

# Innovative Models for Procurement of Major Infrastructure Projects in Development

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## ABSTRACT

Use of collaborative procurement based on target cost contracts is on the increase in construction worldwide. Other innovative arrangements for procurement include Early Contractor Involvement (ECI) design and build. In this paper, the key features and risk allocation inherent in target cost contracts are discussed. The characteristics of ECI contracts are assessed including an evaluation of the payment mechanisms in a major rail project. It is concluded that experience of ECI design and build contracts is still limited. As a consequence, further theoretical research and empirical data analysis are required to collate information which will guide industry in designing effective incentives in collaborative procurement for development projects.

**Keywords:** contracting, development, incentives, partnering, procurement, risk.

## 1.0 INTRODUCTION

In recent years, there have been major advances in collaborative procurement in construction worldwide. All project participants are increasingly working together in a variety of contractual arrangements including partnering, alliances, joint ventures and framework contracts. Building trust is a key ingredient in such arrangements. To achieve true collaboration, a legally binding contract that aligns the motivations of the parties is essential. Although lump sum and admeasure contracts are still widely used, the development of the NEC Engineering and Construction Contract (ECC) has led to widespread use of target cost contracts. Wright and Fergusson (2009) investigated use of the NEC ECC in New Zealand and found that the contract form delivers business benefits in terms of project management, contract clarity and contractual relationships. The contract provides a forward looking proactive environment in which to manage project cost and time although use of the target-sum payment option requires additional time and cost for administration. The authors conclude that the contract form provides the unexpected benefit of added occupational safety most probably due to better forward planning.

The theory of risk sharing and incentives in target cost contracts has been widely reported in the economics literature. This work adopts principally a mathematical modelling approach and specific assumptions regarding the contracting relationship between the client and the contractor. For example, a principal-agent analysis by Weitzman (1980) concludes that an optimal sharing ratio in target cost contracts depends on various factors. These factors include the level of project uncertainty, the degree of risk aversion by the parties and the contractor's ability to control costs. Another principal-agent analysis by McAfee and McMillan (1986) suggests that an optimal contract that minimises procurement costs is never a cost-plus contract. It may be a fixed-price contract but that such contracts should be used much less frequently. They conclude that an optimal contract is usually an incentive contract and that a client's choice of the sharing ratio determines the contractor's choice of cost-reducing activity. The larger the share of costs paid by the client, the smaller the effort expended to lower production costs.

In target cost contracts, the contractor is reimbursed all the allowable project costs. In addition, he is paid a fee to cover overhead expenses and profit. The contractor and the client will also normally share the difference between the target cost and the actual cost of the

project in a pre-agreed proportion. Perry and Barnes (2000) examine the interplay between the fee, the target cost, the sharing fraction and the final contract price. Their analysis shows that some methods of tender evaluation can lead to adverse contractor selection. Consequently, they propose methods of tender evaluation to ensure optimal choice of tender. Based on a case study approach, guidance on selection of appropriate sharing rates is discussed in Broome and Perry (2002). A probabilistic model for structuring incentive fee contracts is discussed in Berends (2000). Meanwhile, Rosenfield and Geltner (1991) suggest that cost-plus and incentive fee contracts have a number of inherent drawbacks and that their use in practice should be limited.

In addition to use of target cost contracts, the concept of Early Contractor Involvement (ECI) design and build has been developed in recent years. ECI seeks to integrate the team members around the project. The contractor is appointed early in the life cycle of the project to work with the client and contribute to development of the design and secure improvements in buildability and economy. ECI contracts are normally in two phases. The first phase of design development is paid for on a cost-reimbursable basis. The second phase of detailed design and construction is paid for on a target cost basis. ECI contracts are gaining widespread use in practice although experience of their use practice is still limited. This paper aims to provide a contribution to this gap in knowledge based on a survey of published work on target cost contracts and review of a £37m rail project in the United Kingdom. Delivery of major infrastructure development projects using ECI design and build offers the potential to improve project performance and value for money.

## **2.0 TARGET COST CONTRACTS**

Target cost contracts constitute a refinement of cost-reimbursable contracts. Just as in cost reimbursable contracts, all allowable costs correctly incurred in project execution are monitored through open book accounting and reimbursed to the contractor. The contractor is also paid a fee to cover his overhead expenses and a profit. The main development in target cost contracts is that a project cost target is agreed between the client and the contractor. If the contractor exceeds the cost target set, he pays a penalty on his fee. If he performs the work at a keener price than the target, he receives a bonus on his fee. In target cost contracts, the contractor has financial incentives to keep project costs down and work can start before the design is far advanced.

The total payment by the client to the contractor in a target cost contract is given by the equation:

$$P = C + F + r(T - C) \quad (1)$$

Where; C = actual cost of the project (which is uncertain at the start of the project), F = fixed fee paid to the contractor, T = project target cost, r = sharing ratio,  $0 < r < 1$ , and F, T and r are fixed at the commencement of the contract. If  $r = 0$ , the contract is effectively a cost-reimbursable contract. If  $r = 1$ , the contract is effectively a fixed price contract. If the actual project cost exceeds the target cost by  $F/r$ , the contractor makes a loss on the contract. Target cost contracts contain mechanisms for negotiation and adjustment of the cost target due to changes in design or scope of the work. The use of target cost contracts generally and the choice of optimal sharing rate in particular are key contributions of this paper. For construction of the Channel Tunnel, all underground construction was based on a target cost contract to which a gross profit (fixed fee) of 12% was paid to the contractor. If the cost was under budget, the contractor received 50% of the savings. If the budget was exceeded, the contractor paid 30% of the cost overrun, up to a limit of 6% of the target cost (Biedleman, Fletcher and Veshosky, 1990). Target cost contracts have been used in defence procurement since the 1960s due to concerns with cost overruns on large defence projects. Tirole (1986) notes that cost overruns in defence programme development costs exceed original predictions by 220% on average and that in some cases costs have exceeded original predictions by as much as 14 times. Cost sharing can be beneficial to the client in such cases if it can bear the

consequences of cost overruns more cheaply than the contractor. Driving down project costs is not the only way the contractor can maximise his payoff. The same objective can be achieved by seeking an inflated target cost during initial negotiation and renegotiations. Analysis by Tirole (1986) has shown that contractors will put in less effort to reduce actual projects costs if there are opportunities to renegotiate the contract sum. Cost sharing provisions and opportunities to renegotiate target costs are two important features in target cost contracts. Their effects on the contractors cost saving effort are presented in Brumm (1992). His empirical analysis of data obtained from 51 defence contracts uses a multiple indicators, multiple causes statistical model to link contractor cost saving effort and the sharing rate, number of contract modifications, and cost uncertainty. Whilst acknowledging the theoretical limitations of his model and the limited data on which the analysis is based, he concludes that contract modifications significantly reduce the contractor's cost saving efforts but that the contract share rate has no significant effect. Brumm (1992) further concludes that in fact incentive pricing does more to encourage a contractor to propose frequent modifications to the contract with the hope of renegotiating higher target costs, than to hold actual costs down.

Target cost contracts require the client to carry more risk than in traditional procurement. They are designed to encourage collaboration. Clear definitions of costs, fees and equitable methods of target cost adjustment are central to running of successful target cost contracts. Perry and Barnes (2000) in their fundamental analysis of target cost contracts firstly propose tender evaluation methods that will lead to choosing a contractor whose final price will be lowest. Secondly, they conclude that the contractor's share of cost overrun or underrun should be set at a value that is not less than 50% since a low contractor's share decreases the motivation to reduce the actual project costs.

Recent research by Badenfelt (2008) based on a case study approach and surveys of clients and contractor organisations in Sweden concluded that the factors that influence the selection of sharing ratio include perceptions of fairness, knowledge of target cost contracts, and long term relationships. Al-Harbi (1998) suggests an approach for selection of sharing fractions based on an analytical approach followed by negotiation of the parties. The analytical method suggested is based utility theory. The utility model takes account of the attitudes to risk of the client and the contractors. However, determination of the utility of money model for decision makers involved in bidding and contractor selection processes can be complex and time-consuming. An interesting conclusion by Weitzman (1980) is that the sharing ratio ought to be above 50% in most reasonable scenarios and that it should sometimes be well above this to create greater incentive for the contractor to reduce costs. Tang *et al* (2008) report the results of an empirical survey on the use of incentives in the Chinese construction industry including their application on the Three Gorges project. They conclude that although the delivery systems currently in use in China retain features of traditional procurement, incentive contracting is being promoted to secure better project performance. They suggest that incentives could be set in a range of areas to improve quality, occupational health and safety and the environment, project time, information management and co-ordination. Earlier research by Bubshait (2003) on use of incentive/disincentive contracts in industrial building in Saudi Arabia found that the most widely used incentive/disincentives relate to project schedule. Other types such as cost, quality performance or safety incentives are used but to a smaller extent. Chan *et al* (2010) analyse use target cost contracts in Hong Kong and conclude that target cost contracts generate a range of benefits throughout the project delivery process including better value for money and overall performance in terms of cost, time and dispute occurrence.

### **3.0 INCENTIVES ON A MAJOR RAIL PROJECT**

This rail project was completed recently in Scotland and involved a variety of organisations. The Employer has requested that commercial confidentiality be maintained and as a consequence, the project and all the participating organisations will not be named in this

paper. The project was estimated to cost £37 million and sought to reopen 21 km of disused and abandoned railway lines. The procurement strategy utilised a unique concept - Early Contractor Involvement (ECI) Design and Build. The contract comprised two distinct phases. Phase 1 covered the period from the Contract Date to the issue of the Notice to Proceed to Construction by the Employer. The contractor's role during this period was to familiarise himself with the project, review the existing preliminary design and adopt it with the aim of improving it or replace it with an improved alternative design. Other duties included supporting the Project Manager and the Employer to steer the project through Royal Assent, identifying site investigations required and establishing third party relationships required through to Phase 2. Detailed design work could be carried out during this phase but only if instructed by the Project Manager. Phase 2 covered the period from the issue of the Notice to Proceed to Construction to the issue of the Defects Certificate for the Works. It should be noted the contractor's duties included everything to ensure the full and complete design and construction of the project, including accommodation works. However, a guide to the main duties anticipated in each phase is provided below. The contractor was required to take on the role of Principal Contractor under the UK's Construction (Design and Management) Regulations 2007. The duties of the Contractor during Phase 1 included the following (order not significant):

- (a) project familiarisation and mobilisation of staff;
- (b) attend partnering workshops and other partnering events;
- (c) attend monthly project progress meetings and other group meetings as required;
- (d) liaise with public utility authorities and agree necessary diversions including costs;
- (e) liaison with statutory and non-statutory bodies being consulted;
- (f) promote public liaison and consultation;
- (g) develop and agree actual cost estimates for submissions;
- (h) attend risk workshops and develop and update the Risk Register;
- (i) review surveys carried out and/or planned to assess suitability/ deficiency and undertake additional surveys as appropriate;
- (j) review previous studies and documents;
- (k) prepare the design and construction proposals including attendance at value engineering workshops with the Employer and Project Manager;
- (l) obtain approval for departures from standards from appropriate organisations;
- (m) obtain approvals from appropriate bodies;
- (n) assist others to obtain approvals from appropriate bodies;
- (o) develop and adhere to the draft code of construction practice;
- (p) prepare quality plans, quality statements and the health and safety plan and update as necessary;
- (q) perform function of Principal Contractor under the CDM Regulations;
- (r) prepare land acquisition plans and schedules and assist Project Manager with land entry procedures;
- (s) incorporate changes to design as a result of the recommendations from the legislature/ Parliament and/or the Employer and develop appropriate mitigation measures;
- (t) develop Prices and agree value of changes as a result of any Bill amendments;
- (u) develop and agree performance targets and associated Key Performance Indicators for Phase 2;
- (v) develop and agree activity schedule for Phase 2
- (w) develop the programme for Phase 2 including possession date(s) and section(s) of the site;
- (x) develop the Works Information and Site Information for Phase 2;
- (y) agree prices for Phase 2.

Throughout Phase 1, no guarantee was given to the Contractor by the Employer that the project would be constructed. The Employer retained the right to terminate the contract at any time due to: project economics if the project cost benefit ratio became unfavourable, failure to obtain an Act of the relevant statutory body/ Parliament, change in government policy and lack of availability of funds to construct the works.

There was explicit provision in the contract that Prices for the works would be agreed at the end of Phase 1. If the Price turned out to be higher than the Employer's Budget Cost, the Employer retained the right to seek competitive tenders for construction of the scheme under a conventional design and build contract. The Employer would be at liberty to use the design produced by the Contractor for the tender, and if lower prices were obtained, the Employer reserved the right to terminate the contract. On termination of the contract, any documentation, reports, brochures prepared by the contractor for purposes of the project would be handed over to the Promoter. All work undertaken by the contractor during phase 1 was paid for on a cost-reimbursable basis. Duties of the Contractor during Phase 2 were agreed during Phase 1. They included the following (order not significant):

- (a) continuing all duties from Phase 1 as required;
- (b) undertake the detailed design of the project;
- (c) assist the Project Manager to complete land entry procedures;
- (d) update the Prices and Actual Cost Estimates;
- (e) maintain and report an open book accounting technique;
- (f) carry out all duties associated with the construction of the project including planning, administration, construction, supervision, liaison, self-certification, testing and commissioning, etc;
- (g) carry out public information/liaison exercises
- (h) perform the function of Principal Contractor under the CDM regulations; and
- (i) rectify any defects.

In adopting ECI design and build, the contractor was appointed early and philosophy behind this decision was that: the project would benefit from an early stage input of construction expertise to improve build-ability, pricing and determination of the optimum scheme; innovation would be encouraged at an early stage of scheme development prior to development of detailed design; preparation and the construction process would be speeded up; the contractor's expertise would be available and could be utilised in developing and implementing the approvals process from relevant authorities. Phase 2 was paid for on a target cost basis and the agreed contractor's share percentages and share ranges under clause 53 of the NEC Engineering and Construction Contract Option C were as indicated in Table 1.

**Table 1:** Share range and contractor's share percentages for the £37 million Rail Project.

Share Range	Contractor's Share Percentage
Up to 100%	15%
100-110%	50%
110-120%	65%
120-130%	75%
Over 130%	100%

The above risk-reward criteria could be criticised on the grounds that the contractor only gets the benefit of 15% of the savings but is penalised quite heavily if he exceeds the total of the prices. It could be argued that the incentive to identify savings and manage risks following Phase 1 is not significant as the Employer gets 85% of all savings. It should however be noted that design and development in Phase 1 was paid for on cost-reimbursable basis. Such a risk-reward strategy was designed to motivate the contractor to undertake a thorough technical evaluation of the scheme and develop a realistic pricing of the Works during Phase 1. If detailed design of some elements of the scheme was necessary in order to arrive at realistic pricing, the contractor could undertake this following a request to do so, and authorisation from the Project Manager. It should also be noted that instructions to bidders included a detailed risk register. Each source of risk was numbered uniquely. The project phase when each source of risk was likely to materialise was also stated. A detailed description of each risk was given including a risk management plan. Probabilities of occurrence of each risk were estimated including an assessment of their likely impacts. A clear statement on

allocation of risk to the party responsible for management of the risk was included in the register. Although the risk register was not a contractually binding document, it was a dynamic project management tool that was updated regularly at each assessment date.

#### **4.0 CONCLUSIONS**

Target cost contracts are designed to motivate the contractor to minimise production costs. They have been widely used in defence procurement in the past and are gaining widespread use in high-risk construction projects worldwide. Several authors in both defence and construction procurement have repeatedly called for sharing rates for cost overruns or under-runs in such contracts to be set at a value of not less than 50% in order to provide adequate incentives for the contractor to drive down costs. Some authors however take the view that contractors will put in minimal effort where there are opportunities to renegotiate the target cost. The key features of the ECI design and build contract and risk sharing mechanisms adopted in a major rail project have been discussed. The main duties of the contractor during Phase 1 which included preliminary design and development of a realistic project cost target are given. Phase 1 was paid for on a cost-reimbursable basis. Phase 2 included detailed design and construction and was paid for on a target cost basis. The sharing fractions for various possible actual project cost outturns are discussed. The target cost was developed collaboratively with the contractor on an open book basis. The client's project manager was able to check proposed plant and labour productivities, types and amounts of resources and estimates of potential subcontractor costs. As a consequence, the client's confidence in the contractor's estimates was greatly enhanced. Any detailed design that was necessary to enable realistic estimating could be undertaken provided this was agreed and sanctioned by the project manager. The contract was clearly designed to strongly motivate the contractor to provide realistic estimates of the target cost. The contractor was rewarded with a share rate of 15% of any cost savings below the target. Since conceptual design and development of the cost target were paid for on a cost reimbursable basis, a higher sharing fraction was considered not appropriate, as this would constitute an unreasonably high reward to the contractor. The compensation event procedures in the contract provided a mechanism for adjusting the project cost target. The client's project managers took the view that if there was a significant cost overrun beyond the target cost, the contractor's estimates of cost for the known work and the risks would have been seriously wrong and a substantial proportion of this risk should be therefore borne by the contractor. The share fractions for cost overruns beyond the target were thus set accordingly to reflect this allocation of risk. The work reported in this paper has important lessons for procurement of major development projects world-wide. Major infrastructure development projects will generally be risky due to a number of reasons. These include project size, complexity or the unfamiliarity of one or more the project participants. Other factors may be logistical. The use of fixed price or lump sum contracts is clearly not recommended except for the simplest of projects. The use of cost-reimbursable contracts is also not recommended except for emergency situations. The use of ECI design and build in conjunction with target cost contracting to deliver major infrastructure development projects potentially offers a number of benefits including the following:

- Better risk management using the knowledge of the contractors involved in the project development.
- Better communication, co-ordination and collaboration between all the project participants.
- Parallelisation or overlapping of procedures and activities including planning, design, and construction leads to early project completion and saving of time.
- ECI facilitates better information exchange between the various procedures and processes including for example, design, environmental impact assessment or indeed route selection in the case of a railway or a road project.
- Transparent decision-making involving contractors, designers and the client leads to better contractual relationships thus reducing the potential for claims and disputes.

- Better opportunities for innovation and creativity. Contractors can input economical methods of construction in the design process leading to better value for money for clients, better prices and improved project quality. The earlier the start of involvement by contractors in the process, the more opportunities there are for innovation.
- Contractors can test the technical and financial feasibility and build-ability of project alternatives.
- Contractors can assist proactively to develop project alternatives and help to steer the proposals through the planning process right through to planning consent.

Although they are gaining widespread use world-wide, experience of ECI design and build procurement in conjunction with target cost contracting on infrastructure development projects is unfortunately limited. It is suggested that this is an area worth further research and investigation to develop best practice guidelines. Other studies comparing conditions and use of early contractor involvement in infrastructure development with findings on early contractor involvement in other sectors such as information technology or ship building will bring invaluable insights and thus is also recommended for further research.

## 5.0 REFERENCES

- Al-Harbi, K. M. A. (1998), *Sharing fractions in cost-plus-incentive-fee contracts*, International Journal of Project Management, 16(2), 73-80.
- Badenfelt, U. (2008), *The selection of sharing ratios in target cost contracts*, Engineering, Construction and Architectural Management, 15(1) 54-65
- Berends, T. C. (2000), *Cost plus incentive fee contracting – experiences and structuring*, International Journal of Project Management, 18(3), 165-171.
- Biedleman, C. R., Fletcher D. and Veshosky D. (1990), *On allocating risk: the essence of project finance*, Sloan Management Review, Spring, 47-55.
- Broome, J. and Perry, J. (2002), *How practitioners set share fractions in target cost contracts*, International Journal of Project Management. 20, 59-66.
- Brumm, H. J. (1992), *Incentives in incentive contracting: an application of the MIMIC model*, Applied Economics, 24, 337-345.
- Bubshait, A. A. (2003), *Incentive/disincentive contracts and its effects on industrial projects*, International Journal of Project Management, 21, 63-70.
- Chan, D. W. M., Lam P. T. I. and Chan A P C (2010), *Achieving better performance through target cost contracts: A tale of an underground railway station modification project*, Facilities, 28(5/6) 261-277.
- Lynch, R. (2005), *Councils drive best value out*. Construction News, Thursday April 14, Issue No. 6912, page 1.
- McAfee, R. P. and McMillan, J. (1986), *Bidding for contracts: a principal-agent analysis*, Rand Journal of Economics, 17(3), Autumn, 326- 38.
- Perry, J. G. and Barnes, M. (2000), *Target cost contracts: an analysis of the interplay between fee, target, share and price*, Engineering, Construction and Architectural Management, 7(2), 202-8
- Rosenfield, Y. and Geltner, D. (1991), *Cost-plus and incentive contracting: Some false benefits and inherent drawbacks*, Construction Management and Economics, 9, 481-492
- Tang, W., Qiang M; Duffield, C. F.; Young D. M.; and Lu Y. (2008), *Incentives in the Chinese Construction Industry*, ASCE Journal of Construction Engineering and Management, 134 (7) 457-467
- Tirole, J. (1986), *Procurement and renegotiation*, Journal of Political Economy, 94(2), 235-59.
- Weitzman M. L. (1980), *Efficient incentive contracts*, Quarterly Journal of Economics, June, 719-730.
- Wright J. N. and Fergusson W. (2009), *Benefits of the NEC ECC form of contract: A New Zealand case study*, International Journal of Project Management, 27 243-249

## **Investigation of the Suitability of Recycled Carpet Fibre as a Soil Reinforcement Material**

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### **ABSTRACT**

The textile industry which includes carpet products produces millions of tons of waste material whose disposal has become a dilemma to most consumers. The bulk of carpet waste is generated from post consumer usage as well as the industrial sector. Majority of carpet wastes are non-biodegradable, require a large amount of energy to recycle and occupy large volumes of landfill space. It is such characteristics that have made carpet waste disposal problematic. Inclusion of carpet waste in soil presents an opportunity to alleviate the waste disposal problem. This study reports on the findings from an investigation into the behavior of recycled carpet fibres randomly distributed as internal reinforcement. Composites of a sandy soil and carpet fibres of varying lengths and concentrations were prepared. Fibre lengths of 7.5 mm, 15 mm and 30 mm were used in dosages of 0%, 0.1%, 0.2%, 0.3% and 0.5%. Direct shear tests were carried out on each of the samples and the resulting shear strength parameters determined. Results from the tests revealed an increase in soil cohesion but no significant effect on the friction angle. From these findings, it was deduced that random inclusion of carpet fibres in sandy soil enhances soil strength and load bearing capacity.

**Key words:** Carpet fibres; Cohesion; Shear strength; Fibre length; Fibre concentration

### **1.0 INTRODUCTION**

The use of carpets for furnishing homes and offices is growing rapidly in many developing countries. This can be attributed to economic growth that has resulted in higher standards of living in these developing countries. To meet these standards, most home and office owners feel the need to redecorate every once in a while and as a result, large amounts of post consumer carpets are discarded for replacement with new carpet coverings. Industry today has a growing concern for the environment and this has prompted recycling efforts in many directions. Earlier, manufacturers only concerned themselves with profit and competition. Today, factors such as government legislation, the increasing cost of landfill space and the growing awareness of the public have encouraged manufacturers to advance towards green engineering and recycling. Much as the carpet industry does not produce waste as hazardous as other industries such as petroleum and oil refining, it still consumes a lot of valuable fossil fuels and produces millions of tonnes of waste material. The rate of carpet disposal is about 2-3 million tons per year in the U.S. and about 4-6 million tons per year worldwide (Wang 2006). Disposal of used carpet is a dilemma to large apartment complexes and office buildings. These places must find a way to dispose of this carpet waste which usually means land filling. As the cost of land filling waste is increasing due to decreasing landfill space, carpet consumers and manufacturers are scrambling for a solution. Carpets are mainly made from natural and synthetic materials such as wool, polypropylene and nylon among others. The fact that carpets are made from different materials using several processes makes separation and subsequent recycling of the carpet fibers extremely difficult. It is even more difficult to recycle post consumer carpets because of the dirt, cleaning chemicals and other materials that accumulate in the carpet over time. Not only does inclusion of carpet waste in soil improve the soil properties, it also offers additional benefits. These benefits include resource utilization,