Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia - Social and Behavioral Sciences 74 (2013) 285 – 294

Procedia
Social and Behavioral Sciences

26th IPMA World Congress, Crete, Greece, 2012

A Method for the Evaluation of Project Management Efficiency in the Case of Industrial Projects Execution

Vassilis K. Bouras*

Hellenic Petroleum S.A., 17Km Nat. Road Athens-Korinthos, 19300 Aspropyrgos, Greece

Abstract

In the present paper a method is proposed for the evaluation of project management success in the case of industrial projects with primarily economic objectives. In order to achieve this, the project management efficiency is initially defined. The definition relation is further developed combining the objectives of completion time, cost and other success criteria concerning the operation and maintenance of the unit. After the final formulation, a parametric study is carried out in order to check the effect of the different parameters appearing in the relations and also suggest the way that these relations can be used. The proposed method can be applied after the completion of a project where the actual total cost and completion time are known. Furthermore, since the operation parameters of the constructed industrial unit can be easily measured, the future earnings can be easily predicted, provided that the market conditions coincide with the initially expected ones. Introducing these data to the proposed relations, the project management efficiency factor can be calculated. The concept of total project management efficiency can reveal the real importance of delay or increase of cost, or any other success criteria which can be included in the method and affect earnings.

Keywords: Project management efficiency; industrial projects; mathematical formulation

1. Introduction

The successful completion of a project was initially considered to be equivalent to the achievement of the well known objectives of cost, time and quality/performance (Lock, 1992), often referred to as The Iron Triangle. Later, more criteria for measuring the success of a project were added by researchers and the Iron Triangle was proposed to become the Square-Route (Atkinson, 1999). In this way, criteria which

* Corresponding author. Tel.: +30-210-5533226; fax: +30-210-5533245.
E-mail address: vmpouras@helpe.gr.

doi:10.1016/j.sbspro.2013.03.008

could be used to measure the success of the project post implementation were included, while the Iron Triangle excluded longer term benefits from inclusion in the success criteria. However a distinction between project success and project management success has to be made (De Wit, 1988). The project success is related to the overall objectives of the project which depends also on the scope of work of the project, as well as the use or operation after the completion of the project. Project management success should be measured against some specific objectives and/or criteria that the project manager and his team are required to achieve. Furthermore, "the difference between success criteria (the measures by which success or failure of a project or business will be judged) and success factors (those inputs to the management system that lead directly or indirectly to the success of the project or business)" needs also to be clarified (Cooke-Davis, 2002). For example in industry, the factor of safe and easy maintainability of a unit can be a criterion for measuring the project management success but it is not a factor that leads to the success the project. In any case the qualitative comparison or the measurement of the degree to which the objectives and/or success criteria have been met will not answer the question "was the project success?" but will tell us "how successful was the project". So, in order to measure the total degree of success of the project management, we need not only to define some specific criteria and measure them one by one after the completion of the project, but also to combine them into one relation which will take into account the particular importance of each one and the specific needs of the owner.

Nomenclature

C_{pd}	Planned total cost of the project or budget
C_p	Actual total cost of the project
E_{pyd}	Planned earnings per year
E_{py}	Actual earnings per year
T_{pd}	Scheduled completion time of the project
T_p	Actual completion time of the project
T_{pmin}	Minimum possible completion time of the project
TC_{pd}	Planned total effective cost of the project
TC_p	Actual total effective cost of the project
Tpba	Approximate value of pay back period
N	Number of years that the industrial unit is scheduled to be in operation
i	interest rate

This combination seems to be feasible in the case of commercial projects, mainly of private sector and some government projects with primary economic objectives. More specifically, in industrial units with profitability directly connected to the operating hours per year and to the availability of the working equipment, there is no doubt that the project overriding objective is economical. For this type of projects, in the present work, the "project management efficiency" is defined and a relation combining all the objectives and taking into account the particular importance of each one is developed. The use of this relation will assess the efficiency of the project management, giving as a result a single value. High value of this efficiency means better total result concerning all the objectives of the project.

There are some different types of projects met in industry and can be assessed by the present method. The construction of a new unit is a classical construction project with its own difficulties besides the issues arising from the fact that the new unit may be located in the neighborhood of other operating units, so interconnecting as well as foundation may need special attention and design. The revamping of a unit is a very complicated project, since a major part of the work may have to be executed while the unit is in operation and the final phase of the project has to be completed as soon as possible in order to minimize production losses. General maintenance is characterized by the minimum available time for completion of the project and the uncertainty of the extent of works to be done, coming from the tests and inspection that are carried out on the working equipment. Finally there is the case of simultaneous revamping and maintenance of a unit.

2. Background information - definition of objectives

The cost of an industrial project can be analyzed into engineering, procurement of material and equipment, cost of human resources, works and usage of tools. Additionally it can be divided to direct cost which can be attributed directly to the project or a piece of it and to indirect cost which are in general proportional to completion time. Furthermore, since more than two partners will be involved, the cost consists of the actual cost of equipment and work as well as the earnings of the vendors and contractors/subcontractors.

In general, the total cost of a construction project varies inversely with the completion time (Efremidis, 1992) starting from a certain point which can be defined as the minimum possible completion time of the project. This minimum time which is usually determined by technical matters, can be achieved through the use of special technology, reduced manufacturing time of equipment, and acceleration of works using additional recourses and/or overtime. The reasonable increase of the time completion leads to a relative reduction of the cost of the project up to a certain point where the cost starts to rise again due the increase of the indirect cost and the reduced productivity of the human recourses (the same result in longer time). The choice of the time completion of the project can be the point where the sum of direct and indirect cost seems to be the minimum one. Furthermore, other constraints such as a latest date for the start up of the unit, or equipment of long delivery time of special equipment may define the scheduled time completion of the project. Finally, the predicted or planned cost of the project will be finalized after the contract or contracts award which may be the result of inquiry for a minimum bidder in order to maximize productivity and/or minimize contractor's earnings. Comparison of the scheduled time T_{pd} and anticipated cost C_{pd} with the actual ones T_p and C_p after the completion of the project will give us the cost ratio:

$$\eta_{pc} = \frac{C_{pd}}{C_p} \tag{1}$$

and the completion time ratio:

$$\eta_{pT} = \frac{T_{pd}}{T_p} \tag{2}$$

Concerning other objectives, after the completion of the project, we expect the industrial unit to satisfy certain specifications or criteria which can be (definitely not the only) the following ones:

- Safe operation

- Production capacity
- Product specifications
- Energy consumption
- Availability of equipment
- Maintainability of equipment

All the above affect earnings, that is, they all can be evaluated, except safety. In any case, safety should be the first priority during the project execution or the operation of the unit. Human life or health can not be assessed and no construction project can be considered successful if serious accidents happen. However, this can and should be a different index accompanying the rest of objectives and success criteria. Concerning the rest of the above list, after the start up of the unit and the relative performance tests, the real production rate, product specifications and energy consumption can be compared to the designed ones. Any deviation will have an economical impact on the earnings. The reasons for these deviations can be the improper engineering of the unit, defects in construction or improper operation of the unit. Most of the above can be attributed to the project management. Even improper operation may be due to lack of training of operators which could be part of the project management responsibilities. The result will be reduced earnings than the expected ones. Furthermore, increased required time for scheduled maintenance (shut down) and low availability of the working equipment due to increased number of unscheduled maintenance and repairs will have the same result. Since all of the above have economical impact on the earnings of the unit, without loss of significance we can group them into the objective of performance/quality and model them through the earnings per year E_{py}. Thus, the relative performance/quality ratio is defined:

$$\eta_{pq} = \frac{E_{py}}{E_{pyd}} \tag{3}$$

This ratio takes values between 0 and 1 and compares the real earnings per year with the planned one

3. Development of relations

The above defined ratios are considered to be the partial efficiencies of the project management activity. The total project management η_{pm} efficiency is a function of these 3 ratios, that is a function of the form:

$$\eta_{pm} = f\left(\eta_{pc}, \eta_{pT}, \eta_{pq}\right)$$

The use of a simple relation, like a mean value, or a linear combination of these partial efficiencies does not take into account the importance of each of the objectives based on the needs of the project owner or customer. The difference between the scheduled time completion T_{pd} and the minimum possible time completion T_{pmin} will create loss of earnings which have been accepted during the scheduling of the project. This accepted loss of earnings may not be avoided, due to external conditions or because the expenses for the acceleration can not be afforded. Thus, by adding to the planned real cost, this loss of earnings, we can define the planned total effective cost of the project through the relation:

$$TC_{pd} = C_{pd} + E_{pyd}\left(T_{pd} - T_{p\,\min}\right) \tag{4}$$

The definition through equation (4) gives us the possibility to include in the calculation the effect of our choice concerning the expected completion time of the project. After the completion of the project, where the actual values of cost, time and earnings per year are known, relation (4) is written again in the form:

$$TC_p = C_p + E_{pyd}(T_p - T_{p\,\min}) + N\lambda_{iN}(E_{pyd} - E_{py}) \tag{5}$$

In equation (5) TC_p is the actual total effective cost of the project. The first term of the right hand side is the real cost direct and indirect and the second term is the loss of earnings due to the difference between the real completion time and the minimum possible completion time. The third term introduces the loss of earnings for the next N working years of the unit coming from the difference between the expected and actual performance of the unit. Coefficient λ_{iN} is used in order to discount back to the real completion time of the project, the earnings per year using an interest rate i and has the form (Holland *et al.*, 1974):

$$\lambda_{iN} = \frac{(1+i)^N - 1}{i(1+i)^N N} \; for \; i \neq 0 \tag{6}$$

Otherwise, for i=0, $\lambda_{iN} = 1$.

Since in the general case the actual cost and time will be different, most probably grater that the scheduled ones the total project management efficiency can now be defined through the ratio:

$$\eta_{pm} = \frac{TC_{pd}}{TC_p} = \frac{C_{pd} + E_{pyd}(T_{pd} - T_{p\,\min})}{C_p + E_{pyd}(T_p - T_{p\,\min}) + N\lambda_{iN}(E_{pyd} - E_{py})} \tag{7}$$

Introducing into the above relation the partial efficiencies, after some algebraic manipulation, η_{pm} takes the form:

$$\eta_{pm} = \frac{\eta_{pc}\eta_{pT}\left[1 + r_{Ep}(1 - \lambda_{Tm})\right]}{\eta_{pT} + \eta_{pc} r_{Ep}(1 - \eta_{pT}\lambda_{Tm}) + \eta_{pc}\eta_{pT}\lambda_{Nl}\lambda_{iNr} r_{Ep}(1 - \eta_{pq})} \tag{8}$$

with:

$$r_{Ep} = \frac{E_{pyd} T_{pd}}{C_{pd}} \tag{9}$$

$$\lambda_{Nl} = \frac{N}{T_{pd}} \tag{10}$$

and:

$$\lambda_{Tm} = \frac{T_{p\,\min}}{T_{pd}} \tag{11}$$

For the case of a new unit construction, the ratio:

$$T_{pba} = \frac{C_{pd}}{E_{pyd}} \tag{12}$$

can be considered as the approximate value of the pay back period of the investment since, so r_{Ep} takes the form:

$$r_{Ep} = \frac{T_{pd}}{T_{pba}} \tag{13}$$

This is valid only in the case of a new unit and not in the case of a revamping or general maintenance where r_{Ep} has to be calculated through relation (9), since the delay in the start up of the unit will cause losses due to the total lack of production and not only the part of earnings attributed to the revamping.

4. Parametric study

Before the application of the method, a parametric study needs to be carried out in order to investigate the effects of the parameters appearing in the relations. Relation (8) is strongly depended on the value of r_{Ep}. For a new unit, with construction time equal to 1 year and 5 years pay back period according to the relation (13) r_{Ep} takes the value equal to 0,2. For other type of projects like revamping or turn around of a unit for maintenance r_{Ep} can take values close to 1. Thus, for:

$$r_{Ep} \rightarrow 0$$

that is, projects with infinitive pay back period, n_{pm} becomes equal to n_{pc}, something reasonable since cost is the most important criterion. On the other hand, for projects with infinitively short pay back period, that is:

$$r_{Ep} \rightarrow \infty$$

from (8) we easily get:

$$\eta_{pm} = \frac{\eta_{pT}(1-\lambda_{Tm})}{1-\eta_{pT}\lambda_{Tm} + \eta_{pT}\lambda_{Nl}\lambda_{iN}(1-\eta_{pq})} \tag{14}$$

that is, n_{pm} depends only on n_{pT} and λ_{Tm}.

The effect of r_{Ep} can be also easily observed in Figures 1 and 2, where the values of n_{pm} are presented in terms of n_{pc} and n_{pT} for two different values of r_{Ep}. Comparing Figures 1 and 2 we can easily observe that for r_{Ep} equal to 0,2, the contribution of n_{pC} is grater than that of $n_{pT,}$ while for r_{Ep} equal to 1,0 the contribution of n_{pT} becomes grater.

Concerning the effect of λ_{Tm}, in Figure 3 the ratio of n_{pm} to n_{pm} for λ_{Tm} =0,2 is presented for different values of r_{Ep}. The values of n_{pc} and n_{pT} have been taken, for simplicity, equal to 0,8. It can be seen that the contribution is rather small. For r_{Ep} equal to 0,2, only 2,5% difference arises for values between 0,2 and

0,8. However for higher values of r_{Ep}, that is projects with shorter pay back period, the effect of λ_{Tm} is getting grater. Now the total efficiency is reducing further for higher values of λ_{Tm}, that is, for projects that have been scheduled to finish as soon as possible (λ_{Tm} close to 1). The values that λ_{Tm} is taken, depend on the specific type of the project and the importance of time completion that has been scheduled. For example in the case of shut down maintenance projects, it will be close to 1 since time is usually of major importance. Also, for cases that no earnings can be achieved for completion time shorter than the scheduled one T_{pd}, then λ_{Tm} can take value equal to 1. In any case an approximate value of λ_{Tm} should be sufficient for the calculation.

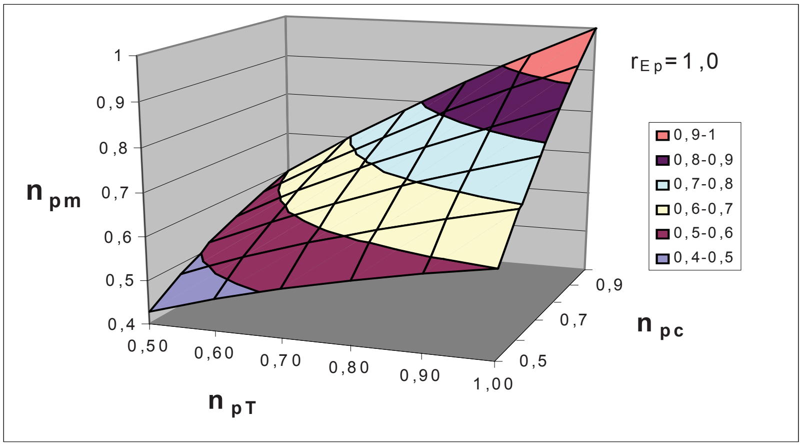

Fig. 1. η_{pm} versus η_{pT} and η_{pc} for η_{pq}=1 and r_{Ep} =1,0

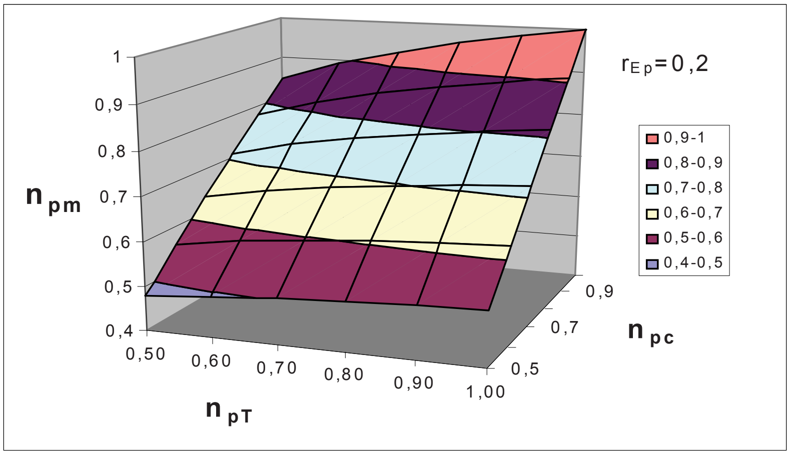

Fig. 2. η_{pm} versus η_{pT} and η_{pc} for η_{pq}=1 and r_{Ep} =0,2

In Figure 4, the case of projects that finish on time (η_{pT} equal to 1) while the cost is within the budget (η_{pc} equal to 1) are presented, for various r_{Ep}. There is again here a strong effect of r_{Ep} on the calculation of the total efficiency which is getting stronger with higher values of r_{Ep}, that is projects with very short pay back period. The number of years introduced in the calculation is equal to 20. The strong effect of the parameter λ_{NI} defined through relation (9) on the total efficiency calculation can be observed easily in Figure 4 where for low values of η_{pq} the values of η_{pm} are extremely low. However, in reality, a unit with such a low η_{pq} will not be put in operation. The project will continue in order all the appropriate corrections to be carried out, or the necessary modifications will be scheduled for the first major shut down, in five years or earlier. So, a 5 years period for loss of earnings seems to be more reasonable. In any case for comparison reasons the number of years has to be noted together with the value of η_{pm}.

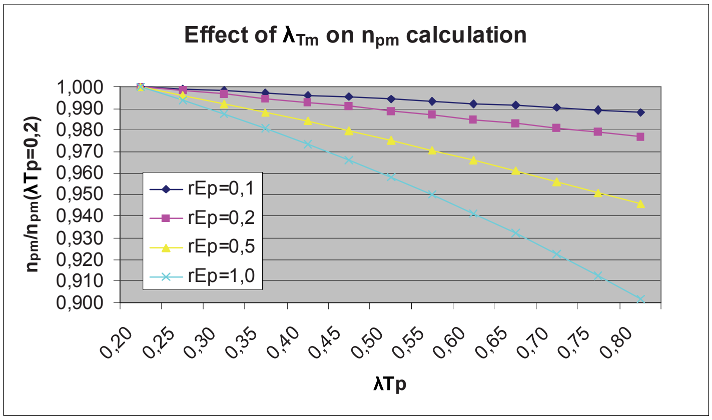

Fig. 3. Effect of λ_{Tm} on η_{pm} calculation for $\eta_{pc} = \eta_{pT} = 0{,}8$

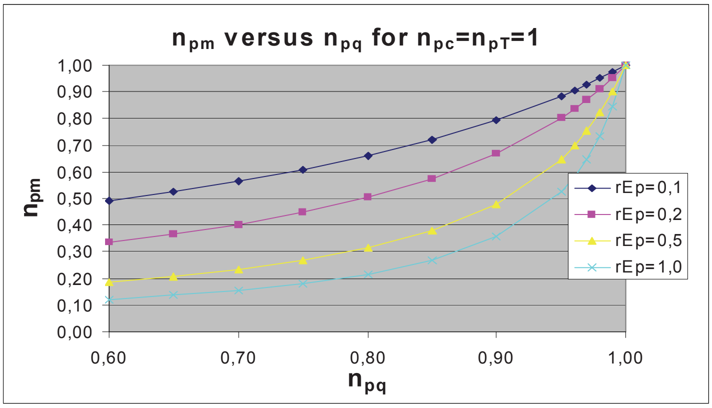

Fig. 4. Variation of ηpm for $\eta_{pc} = \eta_{pT} = 1$

5. Application of the method

The calculation of η_{pm} through relation (8) is quite simple. However we need to define properly the planned and scheduled values of the parameters appearing in the equation. Although the values of r_{Ep}, λ_{iN} ans λ_{NI} can be easily calculated, the phase that C_{pd} will be defined in order to compare with the actual one, after the end of the project, needs some attention. For example, consider the phases of a construction industrial project, like feasibility study, basic engineering, detail engineering, procurement of equipment, construction, commissioning and start up. The feasibility study can not be part of the evaluation of cost efficiency since the necessary time and cost may not be controlled by the project manager. Furthermore, the basic engineering will give a good estimation concerning the cost of basic equipment while the rest of material will be defined after detail engineering. If the definition of cost is done early, then it may be an underestimated budget, so the comparison with the real cost will not be fair. Procurement of basic equipment of long delivery time, although it needs special attention and follow up from the owner's part, may take more time than the expected one or even the official one according to the relative Purchase Order. The problem will appear if this late delivery time will affect the construction works and practically cause delay to the completion time of the project. Thus, it is proposed to define the value of C_{pd} before the start of construction, time that the estimation accuracy is high enough. In this way all the problems coming from the previous phases of the project will arise during construction and will finally affect the cost of the project as well as the completion time.

Concerning the phase that T_{pd} will be defined, according to the definition of η_{pm}, relation (7), only the difference with T_{pd} or T_{pmin} is examined, so any phase of the project can be chosen for the definition of start, provided that the same value of T_{pd} will be used in the calculation of η_{pT} as well as r_{Ep}.

In order to calculate the value of η_{pm} through relation (8) we need the actual values of η_{pT}, η_{pC} and η_{pE}. However, after the end of the project, only the completion time is really known. The cost may be under investigation due to change orders or claims from the contractors, so some more time may be necessary for the final cost to be evaluated. Furthermore, the earnings per year can be anticipated after the performance test and all the measurements taken and compared with the initial assumed ones during the feasibility study of the project. No external effects, like market changes or other factors not related to project management activities must be taken into account. Concerning other criteria, like easy maintenance of the equipment a first estimation can be done using the experience of construction phase. Furthermore, availability of the equipment will need more time, however if there is really a problem this may arise during the first year of the operation.

Differences in the decision making or the organization of a project will give different results of the calculation of the project management efficiency. Concerning for example the revamping of an operating refinery unit in order to do some modifications, the construction works will be performed in two phases, the first one while the unit will be in operation and the second one during a general shut down where the final modifications will be carried out simultaneously with the maintenance works of the unit. For this complicated case, the best possible preparation will eliminate the problems which may appear during the second and most critical phase of the project like wrong piping prefabrication which does not match the existing equipment and piping, additional modifications that were not ready on time, difficulties in the simultaneous execution of construction and maintenance works by more than one contractor in the same area, or even missing special spare parts for maintenance. A better preparation, with project changes like execution of engineering by specialist and construction works by a separate contractor, follow up from a specialist's team dedicated for this work and strict supervision, execution of construction and maintenance by one contractor and increase of the spare parts stock can be more expensive, but the loss of earnings due to a shortest delay can be much more less. It can be easily deduced using equation (8) when comparing two different cases with different values of n_{pT} and n_{pC} that depending on the value of r_{Ep}, a higher project management efficiency can be achieved in the case of a shorter delay (higher value of n_{pT}) although the real cost is higher (lower value of n_{pC}).

6. Conclusions

A method for the measuring of the project management success of industrial projects has been developed and presented. The method is applicable for industrial projects with primarily economic objectives, that is, profitability directly related to operating hours and to the availability of the working equipment. In order to evaluate the success of the project management the relative project management efficiency was defined and the final relation was developed.

The method combines the objectives of cost and time completion as well as other success criteria related to the operation and maintenance of the unit and subsequently the relevant earnings, into a unique relation using only non dimensional quantities. In this way the importance of each of the various objectives and the other success criteria is taken into account giving as a result the value of the total project management efficiency instead of comparing separately the actual cost and time with the scheduled ones. The inclusion of post implementation success criteria like operation and maintenance issues of the unit is also of major importance since it can motivate the stakeholders as well as the project manager and his team for improvements in the scope of work which otherwise could have been omitted in the initial design. The continual improvement and the experience acquired of the people involved in the specific type of projects considered may be reflected to the values of the project management efficiency calculated through the present method.

The concept of total project management efficiency can reveal the real importance of delay or increase of cost. The delay of a project may be less "expensive" than other problems which may appear during operation after an "early" start up of the unit.

Depending on the type of the project a target value for the p.m. efficiency can be defined before the start of the project instead of separate allowance of cost increase or time delay. During project execution, the method can be used as a tool in order to find the most profitable solution to problems that may appear.

The systematic use of the evaluation method using the non dimensional parameters appearing in equations for grouping similar projects can give useful results concerning the effectiveness of teams involved in projects as well as practices that are followed by a company or an organization.

References

Atkinson, R. (1999). Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of project management*, 17(6), pp. 337-342.

Cooke-Davies, T. (2002). The "real" success factors on projects. *International Journal of Project Management*, 20(3), pp. 185-190.

De Wit, A. (1988). Measurement of project success. *International Journal of Project Management*, 6(3), pp. 164-170.

Efremidis, H. (1992). *Time scheduling and financial planning of construction*. Athens: Symmetria Publishing Company (in Greek).

Holland, F. A., Watson, F. A., & Wilkinson, J. K. (1974). *Introduction to Process Economics*. London: John Wiley.

Lock, D. (1992). *Project Management*. (5th ed.). USA: Gower Publishing Company.