TRIANGLES, TRADEOFFS AND SUCCESS: A CRITICAL EXAMINATION OF SOME TRADITIONAL PROJECT MANAGEMENT PARADIGMS

Ramesh Vahidi
Northumbria University, Newcastle-upon-Tyne, UK
ramesh.vahidi@northumbria.ac.uk

David Greenwood
Northumbria University, Newcastle-upon-Tyne, UK
david.greenwood@northumbria.ac.uk

The concept of the 'project triangle', together with the related issues of project tradeoffs and project success factors are frequently discussed together in project management (PM) literature. However, these discussions rarely examine their interconnection critically. As a consequence, the models that are developed from and for these concepts are not properly connected; essentially, the *tradeoff* and *triangle* models can only deal with a limited range of *project success* elements. This paper is a conceptual study to highlight the significance of this 'triple connection' through a comprehensive review of PM literature. It then compares the traditional approach with suggested alternative ways of dealing with the concepts separately and jointly. Finally, the features of an improved framework for making tradeoff decisions are identified and discussed.

KEYWORDS: project triangle, project tradeoffs, project success, tradeoff framework.

INTRODUCTION

In 1969, Dr Martin Barnes, illustrated the construction projects' time, cost and quality relations by drawing a triangle to emphasize the importance of managing 'quality' besides time and cost (Barnes, 2006). Barnes's purpose was to envisage, for the first time, the necessity and significance of integrating the three elements to improve project control. This simple illustration set the foundation of the well-known classic *triangle* in PM history.

Three issues of *project triangle*, *project tradeoffs* and *project success/failure*, referred to as *'Triple Issues'* in this paper, are closely interwoven in project management thinking. The pairwise relations between these issues are frequently addresses in PM literature; however, the relation between the three and its implications is not clearly established. On the one hand, the lack of common consent on the concepts and elements involved in each issue, and, on the other, their discussion in different contexts, cause difficulties of their rational integration.

This paper is a conceptual study aimed at examining the project success, project tradeoffs and project triangle coherence as three crucial and closely interrelated concepts in PM. To achieve this purpose, the history and status quo of factors and trends associated with each concept are discussed and compared to each other. It is supposed that a meaningful relation between the Triple Issues supported by a consistent set of elements for each will facilitate making critical decisions and increase the chance of project success.

For the purpose of this study, to reveal the growing trend in recognition of new elements for the Triple Issues plays an important role. Hence, examples of the resources, which are evidences of this trend, whether by adding new criteria or suggesting a new classification of the criteria, will be addressed to highlight the trend. Deciding whether a specific element or a set of elements should be included in each issue or not, is of significance in PM but it is not in the scope of the current paper. This paper is a snapshot of an ongoing research on project critical decisions.

THEORETICAL FRAMEWORK

Project Triangle Concept

Since its early utilization by Barnes, the *project triangle* has been discussed in different areas in the PM and construction project management literature but the concept had not been subject to a major change, to the extent that Gardiner and Stewart (2000) address it as a well-worn cliché. The author of the only book dedicated to 'the triple constraints', refers to the subject as "fundamental and yet surprisingly unexplored" and one of "the most-overlooked" concepts in PM (Dobson, 2004, p. xi, xiii).

Project Triangle Developments

In his early version, Barnes named the corners of the triangle 'time, cost, quality' but in a later version developed soon after, changed 'quality' to 'performance' (Lock, 2007). 20 years later, the concept was called 'the triangle of objectives' by the initiator (Barnes, 1988).

Since then, the most significant trials to develop the 'triangle concept' have led to a number of different illustrations through adding one or more sides to the shape and/or changing the dimensions from two to three. The illustration has taken the forms of a *tetrad* (Wideman, 2004), *tetrahedron* (Atkinson, 1999; Davis, cited in Wideman, 2004; Burke, 2006), *pyramid* (Marasco, 2004), and *cube* (Hamilton, 2001) so far.

The above mentioned combinations of the elements are referred to as *triangle of objectives* and *trade-offs* (Barnes 1988; Lock, 2007); *project triangle* (Devaux, 1999; Nokes et al., 2003); *triple constraints* (e.g. Turner and Simister, 2000; Hamilton, 2001; Frame, 2002; Bennett, 2003; Dobson, 2004); *criteria's of success* (Williams, 2002); *the iron triangle* (Atkinson, 1999); *Project's Building Blocks* (Orr, 2007); *the Square Route* (Atkinson, 1999); *the project pyramid* (Marasco, 2004); and so forth.

Various names have also been given to the vertices and/or sides of the shapes; nevertheless, 'time' and 'cost' are almost invariably the fixed ones, though they may be referred to as 'schedule' or 'budget'. Despite all of the different versions, the original, developed by Barnes remains the most popular in PM literature (see, for example, Turner and Simister, 2000; Hamilton, 2001; Williams, 2002; Dobson, 2004; Burke, 2006; Kerzner, 2006; Pollack-Johnson and Liberatore, 2006) and specifically that related to construction (see Clough et al., 2000; Woodward, 2003; Bennett, 2003; Lock, 2004).

Besides 'time' and 'cost' other suggested elements have been *quality* (Klein, 1993; Turner and Simister, 2000; Davis, cited in Wideman, 2004; Wideman, 2004; Marasco, 2004; Barnes, 2006; Burke, 2006; Pollack-Johnson and Liberatore, 2006; Orr, 2007); *performance* (Barnes,

1988; Hamilton, 2001; Williams, 2002; Dobson, 2004; Kerzner, 2006; Nicholas and Steyn, 2008); *scope* (Devaux, 1999; Nokes et al., 2003; Davis, cited in Wideman, 2004; Wideman, 2004; Gradiner, 2005; Orr, 2007); *specifications* (Frame, 2002; Lock, 2007); *resources* (Davis, cited in Wideman, 2004; Wideman, 2004); *Net Present Value (NPV)* (Gardiner and Stewart, 2000); *frugality, speed, risk* (Marasco, 2004); *people* (Lock, 2007; Kliem and Ludin, cited in Lock, 2007); and the three factors: *information system*, *benefits to organization*, and *benefits to stakeholder community* besides the *iron triangle* (Atkinson, 1999).

Project Tradeoff Decisions

Originally, the concept of *trade-off* in PM appears to refer specifically to problems which demand finding a balance between the project's '*time* and *cost'* and it is said to be the origin of the critical path method (CPM) developed in 1950s (Pollack-Johnson and Liberatore, 2006). According to Leu et al. (2001), one of the most important aspects of planning and control in construction is trade-off analysis between time and cost. Thus, when time and cost are considered as *'resources'*, tradeoffs might be necessary due to their scarcity (Dobson, 2004) and when they are considered as *'objectives,'* tradeoffs serve as a balancing act when these objectives conflict (Williams, 2002; Lock, 2007). In fact, if a project went well according to the plan or had the benefit of unlimited resources, there would not be a need to make a tradeoff (Williams, 2002; Kerzner, 2006). In general, a tradeoff comprises 'making a decision'; hence, it can be perceived as a type of decision making problem and not simply a controlling or scheduling tool like CPM.

Elements of Project Tradeoffs

A considerable amount of research has aimed at resolving the *time-cost* tradeoffs on projects, either by developing new methods or technically improving the current ones (see, for example, Deĭneko and Woeginger, 2001; Yang, 2007; Wuliang and Chengen, article in press). However, the main focus of this study is another line of research, which claims project tradeoff and/or its resolution method should consider *other factors* besides time and cost (Barnes, 1988; Babu and Suresh, 1996; Shenhar et al., 1996; Leu et al., 2001; Pollack-Johnson and Liberatore, 2006). As one of the pioneers in this line, Dr Barnes (Barnes, 1988) highlighted the significance of considering *performance* as a factor alongside *time* and *cost* in construction projects' decisions.

Over a decade ago, Babu and Suresh (1996) claimed that they could not find a model in the literature to simultaneously consider the three objectives of *time, cost, quality* in tradeoffs. Hence, they developed a mathematical method based on three linear programming models to overcome the problem. Ten years later, Pollack-Johnson and Liberatore (2006) were still criticising the traditional time-cost tradeoffs for ignoring the *quality* factor. They suggest a framework to combine different definitions of quality with their related time, cost, and priorities. They used mixed integer linear programming, goal programming, mixed integer linear program for problem modelling and the Analytic Hierarchy Process (AHP) for choosing among the alternatives.

Shenhar et al. (1996) link project tradeoffs with the recognition of top management and the project team's expectation at the project start up.

Leu et al. (2001) associate the construction project's uncertainties with the various external environment's factors and developed a method to find the best balance between time and cost, considering the risk levels. Their model is based on Fuzzy Set Theory and searches for an optimal solution by Genetic Algorithms (GAs). The consideration of other parameters in the model, such as *total cost* rather than only *direct costs* is left for future research.

Marasco (2004) suggests four elements i.e. *scope, time, quality* and *resources* that should be included in the project tradeoffs. Illustrating these elements as a pyramid, he resolves the tradeoff by calculating the pyramid's volume.

Tareghian and Taheri (2006a) developed a method to resolve the time-cost tradeoff in 2006, but soon after, in two subsequent papers (Tareghian and Taheri, 2006b, 2007) they included *'quality'* in their mathematical methods. These papers used (respectively) 'the fast algorithm of randomized minimum cut'; three 'inter-related integer programming models'; and 'electromagnetic scatter search' as tradeoff methods.

Kerzner (2006, p.684) gives a schematic view of some of the factors affecting, or 'forcing' the tradeoffs. The illustration is not explained in detail; however, it seems that some of these factors like *reputation, market position* and *profit* are perceived as internal and some external such as *reliability, service, response* and *controls*.

Project Success/ Failure

The project management community's obsession with project success/ failure is not a recent issue. Bryde and Robinson (2005) date back the studies to the 1960s or earlier. In fact, project success is such closely interwoven with the field that the most globally accepted success criteria ('*time, cost* and *quality/performance'* or the *'Iron Triangle'*) invariably play their part in the various definitions of PM (see Atkinson, 1999). Referring to the way PM was defined in the 1950's and reviewing a few recent definitions; Atkinson (1999) shows that PM fundamentals and concepts of project success were unchanged in half a century. Belassi and Tukel (1996) portray the era as 'highly focused on project scheduling based on the triple elements, in the hope of having more successful projects through better schedules'.

Shenhar and Levy (1997, p.337) acknowledged that project success might be "the most frequently discussed" topic in PM; while, just one year before them Belassi and Tukel (1996) stated that there was a small number of studies in this field. Nevertheless, both sources agree on the wide range of disagreement and lack of common consent on the topic. A decade later, after conducting comprehensive research on project success, Prabhakar (2006) continues to highlight the lack of agreement on success criteria.

The deficiency of the project triangle elements in reflecting the reality of 'what it takes to have a successful project' was raised by Belassi and Tukel (1996); Shenhar et al. (1996); Winch et al. (1998); Atkinson (1999); Gardiner and Stewart (2000); Morris et al. (2000); Bryde and Robinson (2005); Prabhakar (2006); and Kerzner (2006), to name but a few.

The importance of considering the 'client satisfaction' as central to PM and its necessary involvement in project definition is put forward by Winch et al. (1998).

The fact that the project parties might perceive and evaluate success criteria in different ways has been recognised for a long time (Barnes, 1988; Belassi and Tukel, 1996; Shenhar and Levy, 1997; Atkinson, 1999; Morris, 2005; Cleland and Ireland, 2006; Lock, 2007). It is this difference (between the client and contractor's views on success criteria) that is the basis of a study by Bryde and Robinson (2005). Woodward (2003) specifically refers to the difference between viewpoints of construction project's parties on project *cost*, despite sharing the same intention to complete the project *on time*.

Many of the attempts to classify success criteria have been discussed by Belassi and Tukel (1996). They categorize the related literature into two major categories, i.e. theoretical and empirical, and further compare the critical success factors suggested by seven authors. To overcome the shortcomings of these categories, they propose another framework for categorizing the success factors (Belassi and Tukel, 1996, p.143) including the factors related to the project; project manager and team members; organization; and external environment.

Gardiner and Stewart (2000) replace the phrases 'on time and to budget' with 'best achievable NPV (Net Present Value)' to ensure the shareholders' benefits in the long run. They also highlight the significance of the non-financial factors in project success.

Cooke-Davies (2002) distinguishes '*success criteria* from *success factors'* and '*project management success* from *project success'*. Based on these distinctions he puts forward three questions and ultimately extracts 12 success factors. Besides, he emphasises the importance of human resources in project success, though it is not included in the suggested factors.

INTERRELATION BETWEEN THE 'TRIPLE ISSUES'

Previous sections provided a general view of elements present within a project's *triple issues* and the changing views regarding each topic. This section portraits the pairwise relations between the topics and the trio in order to clarify the need for coherence between their elements. One common area for discussing these topics is 'decision making' in projects. Generally speaking, in this context, a successful project needs to establish a proper balance between its success criteria, which can be analysed and decided through tradeoffs.

Triangle-Success
The *project triangle* has been discussed in project 'success/failure' context as the projects' success criteria or at least a main part of it. A few instances of this are Atkinson (1999), Turner and Simister (2000), Williams (2002), Marasco (2004), Gardiner (2005), Cleland and Ireland (2007), and Lock (2007).

Triangle-Tradeoffs
A number of other academics emphasize the role of the triangle as the basis of project decisions in general and/or tradeoffs in specific. Barnes (1988), Klein (1993), Devaux (1999), Williams (2002), Nokes et al. (2003), Dobson (2004), Wideman (2004), Gardiner (2005), Kerzner (2006), Pollack-Johnson and Liberatore (2006) and Nicholas and Steyn (2008) are a few examples.

Tradeoff-Success
The relation between project decisions (or more specifically tradeoffs) and project success is the least discussed theme. Belassi and Tukel (1996, p.150) include the project manager's "ability to do tradeoffs" as one of the project success factors. Shenhar et al. (1996) emphasizes *success criteria* as the foundation of project tradeoffs both in the launch of and during the project. The methodology for project tradeoffs is called 'facilitation for project success' by Babu and Suresh (1996).

Triangle-Tradeoff-Success
A limited number of the references reviewed explicitly associate all the triple issues with each other. Williams (2002) refers to *the triangle* simultaneously as a set of success criteria and the foundation of 'project tradeoffs'. Lock (2007) stresses the significance of the decisions or tradeoffs between the conflicting objectives, i.e. *Time, cost, specification* and *people* in centre, and their impact on project success. Babu and Suresh (1996) have much the same discussion; however, they use *quality* instead of *specifications* and exclude *people*. Marasco (2004) links the probability of project success in an extended model of triangle and discusses this model as the basis for tradeoffs required for achieving project success.

Upon reviewing a wide range of PM literature, it has thus been demonstrated that neither pairwise relations between project tradeoffs and project success nor an integrated relationship between the Triple Issues are sufficiently focused or clear, especially when compared to success-triangle and triangle-tradeoff relations.

DISCUSSION

The theoretical framework reveals a growing trend in criticising the traditional views on the Triple Issues. There is a common consent between a large number of PM researchers that each one of these issues needs to consider further elements than they traditionally did. Nevertheless, there is no agreement on the *new* or *alternative elements* themselves. A schematic view of the traditional and most emphasised alternative elements is summarized in Table 1. It should further be mentioned that there still exist many PM sources that are not affected by such discussions and continue to recycle the same old theories.

It can be seen in Table 1 that the non-traditional views range from very specific, tangible, measurable factors (like NPV) to hard to measure, intangible and very general ones such as external environment. The largest number and variety of alternative elements were found in relation to *project success*, though only a few could be discussed in this paper.

Table 1: Traditional and Some Alternative Elements of Triple Issues

	Project Triangle	**Project Tradeoffs**	**Project Success-Failure**
Traditional Elements	Time, Cost, Quality/ Performance	Time, Cost	Time, Cost, Quality, Performance
Examples of Other Suggested Elements	Scope, Specifications, Risk, People, Resources, NPV, Frugality, Speed, External Environment, Information System, Benefits to organization, Benefits to Stakeholder Community	Quality, External Environment, Scope, Top management & project team's expectations, Resources, Reliability, Control, Service, Response, Reputation, Market Position, Profit	Scope, Stakeholder's Different success criteria, Client satisfaction, NPV, External Environment, Organizational factors, Project managers and team members' factors, Many other factors and classifications

Reviewing the various views reveals that in terms of the triangle concept, PM academics have not, so far, been able to think 'out of the box'. In fact, it seems that all that is being done is to try to make the 'box' at first, by adding more and more sides' before inventing a totally new way of illustrating it. The question is whether the basis of the tradeoffs and project success criteria should be necessarily drawn as a triangle; or indeed in a geometrical format at all? Is it more important to retain the form or reflect the real content? Frame (2002, p.6) criticizes the traditional PM approach because it puts too much emphasis on: "satisfying the famous triple constraints of time, budget, and specifications" (though his real point is merely that the role of *customer satisfaction* is being ignored).

Additionally, different methods developed to resolve tradeoffs reveal that despite the identification of other factors, researchers' efforts are mainly focused on time-cost tradeoffs, and, at most, adding *quality* to their predominantly mathematical methods. It is worth noting that the necessity for alternative/additional elements is mainly discussed in papers that are not concerned with actually solving the tradeoff. In other words, when it comes to developing a resolution model, the elements considered are normally limited to the original 'triangle'.

The above considerations raise a major question: namely, whether the *tradeoff methods* are chosen based on their capability to deal with the real factors, or the *tradeoff factors* are chosen based on the capabilities of the available methods?' The case seems more closely to support the latter. Frame's (2002, p.6) statement, referring to a "[traditional PM approach] … single-minded focus on a fixed set of tools for dealing with scheduling, budgeting, and resource allocation" appears to be appropriate. Clough et al. (2000, pp.140-141) pinpoint the limitations and failures of the time-cost based computerized methods to solve the construction tradeoffs. They associate the failures with "oversimplification" of the *tradeoffs' reality* which ultimately leads to a continued dependence on "human judgment and insight" as the most important role in such decisions.

CONCLUSIONS

The status quo of the studies on project triangles, project tradeoffs and project success/failure reveals a real need to change the traditional viewpoints on their constituent elements. However, the significance of the interrelation between these issues is overlooked in the related literature, and this leads to lack of cohesion and connectivity between the studies carried out on them. Hence, tradeoff and triangle models can deal with just a few limited factors and the success-failure models suggest so many factors with different natures that the most accepted methods are incapable of dealing with them, either as success criteria in reviews or decision criteria in tradeoff assessments.

To overcome these problems, such studies should look for creative viewpoints, methods and models capable of dealing with the real influencing factors. The continuing identification of missing elements, while trying to preserve the traditional PM paradigms, will not improve the situation. It is time for a radical overhaul of the models and methods in use.

Project tradeoff decisions should be taken within an integrated framework linking project objectives, constraints and success criteria. Such a framework should also provide proper methods of dealing with as many as possible of the recognised influencing factors. Projects are often considered as unique entities with different objectives, constraints and success criteria from one to the other; furthermore, within each project, stakeholders also might have

different perspectives on each of these. Yet traditionally, PM models are perceived to be applicable for every project, and the limits of their applicability are rarely mentioned. The future paradigms called for here should also be general and flexible enough to deal with this wide range of variations. Obviously, a set of predefined criteria and methods might not be applicable for any type of project.

This paper is a snapshot of an ongoing research project aimed at developing a proper decision making framework, based on decision science theories, to model and solve project tradeoffs. Whilst the deficiencies of existing models have been exposed, further work is now required to put better, alternative approaches in place.

REFERENCES

Atkinson, R. (1999) Project management: cost, time and quality, two best guesses and a phenomenon; it's time to accept other success criteria. International Journal of Project Management, 17 (6), 337-342.

Babu, A. J. G. and Suresh, N. (1996) Project management with time, cost, and quality considerations. European Journal Operations Research, (88), 320-327.

Barnes, M. (1988) Construction project management. Project Management, 6 (2), 69-79.

Barnes, M. (2006) "Some origins of modern project management-A personal history", available at: http://www.pmforum.org/viewpoints/2006/08_4.htm

Belassi, W. and Tukel, O. I. (1996) 'A new framework for determining critical success/failure factors in projects', International Journal of Project Management, 14 (3), 141-151.

Bennett, L. (2003) The Management of Construction- a project life cycle approach. Burlington: Gower Publishing Limited.

Bryde, D.J. and Robinson, L. (2005) Client versus contractor perspectives on project success criteria. International Journal of Project Management, 23, 622-629.

Burk, R. (2006) Project management- planning and control techniques. 5 edn. Burke Publishing.

Cleland, D. I. and Ireland, L. R. (2006) Project management – strategic design and implementation. 5 edn. McGraw-Hill.

Clough, R. H., Sears, G. A. and Sears, S. K. (2000) Construction Project Management. 4 edn. Canada: John Wiley & Sons, Inc.

Cooke-Davies, T. (2002) The ''real'' success factors on projects. International Journal of Project Management, 20, 185-190.

Deĭneko, V. G. and Woeginger, G. J. (2001) Hardness of approximation of the discrete time-cost tradeoff" problem. Operations Research Letters, (29), 207-210.

Devaux, S. A. (1999) Total project control-A manager's guide to integrated project planning, measuring, and tracking. New York: John Wiley & Sons, Inc.

Dobson, M. S. (2004) The triple constraints in project management. United States of America: Management Concepts Inc.

Frame, J. D. (2002) The New Project Management: Tools for an Age of Rapid Change, Complexity, and Other Business Realities. 2 edn. Jossey-Bass.

Gardiner, P. (2005) Project Management: A Strategic Planning Approach. New York or Hampshire: Palgrave Macmillan.

Gardiner, P.D. and Stewart, K. (2000) Revisiting the golden triangle of cost, time and quality: the role of NPV in project control, success and failure. International Journal of Project Management, 18, 251-256.

Hamilton, A. (2001) Managing Projects for Success- A Trilogy. London: Thomas Telford Publishing.

Kerzner, H. (2006) Project Management: A System Approach to Planning, Scheduling and Controlling. 9 edn. New Jersey: John Wiley & Sons.

Klein, J. H. (1993) Modelling Risk Trade-Off. The Journal of the Operational Research Society, 44 (5), 445-460.

Leu, S. S., Chen, A. T. and Yang, C. H. (2001) A GA-based fuzzy optimal model for construction time-cost trade-off. International Journal of Project Management, 19, 47-58.

Lock, D. (2004) Project Management in Construction. Burlington: Gower Publishing Limited.

Lock, D. (2007) Project Management. 9 edn. Hampshire, UK: Gower Publishing Limited.

Marasco, J. (2004) The Project Pyramid, available at: http://www.ibm.com/developerworks/rational/library

Morris, P. W. G. (2005) "Managing the Front-End: how project managers shape business strategy and manage project definition", available at: http://www.indeco.co.uk/filestore/Morris-ManagingtheFront-End2005.pdf

Morris, P. W. G., Patel, M. B. and Wearne, S.H. (2000) Research into revising the APM project management body of Knowledge. International Journal of Project Management, 18, 155-164.

Nicholas, J. M. and Steyn, H. (2008) Project Management for Business, Engineering, and Technology- Principles and Practice. 3 edn. Oxford: Elsevier Ltd.

Nokes, S., Major, I., Greenwood, A., Allen, D. and Goodman, M. (2003) The definitive guide to project management. Great Britain: Pearson Education Limited.

Orr, A. D. (2007) Advanced project management –A complete guide to key processes, models and techniques. 2 edn. London: Kogan Page Limited.

Pollack-Johnson, B. and Liberatore, M. J. (2006) Incorporating quality considerations into project time/cost tradeoff analysis and decision making. IEEE Transactions on Engineering Management, 53 (4), 534-542.

Prabhakar, G. P. (2006) A switch in time saves nine: Discovering a new methodology to succeed in projects using transformational leadership in cross-cultural settings. ESC Lille.

Shenhar, A. J., Renier, J. J. and Wideman, R. M. (1996) "Improving PM: linking success criteria to project type", available at: http://www.pmforum.org/library/papers/2002/improvingpm_wideman.pdf

Shenhar, A. J. and Levy, O. (1997) Mapping the dimensions of project success. Project Management Journal, 28 (2), pp. 337-342.

Tareghian, H. R. and Taheri, H. (2006a) 'An application of randomized minimum cut to the project time/cost tradeoff problem', Applied Mathematics and Computation, (173), 1200-1207.

Tareghian, H. R. and Taheri, S. H. (2006b) On the discrete time, cost and quality trade-off problem. Applied Mathematics and Computation, (181), 1305-1312.

Tareghian, H. R. and Taheri, S. H. (2007) A solution procedure for the discrete time, cost and quality tradeoff problem using electromagnetic scatter search. Applied Mathematics and Computation, (190), 1136-1145.

Turner, R. and Simister, S. (eds.) (2000) Handbook of Project Management. 3 edn. Gower.

Wideman, M. (2004) "An Exciting New Model of Project Management", available at: http://www.maxwideman.com/musings/newpmmodel.htm

Williams, T. (2002) Modelling Complex Projects. West Sussex: John Wiley & Sons.

Winch, G., Usmani, A. and Edkins, A. (1998) Towards total project quality: a gap analysis approach. Construction Management and Economics, 16, 193-207.

Woodward, L. (2003) Construction Project Management. London: Thomas Telford Publishing.

Wuliang, P. and Chengen, W. 'A multi-mode resource-constrained discrete time–cost tradeoff problem and its genetic algorithm based solution'. International Journal of Project Management (2008), doi:10.1016/j.ijproman.2008.10.009

Yang, I. T. (2007) Performing complex project crashing analysis with aid of particle swarm optimization algorithm. International Journal of Project Management, (25), 637-646.