represented here by "I_s". It is based on the linearity of the learning and working periods of the planned and real curves, as in fig. 2. Linear hypothesis is not treated here and will be studied in continuity of this problem. Here the end of planned learning period is represented by "I_j" and of real learning stage by "I_{Rj}" (*j* is the number of country omitted for simplicity):

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

where,
Schedule Performance Index = I_s
Point in time where the planned learning period ends = I
Point in time where 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}

As an example, performance of two countries is shown in fig. 2, which depicts one working faster and the other slower. At an update "t" re-planning is done using with-reallocation, so that the remaining work is shared and the final duration of project transforms from T_f to T_f'. Country 1 and 2 will then end recruitment at T_f' instead of T_{f1}' and T_{f2}' respectively, with N_1' and N_2' patients to recruit respectively as shown in fig. 2. The dashed line shows the global re-planning for both countries. If "D_{tc}" is the average remaining duration to complete the project, then T_f' for with-reallocation can be defined as:

$$T_f' = t + D_{tc}$$

where,
D_{tc} = (Total Remaining patients)/(Average d_{R2})

Once the real recruitment data are generated, actual budget is calculated by following the steps defined for estimating the planned budget in the previous section. Also if with-reallocation was used, a certain amount of transfer cost 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 and thus transferring patients from slower countries to this new country. But it should be kept in mind that the new country will be in the learning period first and thus may not be beneficial. Also for this transfer additional charges can also be applicable.

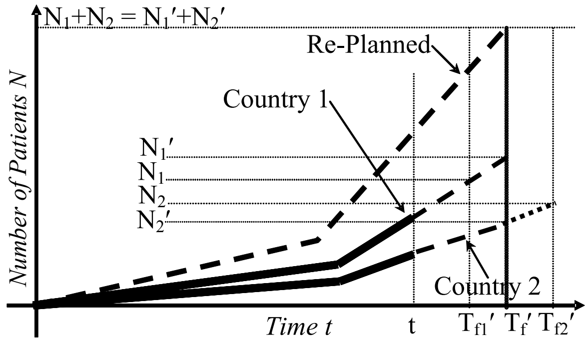

Fig. 2. Work re-allocation with two countries

C. Simulation and Results:

The program is built in Microsoft Excel with programming in Visual Basic Applications. We chose the simplest option available for each variable, so that ambiguities can be avoided. This problem, due to the presence of a number of variables, offers interesting insight for managing large-shared projects with the emphasis on following a standard procedure for the definition of variables or performance indicators which if properly defined and vigilantly watched can improve the results.

A number of instances of the problem are created by varying the values of variables so that 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. Table 1 show results for two instances, where 10004 patients are divided among 5 countries, which are created by varying the performance of countries. In the first instance country 1 and 3 are recruiting with the performance of 90% and 75% respectively, while other countries are working as planned i.e. 100%. Planned duration of the project was 547 days but if without-reallocation is used, it will take 730 days to complete the project. On the other hand if with-reallocation is used at a certain update, it will take 669 days to end the project and thus optimizing project duration. With the same description for the next instance, it is not surprising to note from the results of table 1 that with-reallocation comes out to be the champion approach for the optimization of project duration in a shared environment.

TABLE I
RESULTS OF TWO INSTANCES OF THE PROBLEM

Performance of	Without-Reallocation	With Reallocation	Planned Duration
Country 1 and 3: 90% and 75%	Duration: 730 days	Duration: 669 days	547 days
Country 2, 4 and 5: 110, 120 and 70%	Duration: 1551 days	Duration: 539 days	

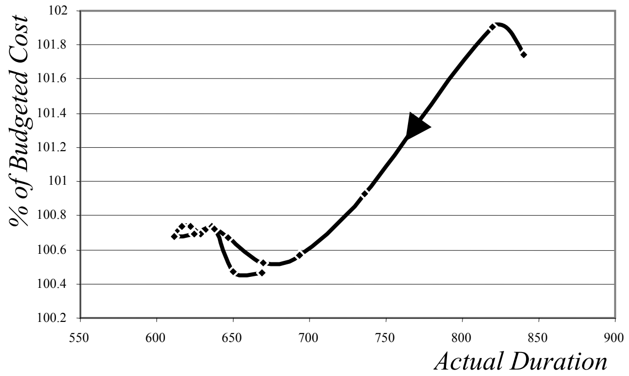

Fig. 3 Use of reallocation in different stages of project

It is also interesting to know when to use reallocation to produce better results. Reallocation is applied on the 1st update after the POI and the results were noted, then starting all over again and using reallocation on the 2nd update after POI for the same scenario and so on. Transfer costs are also added for the number of patients transferred. Fig 3 (ordinate: cost at completion as % of budgeted cost; x-axis: actual duration) shows the results. Here cost is getting closer to 100% i.e. planned cost as we apply reallocation in later updates with duration also getting close to planning or towards minimum lateness. So, we can infer that reallocation if used in later stages of the project, with 2/3 of the project duration passed will produce better compromise between duration and cost.

IV. CONCLUSION

The basic objective of treating this problem was to find out what is the best solution i.e. with the best compromise possible for project duration and budget. Not much attention has been given to the part of planning, for large projects, in literature. The lessons learned may not be generalized but may be helpful in the realization of similar goals. Project management is still a developing field which helps us to resolve the questions related to the problem of shared projects. Mature industries, by their use of Project management, can help less mature industries by benchmarking various processes, management techniques and practices. For better organization of shared projects, techniques like Concurrent engineering can be of great help, as the establishment of a multi-functional team can be effective in reducing project time and cost.

With the improved understanding due to this study, we suggest several avenues for its extension like: a penalty for late project completion can be incorporated; transfer costs can be charged when patients 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 patient is in. While more generalized propositions may be: improving risk management techniques and their applications as today the management of uncertainties is inseparable from project's progress. There is also a need of project specific management methods.

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