Risk and its management in construction projects

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The Authors are to be congratulated on providing a lucid and thorough review of the risk analysis techniques now available and for exploring the way in which they may be applied in order to secure better management of risk on construction projects. The following comments are offered in elaboration of particular points made by the Authors. They are based on our own experience of measures adopted with the object of managing risk.

89. In § 8, the Authors mention that, from a corporate viewpoint, it may well be more important to assess the cumulative effect of risks from all contracts of projects being handled than to consider single projects. They report little evidence of any formal approach to considering risk in this way and suggest that further research in this area may be fruitful. There are certainly many examples of clients engaged in extensive capital works programmes making policy decisions about how projects which involve risk management should be run. For instance, it is not unknown for clients to accept the risk of damage to their projects arising from flood, fire and normally 'excepted risks' rather than passing them to contractors or reinsuring them with an insurance company. The view taken is that the premium which either of these two other parties would charge would be more than the consequential costs of the average incidence of these risks actually materializing. Another example is the choice of forms of contract. Private sector building project clients are increasingly adopting 'design and build' and 'management' contract forms for their projects, primarily because they perceive them as capable of reducing the risk of missing time, cost or performance targets. Research into corporate risk management attitudes could well illuminate the effectiveness of such decisions.

90. In §§ 28 and 29, the Authors discuss the application of probability analysis to estimating, setting contingency allowances and tender evaluation. Such techniques can certainly be used by clients to assess a reasonable contingency allowance which contractors might include in their tenders for the risks allocated to them by the contract. However, we do not see how in practice this could be extended to indicating the level of confidence that could be placed by the client in individual tenders or to deducing the likely 'claims consciousness' of an individual tenderer. Our own experience does not suggest that the precision of estimating which is achievable by a client before tenders are obtained or the statistical robustness of a set of actual tenders justify drawing conclusions of this type. The Authors refer at this point to Fig. 1 in which it is implied that accurate estimates tend towards optimism, less accurate towards pessimism. Do they have figures to support this? Our view, not supported by figures, is that the inaccurate estimates

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are also likely to be the optimistic ones. This is on the grounds that careful preparation of an estimate not only leads to more accurate prediction of cost but to the omission of fewer cost generating factors from the synthesis.

91. We concur with the caution expressed in § 34 about the need to be realistic and to take account of natural human optimism when assessing likely ranges of possible outcomes. We have been involved recently in more than one tunnelling project where experienced engineers have estimated overall rates of advance for tunnel excavation, having made allowance for such things as the foreseeable ground conditions. In each case, they also recognized that a wide variety of conditions could arise but found it most difficult to accept that their possible consequences on plans and cost estimates should or could be tested. On one project, and only after lengthy discussion, the engineer reluctantly accepted that the rate of advance might vary by $\pm 10\%$. This was for a large diameter tunnel in alluvial soils with a 10 m to 15 m head of water pressure. Clearly, such a small variation in average drive rate was one which might be experienced as a result of variation in the foreseeable ground conditions. It could take no account of the variation that might be experienced because of all the other uncertainties present. In conducting a sensitivity analysis, we were concerned with identifying the likely magnitude of the total risk of rates of advance varying from a reasonable mean. A real human problem seems to be how to assess the variability of assumptions subject to low probability or less foreseeable risks? Enthusiasts for risk analysis can make assumptions easily enough, but it is difficult to convince others that they are realistic and relevant. The importance of assessing the range chosen for variables such as tunnel drive rates when using probability analysis techniques, is highlighted in § 43.

92. Probability analysis (described in §§ 40–48) is very useful for determining the likely variation in cost or time outcomes for a project. Used on its own, however, it cannot help to identify the major risks affecting a project which need to be managed. It can reveal only that there are some risks which have high potential impact. This suggests that, during feasibility or early design stages when risk management can be practised to best effect, use of probability analysis alone is insufficient and that use of a technique such as sensitivity analysis is more important and should be complementary.

93. In § 60, the Authors have suggested that risk management can be applied to the construction phase, albeit with less effect than during earlier phases. This is certainly true. Once construction gets underway, it is the maxim 'control time and cost will take care of itself' which has the strongest force. It suggests a possible change in emphasis in the techniques which can usefully be applied. For instance, probability analysis based on time variables only (§ 46(a)) seems to us to have little value during early project phases unless the objectives for the project really are massively dominated by time considerations. For example, Taylor²⁸ has described the use of probability techniques for the determination of the minimum wave height which should prevent offshore installation plant from working. This was undertaken in order to give an acceptable degree of assurance that work could be completed within a weather window.

94. In § 75, reference is made to the British Property Federation system as a radical new approach to construction project management, founded on a review of risk allocation. Having been responsible for designing the BPF system, we would like to draw attention to the fact that it has two elements of risk consideration. Not only is the traditional risk allocation changed, but measures are included

aimed at an overall reduction of risk. The new system is based on the principle that if the *total amount* of risk to be carried by contractors can be reduced by more foresight in the conduct of a project, they will not be averse to accepting a longer list of risks which make up the total.

95. We support the Authors' conclusions but would offer another which we consider justifies inclusion and emphasis. It is that risk reduction is an important part of risk management. It has been neglected in writings on the subject but can be very effectively introduced. For individual projects it can be achieved by sometimes quite simple changes in design and by the proper consideration of contract strategy which the Authors advocate. For projects generally, revised conditions of contract aimed at stimulating effective management and consequent risk reduction is now a practical goal.

Mr R. J. Butler, L. G. Mouchel & Partners

The Paper is a timely reminder of the importance of the subject. Discussion among various professions and industries on risk management has increased considerably. This is not so much because of its role in decision-making for businesses, projects, portfolios and insurance purposes, but as a result of the growing pace of change in today's environment, fluctuating exchange and interest rates, and shortcomings in traditional methods of management accompanied by new techniques. For engineers moving into engineering-management positions and for project managers wishing to formulate decision making rationally, risk management techniques introduce a degree of realism into calculations by considering the risks and uncertainties that underlie estimated costs and revenues. Knowledge of these techniques seems essential for the future and deserves greater attention in the general context.

97. In moving towards better control of major projects, the industry has the benefit of hindsight stemming from decades of experience and has removed many of the problems which dogged a great number of the earlier projects, but experience has also highlighted areas in which there is still room for improvement. The main problem is to forecast activities and associated changes in their overall environment. In these forecasts, analysts have developed various techniques to assist decision makers, which as yet are not widely accepted. Related to this main problem are important considerations about engineering management, project management, business and financial risk, professional viability and the general management of change.

98. Shortcomings in traditional engineering management seem to focus on the engineer's willingness to accept engineering risks, in the sense that his tasks are deterministic, and to develop a high tolerance to uncertainty. This appears to be unsuitable for engineering management in the future and, in turn, has not helped the engineer to come to terms with the business environment. Emphasis should be on the interdependence of engineering and management systems in the engineering professions—and no less so in the construction industry where projects are often in very uncertain conditions. Cleland and Kocaoglu²⁹ point out that in areas of engineering management, management science techniques and management theory can be blended with sufficient confidence for the engineering manager to recognize that quantitative approaches to management provide a rational basis for decision making, and a valuable aid to complement his judgement. Such techniques are coming into favour to evaluate better the risk and uncertainty of engineering-management decisions. The Authors' attention to sensitivity analysis,

stochastic methods, Monte Carlo schedules, decision trees and utility theory should, in my opinion, also include basic forecasting methods, environmental types, linear programming, selection methods, all forms of network, and the development of methods to ensure that the overall analytical process is carried out in an orderly manner. In addition, one-topic recently covered by an ASCE Paper³⁰ was that of research which was needed into construction engineering uncertainty including items such as scheduling uncertain durations, range estimating, structural failure and construction safety, contractual risk, bidding and mark-up analysis, decision theory, and the process and project simulation.

99. With the concepts and methods of engineering management developed around the focal point of a project, it seems helpful to look at a project in the manner recently described by Snowden,³¹ as not just a series of steps from conception to operation but as an instrument of change; that is, a client has created a project to improve his business by way of greater amenity, greater profit, improved service or other worthy ambitions. As every project, however small, involves change and uncertainty, and should be sanctioned only if it represents a worthwhile expenditure of resources, one would wish to predict as far as possible the actual changes necessary to reach the ultimate objective, by taking account of the various issues not being all of equal importance, some being undesirable and others being virtually unpredictable. Similarly, subsequent changes can occur and cause things to go 'wrong' unless change is managed. Exceptional effort is therefore required to foresee events and be able to control them before any financial commitment on hardware is made.

100. The riskier looking the project, the more effort is required and the more likely that equity funding and extra contractual safeguards will be sought. An index of choices at relevant decision levels will provide management with a better decision framework. In this process there are, in addition to pay-back and return-on-investment methods, other measures to evaluate the merit of a new proposal. The simplest is break-even analysis and the most complex is risk analysis, which is particularly crucial with the cost of capital and its relation to risk and reward tending to be more sensitive. Regrettably, there is no short-cut method that allows for risk.³²

101. Risk in this context is defined as a situation where events can to some extent be quantified so that the probability that a specific investment will yield a certain return can be calculated. It offers, therefore a degree of certainty.

102. Uncertainty, on the other hand, is the more usual probability assignment where no statistical probability estimates are possible. It is characterized by unknown alternative outcomes which are not susceptible to repeated trials. Such situations involve forecasts concerned with unique events involving managerial decisions of the non-routine, non-programmatic type. By pooling experience and viewpoints of various disciplines and those from various managerial functions an informed or, rather, subjective probability can be expressed regarding possible alternative outcomes. The extent of the uncertainties may be reduced by either making advanced arrangements to deal with adversities or by substituting a less risky alternative for the one first considered, or in many other ways. It must be remembered though that careful planning against particular undesirable contingencies may be better than replacing a risky-looking outcome with a more timid alternative.³²

103. In 1969, the Consulting Engineers' Council³³ drew attention to the problems of decision making related to consulting engineers' professional liability and

to the nature of the engineer himself, and proposed there should be some understanding of decision making as a business process, with a willingness not to base decisions on experience accumulated years ago.

104. With the increasing pace of technological growth and change and with new requirements for organizational survival in the face of ever-intensifying international competition, firms in tomorrow's environment will need to raise their overall performance. This will entail more creative planning, the development of valid and useful knowledge of new techniques, a long-range commitment to change, and an increasing understanding of the criteria for effectiveness. Use of the quantitative approach will assist in evaluating the risks of planned change and the possibilities of conflict, while the courage to act boldly in the face of apparent uncertainty can be greatly bolstered by the clarity of portrayal of the risks and possible rewards.

105. The critical questions to be answered are: who will benefit from engineers not understanding management techniques, how will engineers respond to new technologies in their environment, and do other constraints exist which may prevent the full development of their potential? It should also be a goal of industry to come to a better understanding of the cost growth in cost risk.

Mr R. K. Corrie, W. S. Atkins & Partners

The Paper represents an excellent overview of a subject to which engineers do not normally apply themselves in their accustomed disciplined analytical way. However, in attempting to cover such a wide topic in a short Paper, it is perhaps inevitable that assumptions will be made on reader comprehension and familiarity with terminology which may not be valid.

107. Every day, at a personal level, individuals take project type decisions based on subconscious evaluation of risk. By subconsciously applying probability theory, we will calculate a different time allowed to catch the last train of the day than to catch the midday hourly service. In doing so we may ignore accident 'hazards' en route, or do we? In taking construction management decisions, the manager makes subconscious evaluations of risk in much the same way. It is the formalization of this process which the engineer finds most difficult to achieve.

108. In the introduction, the Paper refers to the difference between 'risk' and 'uncertainty' and in the synopsis dismisses 'hazard'. It would be helpful if the Authors could give their view of the commonly accepted definition of these terms. Inclusion of war and revolution in Table 1 as 'risk' rather than 'hazard' may be legitimate for a few countries but is perhaps misleading when getting to grips with the semantics of the subject.

109. Utility theory is clearly, if briefly, explained but I must admit that the significance of the numbers on the vertical axes of Fig. 6 was lost both on me and, at the outset, on my more specialist colleagues who make regular use of sensitivity and probability techniques as tools in their economic and project simulation models.

110. In commenting on management perspectives (§ 57), the Authors refer to the perceived dominant influence of people, machines and money in project decision taking. However, utility theory is the nearest the Authors get to considering the effect of people in the risk equation. Is there any research in progress towards assessing the magnitude of the people factor in risk assessment or is this regarded as too difficult an area?

111. Probability and Monte Carlo methods are frequently used by Atkins in

feasibility studies. For control of construction timing and cost, however, use of these techniques has been confined to large project strategic decision taking. Experience on the large projects has shown the value of concentrating on the frequent subcritical activities and the least defined activities. Very often, identifying risks for the initial analysis is in itself very beneficial.

112. Probabilistic analysis networks using Monte Carlo techniques involves greater effort, cost and computing power than deterministic methods. This is difficult to justify to promoters and project managers in the form of tangible benefits on small and medium sized projects. In the writer's organization, it is the availability of effort and cost factors, not the 'aura of mystique', which inhibits application of the techniques described. This has a chicken and egg effect. Management is not gaining the experience necessary to evaluate the applications or to develop the confidence needed to simplify the approach and reduce the cost. We are also hopeful that rapidly increasing power of cheap micro computing will change this situation.

Mr Perry and Mr Hayes

We thank all the contributors for amplifying and elaborating on items raised in the Paper. The need for a wider application of risk management and for a deeper understanding of its concepts and goals seems well supported.

114. We would agree with *Dr Barnes* and *Mr Norman* on the general tenor of their comments, while answering specifically their comment in § 90.

115. Both § 29 and Fig. 1 seem to have been open to misinterpretation, for which we apologize. We agree with *Dr Barnes* and *Mr Norman's* view that inaccurate estimates are more likely to be optimistic than pessimistic, but cannot provide data to support this. However, it is with this knowledge that the cost dispersion profiles shown in Fig. 1 may be useful. The assumption is that they will have been developed by the client as part of his pre-tender estimate. Consider the situation where the client's estimate suggests a cost dispersion similar to Profile 2. This may be because the client's estimator has taken a pessimistic view of the effects and ranges of risk or because the uncertainty of the work definition produces a low level of estimating confidence. A contractor's tender which is in or below the extreme low region of the client's cost profile should prompt searching questions prior to contract award. We suggest that the understanding of the work and its associated risk which the client will have gained from producing the cost dispersion profile would enable him to direct his questions to maximum effect. It should certainly enable him to reach a sound assessment of the contractor's appreciation of the risks allocated to him. It may also indicate a likely attitude to claims.

116. If *Dr Barnes* and *Mr Norman* are making the point that the client's use of such data is dependent more on managerial judgement than on statistics, then we would agree. Nevertheless, we believe a greater quantification of risk by the client should lead to a better quality of decision at the contract award and a better level of preparation for cost control during the contract.

117. A point made or implied by all the contributors bears repeating. It is that of the difficulty of estimating the range of uncertainty to be used in any analysis. The contributors all emphasize the problem of the human attitudes to risk, a problem we raised in §§ 57–59. Assessing the range of risk is difficult, and we would certainly agree with *Mr Corrie* that much of the benefit in risk analysis is the discipline of identifying the risks themselves (§ 111). The attitude of people towards risk is a factor of some importance in the assessment and response to risk, but this

area was intentionally discussed only briefly in our Paper. Utility theory is an attempt to quantify this and to treat an essentially subjective problem in an objective way.

118. In § 109, Mr Corrie seeks clarification of Fig. 6. It should be made clear that a utility curve indicates the unique risk response of an individual or corporation. The curves on Fig. 6 are indicative only. For instance, the risk averse curve is a generalization, which becomes unique in scale and shape to the individual only when specific points have been defined by him. The x axis indicates increasing amounts of money; the y axis the preference or desirability of that amount of money. The curve shows the relative preference for money values when faced with a decision which may have different financial outcomes. For example, consider the decision with a possible gain of +2 or a possible loss of -2. The risk neutral decision maker has a consistent attitude in that his preferences for the outcomes are equal. The risk seeker has a preference of +3 for the gain and -1.5 for the loss. The risk curve decision maker has a preference of +1.2 for the gain and -3 for the loss. In application, the values of a decision would be multiplied by the preference values obtained from the individuals' specific curve. The different risk attitudes of the decision takers are thereby quantified.

119. For further understanding of utility theory, readers are directed to the various texts on decision analyses, for example chapter 5 of reference 12. We do not know of research into assessing the magnitude of the people factor (§ 110), although we have in our research attempted to identify reasons why so little systematic assessment of risk is done. We hope to be able to amplify these reasons in a subsequent publication, but evidence so far would appear to contradict the experience of Mr Corrie (§ 112). Lack of understanding by management—of techniques, opportunity for use, and meaning of results—and lack of time to accomplish such analysis (particularly in contracting organizations at tender stage), appear to be far more important than cost. In general, once the purpose and benefits of risk management and analysis, including probabilistic analyses, have been perceived, cost does not seem to be a limiting factor.

120. Like Mr Corrie, we would accept that large projects are suitable for such analysis. However, the deciding factors in whether or not to use such techniques may not be the size of the project per se, but whether it is economically marginal or not, contentious or popular, high risk or low risk.

121. Again, like Mr Corrie, we see a future in the advent of powerful micro-computers. We have developed a risk analysis program, CASPAR, to run on a micro-computer,³⁴ from which Figs 3-5 were produced, and find that at the appraisal stage of a project, estimates of uncertainty can be rapidly made and the effects of these uncertainties seen.

122. The management resistance to risk management suggests a need for training. Mr Butler, in § 98, draws our attention to basic forecasting methods, and we agree that these techniques are an important part of project management and planning. We would go further, however, and suggest that such techniques are essential tools of project management. If basic forecasting techniques as stated are not being used within the construction industry, it only serves to reemphasize the need for training.

123. Failure to understand all these approaches, both the basic ones and the more advanced approaches listed in our Paper, only weakens the service the engineering profession offers to its clients; and it provides opportunity for other professions, as is inferred by Mr Butler.

124. Finally, perhaps a comment on the definition of risk and uncertainty. We did not distinguish between them intentionally as we considered it unhelpful (§ 3). We have adopted an approach which is different from that suggested by *Mr Butler* and indeed much of the literature. Our approach considers uncertainty as implying there is a known likelihood of variation in an event which will occur (such as resource productivity) and some degree of knowledge of the range (from historic data or prior experience); we consider risk as the effects of events which may or may not occur. In some of these cases, but not all, it may be very difficult to predict the impact of the event and its likelihood. Inevitably, the boundaries are unclear between uncertainty and risk, and risk and hazard (where the effect is out of all proportion to the event). For example, should delay at ports be defined as a risk or as an uncertainty? The event would be fully expected and a range of delay predictable from experience. However, the possibility of embargo is much more difficult to predict in terms of both likelihood and impact. We have chosen, so far, not to concern ourselves with the problems of precise definition and semantics, preferring to concentrate on the more practical aspects. Two of these, emphasized by *Mr Corrie* and *Dr Barnes* and *Mr Norman* respectively, appear to us to be considerably more important than precise definition. Firstly, that a major benefit derives from the identification of the sources of events which change predictions, because this yields a deep understanding of the project. Secondly, that the customer must be persuaded of the relevance and credibility of the assumptions made by the risk analyst.

125. In conclusion, the scope for further research, development of application methodology and training seems considerable, and the potential benefits in terms of greater realism of prediction and quality of decision making seem well worth the effort.

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