UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

COMMISSIONERS:

Victor Gilinsky, Acting Chairman
Richard T. Kennedy
Peter A. Bradford

In the Matter of **Docket Nos. 50-443**
50-444

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, et al.

(Seabrook Station, Units 1 and 2) **January 6, 1978**

Upon consideration of intervenors' requests for review of ALAB-422, 6 NRC 33 (1977), the Commission (1) agrees with the conclusion of the Licensing Board and Appeal Board majority that the applicants have reasonable assurance of obtaining the funds necessary to build the facility, but imposes a monitoring requirement on the staff with respect to the possible withdrawal of two participating companies; (2) affirms the Appeal Board decision to give binding effect to certain findings of the Environmental Protection Agency made pursuant to §316 of the Federal Water Pollution Control Act; and (3) rejects claims that the Appeal Board distorted the meaning of testimony in its factual findings. The Commission also directs (1) further staff studies of the effects of relaxing the Commission's standards for a stay so that site-related issues may be considered earlier, and of ways in which the Commission's appellate administrative procedures may assure earlier resolution of issues; and (2) initiation of a rulemaking proceeding in which the factual, legal, and policy aspects of the financial qualifications issue may be reexamined.

Appeal Board decision affirmed.

ATOMIC ENERGY ACT: SCOPE OF INFORMATION REQUIRED FOR LICENSING (FINANCIAL QUALIFICATIONS)

The Atomic Energy Act does not impose any financial qualifications requirement but merely authorizes the Commission to do so. The Commission's implementing regulations, 10 CFR Part 50, Appendix C, make clear

that the "reasonable assurance" concept embodied in that regulation is more flexible than many of the Commission's safety criteria. It does not normally contemplate refined analyses of an applicant's likely future ability to meet specific costs.

ATOMIC ENERGY ACT: SCOPE OF INFORMATION REQUIRED FOR LICENSING (FINANCIAL QUALIFICATIONS)

More detailed financial information may be required of a new corporate entity formed for the purpose of constructing the facility in question than from an established organization. 10 CFR §50.33(f) and Appendix C.

ATOMIC ENERGY ACT: SCOPE OF INFORMATION REQUIRED FOR LICENSING (FINANCIAL QUALIFICATIONS)

The "reasonable assurance" requirement of 10 CFR §50.33 contemplates actual inquiry into the applicant's financial qualifications. It is not enough that the applicant is a regulated public utility.

ATOMIC ENERGY ACT: SCOPE OF INFORMATION REQUIRED FOR LICENSING (FINANCIAL QUALIFICATIONS)

The "reasonable assurance" requirement of 10 CFR §50.33 means that the applicant must have a reasonable financing plan in the light of relevant circumstances.

ATOMIC ENERGY ACT: SCOPE OF INFORMATION REQUIRED FOR LICENSING (FINANCIAL QUALIFICATIONS)

Anticipated difficulties in raising funds are relevant to the reasonable assurance determination in connection with a financial qualifications inquiry, but a showing of some potential difficulty would not necessarily preclude that determination, all other relevant factors being taken into account.

ATOMIC ENERGY ACT: OWNERSHIP

A transfer of ownership of a utility's share of a nuclear power plant requires Commission approval. Section 184, Atomic Energy Act, 42 U.S.C. 2234.

NEPA: COST-BENEFIT BALANCE

The Commission may accept and use without independent inquiry the Environmental Protection Agency's determination of the magnitude of marine environmental impacts from the cooling system in striking an overall NEPA cost-benefit balance for the facility.

RULES OF PRACTICE: COLLATERAL ESTOPPEL

Where another agency has acted in a judicial capacity and resolved disputed issues of fact properly before it which the parties have had an adequate opportunity to litigate, the Commission will not hesitate to give *res judicata* or collateral estoppel effect to its findings "to enforce repose."

RULES OF PRACTICE: COLLATERAL ESTOPPEL

Although the judicially developed doctrines of *res judicata* and collateral estoppel are not fully applicable in administrative proceedings, the considerations of fairness to parties and conservation of resources embodied in them are relevant. *Houston Lighting and Power Company* (South Texas Projects, Units 1 and 2), CLI-77-13, 5 NRC 1303, 1321 (1977).

NEPA: FINAL ENVIRONMENTAL STATEMENT

Where the Environmental Protection Agency has decided to change the location of a water intake structure in order to mitigate environmental impacts, reliance by the Commission on such decision without circulating for comment a supplemental impact statement reflecting the change does not violate the National Environmental Policy Act.

RULES OF PRACTICE: AUTHORITY OF APPEAL BOARD

The Commission or an appeal board has authority to modify or set aside findings made by a licensing board. 10 CFR §§2.740(b), 2.785.

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Ms. Karin P. Sheldon, Washington, D.C., for the intervenor, New England Coalition on Nuclear Pollution.

Mr. Robert A. Backus, Manchester, New Hampshire, for the intervenors, Seacoast Anti-Pollution League, the Audubon Society of New Hampshire, and the Society for the Protection of New Hampshire Forests.

Ms. Ellyn R. Weiss, Washington, D.C., Counsel for the Commonwealth of Massachusetts.

Mr. Richard C. Browne (with whom **Ms. Marcia E. Mulkey** was on the briefs), for the Nuclear Regulatory Commission staff.

MEMORANDUM AND ORDER

In March 1973, Public Service Company of New Hampshire (PSCO) and several other New England utilities jointly applied to the Atomic Energy Commission for permission to build a two-unit nuclear electric generating station near the New Hampshire seacoast in the town of Seabrook. After extensive and vigorously contested hearings, the Atomic Safety and Licensing Board, by a divided vote, authorized issuance of construction permits in the summer of 1976. LBP-76-26, 3 NRC 857 (1976). Construction work commenced shortly thereafter and is taking place at the present time.

This case is now before us for the third time.[1] Our most recent consideration of the matter involved review and affirmance of the Appeal Board's action early last year staying the effectiveness of the construction permits because the uncertainty surrounding the type of cooling system that would ultimately be required by the Environmental Protection Agency made it impossible to strike a cost-benefit balance under the National Environmental Policy Act. As we noted at that time, numerous exceptions to the Licensing Board's decision were then still pending before the Appeal Board. In the interim, the EPA has acted on the cooling system question and, with one exception,[2] the Appeal Board has resolved the remaining

[1] *Public Service Company of New Hampshire, et al.* (Seabrook Station, Units 1 and 2), CLI-77-8, 5 NRC 503 (March 31, 1977); *Public Service Company of New Hampshire, et al.* (Seabrook Station, Units 1 and 2), CLI-76-17, 4 NRC 451 (1976).

[2] There are pending before the Board exceptions to the Licensing Board's July 1977 Supplemental Initial Decision concerning southern New England sites. LBP-77-43, 6 NRC 134. The Board deferred that matter pending the Licensing Board's completion of a comparative analysis of Seabrook with other sites on the assumption that cooling towers will be employed. That analysis has now been completed, and the Appeal Board will proceed with consideration of both issues.

issues before it. We will summarize these and other intervening events to place the present review in context.

In November 1976, the EPA Regional Administrator withdrew his earlier approval of once-through cooling for Seabrook. That decision was reversed by the EPA Administrator in June 1977. In his June decision, discussed more fully below, the Administrator found that the impacts on the ecology of the ocean areas near the underwater intake and discharge structures of the proposed once-through cooling system would be small. He therefore approved the applicants' request for an exemption from EPA's closed-cycle cooling requirement. That decision removes the "considerable doubt ... as to the cooling system required for the Seabrook facility"[3] that prompted us in March to affirm the Appeal Board's suspension of the Seabrook construction permits. Unless the EPA Administrator's decision is modified or reversed,[4] we know what kind of cooling system will be built at Seabrook and the environmental impacts estimated from that system.

In late July 1977, the Appeal Board rendered two decisions: ALAB-422, 6 NRC 33, resolving all but one of the pending exceptions to the Licensing Board's decision; and ALAB-423, 6 NRC 115, granting the applicants' motion to reinstate the previously suspended construction permits. Construction resumed shortly thereafter. Timely petitions to review ALAB-422 were filed by the applicants and the New England Coalition on Nuclear Pollution ("NECNP"). We denied the applicants' petition and granted in part that of NECNP. Review was granted on the four issues discussed below: the applicants' financial qualifications, the effect of the EPA determinations of aquatic environmental impacts, alleged distortions of the record by the Appeal Board, and the presumptive validity of a recent supplemental initial decision of the Licensing Board concerning alternative sites.[5] On November 4, after visiting the Seabrook site and hearing oral argument, we denied a motion by NECNP for a further stay of construction pending completion of our review.

When this case was argued before us, different aspects of the Seabrook project were being considered by an atomic safety and licensing board, an atomic safety and licensing appeal board, the Commission itself, and the United States Court of Appeals for the First Circuit. Furthermore, each of the NRC levels of review had already issued at least one major decision in the case, as had two separate reviewing levels within the Environmental

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[3] 5 NRC 503, *supra*, at 509.

[4] The validity of that decision has been challenged in Federal court, where a decision is pending. *SAPL* v. *Costle*, No. 77-1284 (1st Cir.).

[5] See note 2, *supra*. We also extended the time for review on the seismic issue until Mr. Farrar renders the further dissenting opinion promised in his partial dissent from ALAB-422.

Protection Agency. The First Circuit Court of Appeals, in an unpublished order denying a motion for a stay of construction at Seabrook, said of this process:

> We are unable to identify any other field of publicly regulated private activity where momentous decisions to commit funds are made on the strength of preliminary decisions by several agencies which are open to reevaluation and redetermination. The risk of loss to the private investors is necessarily a real and always present one. Perhaps more important to the public weal, the risk of public agencies and courts accepting less desirable and limited options or, worse, countenancing a *fait accompli* are foreboding.[6]

We ourselves expressed serious concern with the Seabrook proceeding in our last opinion:

> This case has been widely depicted as a serious failure of governmental process to resolve central issues in a timely and coordinated way—a paradigm of fragmented and uncoordinated government decisionmaking on energy matters and of a system strangling itself and the economy in red tape.[7]

Many of the difficulties with the Seabrook case have resulted from the lack of coordination between the EPA in exercising its FWPCA responsibility and the NRC in carrying out its NEPA obligation. The framework for improved coordination now exists[8] and is being implemented in licensing proceedings now underway. We can therefore expect that this aspect of the Seabrook case is unlikely to recur.

However, there are other areas where jurisdiction is not clear and where interagency coordination is yet to be achieved. And there are problems in our licensing process itself.

Steps are now being taken which should go a long way toward assuring that the problems of the Seabrook case do not recur in future licensings. For example, early site review should eventually relieve the process of many of its pressures. Meanwhile, however, our rule giving immediate effectiveness to our Licensing Board's grant of a construction permit and our stay rule often operate together to assure that Commission-level review will not take

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[6] *Audubon Society of New Hampshire* v. *United States,* No. 76-1347 (December 17, 1976).

[7] 5 NRC 503, 509.

[8] "Second Memorandum of Understanding and Policy Statement Regarding Implementation of Certain NRC and EPA Responsibilities," 40 Fed. Reg. 60115, effective January 1, 1976.

place until such time as construction is well underway.[9] This case illustrates the need to develop a procedure for assuring early Commission-level review of controverted licensing proceedings, where appropriate, particularly where siting is an issue. Consequently, we intend to develop a process which will allow the Commission to monitor more effectively the proceedings of its lower boards.

We have also decided to initiate a study addressing but not necessarily limited to:

1. the effect which would be achieved by relation of our stay standards so that site-related issues in potentially troublesome cases may be taken up before large sums of money are committed and sites are irrevocably altered, and
2. ways in which our appellate administrative procedures may assure earlier resolution of all the issues arising out of a licensing and cut relitigation and piecemeal review to a minimum.

We therefore direct our Office of Policy Evaluation and our General Counsel to prepare a draft scope of work for this review for consideration by the full Commission. We take no larger step at this time because the generic problems illustrated by the experience of Seabrook should be addressed by the full Commission. Chairman Hendrie has disqualified himself from this proceeding because of his earlier involvement with the Seabrook application as Deputy Director for Licensing and Technical Review of the Atomic Energy Commission.

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[9]At oral argument the Commission requested that the parties discuss the possibility of a remand on the issue of financial qualifications, and whether a stay would then be appropriate. The applicant answered in the negative to both questions. Commissioner Bradford then asked:

> If we followed that logic as far as one can take it, would it be possible to actually complete construction of a nuclear plant, say, the Seabrook nuclear plant, while the agency still had the construction permit under review?

To which the applicant responded:

> Yes. I think it is going to happen in Midland. Maybe you won't have it under review, but the Supreme Court or somebody will. This is the reason you have had the rule, and have had it since time immemorial, that you give out the permits.... The Board authorizes them and you get them.
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> The Commission review, the way we are going, is someday going to be going on, I think, when a plant is completed.

See Transcript pp. 153-154.

I. FINANCIAL QUALIFICATIONS

Introduction

The Licensing Board, unanimously, and the Appeal Board, by a divided vote, determined that the applicants had the requisite "reasonable assurance" of obtaining the necessary funds to cover the construction of Seabrook. The Commission's order granting review on this issue asked the parties to review the nature of the Commission's responsibilities under the Atomic Energy Act with regard to the financial qualifications of applicants and, more narrowly, to assess the state of the evidence in the present record on the financial qualifications issue. The discussion of these heretofore largely unexplored issues[10] has shown the comparative vagueness of current NRC requirements and the speculative character of financial qualifications inquiries concerning complex, costly and long-term construction projects. Our independent assessment of the record in this case leads us to agree with the conclusion of the Licensing Board and of the Appeal Board majority—that there is a "reasonable assurance" that these applicants are financially qualified.[11] We describe hereafter the reasoning that leads us to that conclusion.

A. The Atomic Energy Act and Implementing Regulations

The Atomic Energy Act of 1954 provides in Section 182.a that:

> Each application for a license hereunder ... shall specifically state such information as the Commission, by rule or regulation, may determine to be necessary to decide such of the technical and financial qualifications of the applicant ... as the Commission may deem appropriate for the license. 42 U.S.C. § 2232(a).

[10]Prior to 1973, when many utility applicants first began to experience substantial difficulties in raising large sums for capital investments, an applicant's financial qualification was rarely a contested issue. To date, the question has been litigated in relatively few cases. See *Power Reactor Development Corporation,* 1 AEC 128, 150 (1959). In *Northeast Nuclear Energy Company* (Millstone 3), the Licensing Board found that a 3.694% participant possessed only "marginal" financial qualifications; its earnings had plummeted, and Moody's Investors Service had withdrawn its ratings of all of the utility's outstanding first mortgage bonds. LBP-74-58, 8 AEC 187 (1974). Despite the weakness of this participant, the Licensing Board found that the applicant possessed the necessary financial qualifications. The Appeal Board endorsed the Licensing Board's findings, and observed that if the participant had owned a substantially larger share of the facility, such as the 40% interest of another participant, the applicant's financial qualifications would have been "doubtful." ALAB-234, 8 AEC 643 (1974).

[11]We note, however, that two of the present participants may withdraw from the project, and we are therefore imposing a monitoring requirement on the staff, as we describe below.

The legislative history is silent as to the purpose of the financial qualifications showing. However, the statute itself does not impose any financial qualifications requirement; it merely authorizes the Commission to impose such financial requirements as it may deem appropriate.

The Atomic Energy Commission adopted the relevant financial qualifications implementing regulation in 1968:[12]

> Each application shall state ... [i]nformation sufficient to demonstrate to the Commission the financial qualifications of the applicants to carry out, in accordance with the regulations in this chapter, the activities for which the permit or license is sought. If the application is for a construction permit, such information shall show that the applicant possesses the funds necessary to cover estimated construction costs and related fuel cycle costs or that the applicant has *reasonable assurance* of obtaining the necessary funds, or a combination of the two. 10 CFR §50.33(f). (Emphasis added.)

The regulations are amplified by Appendix C to 10 CFR Part 50, which sets forth guidance on the financial data required of license applicants. The appendix makes clear that the "reasonable assurance" concept embodied in the regulation is more flexible than many of the Commission's safety criteria.[13] It states that:

> The kind and depth of information described in this guide is not intended to be a rigid and absolute requirement....
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> * * * * *
>
> In determining an applicant's financial qualifications, the Commission will require the minimum amount of information necessary for that purpose. No special forms are prescribed for submitting the information. In many cases, the financial information usually contained in current annual financial reports, including summary data of prior years, will be sufficient for the Commission's needs.

Appendix C goes on to specify the information to be furnished by applicants. For established organizations, like the utilities involved here, the applicant is required to submit estimates of construction costs, a "brief statement of the applicant's general financial plan for financing the cost of

[12]Prior to 1968, the Commission's regulations provided only that applications should state: "(f) The financial qualifications of the applicant to engage in the proposed activities in accordance with the regulations in this chapter." 10 CFR §50.33. The regulations offered no guidance as to how financial qualifications were to be demonstrated.

[13]See, for example, the highly quantified criteria for emergency core cooling systems in Part 50, Appendix K.

the facility, identifying the sources upon which the applicant relies for the necessary construction funds," its latest published annual financial report, and any pertinent interim financial reports. More detailed information may be required of a new entity formed for the purpose of constructing the facility in question.[14]

The history of the adoption of Appendix C also indicates that the "reasonable assurance" requirement is not rigid and that it does not normally contemplate refined analyses of an applicant's likely future ability to meet specific costs. The adoption of Appendix C in its present form followed the proposal and withdrawal of an earlier version. As the statement of considerations reflects, the appendix finally adopted eliminated much of the detail of the original proposed version. A comparison of the two is instructive.

Appendix C as first proposed in June 1967 would have required applicants for reactor construction permits, whether established utilities or entities formed specifically for the purpose of building a plant, to submit highly detailed information to the Commission. See 32 Fed. Reg. 8423. Cost projections of considerable specificity and detail were to be provided, to permit an item-by-item evaluation of the reasonableness of the estimates. Analyses of sources of funds of each applicant were to be similarly detailed, also on an item-by-item basis. The guide provided that "the capability or reasonable assurance of each source to produce its assigned portion of the estimated fund requirements should be demonstrated."

In July 1967, the first proposed version of Appendix C was withdrawn. 32 Fed. Reg. 10816. In response to a query from the Executive Director of the Joint Committee on Atomic Energy, the Director of Regulation explained the Commission's action. In a letter dated August 25, 1967, which was entered in the public docket file, the Director stated that:

> After publication, and as a result of questions about the purpose of the guide, we carefully re-reviewed it and concluded that it would call for substantially more information in scope and detail than is likely to be necessary, particularly in the case of operating utilities with a history of financial stability.

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[14]The introduction to Appendix C states that:

> It is important to observe also that both §50.33(f) and this appendix distinguished between applicants which are established organizations and those which are newly formed entities organized primarily for the purpose of engaging in the activity for which the permit or license is sought. Those in the former category will normally have a history of operating experience and be able to submit financial statements reflecting the financial results of past operations. With respect, however, to the applicant which is a newly formed company ... somewhat more detailed data and supporting documentation will generally be necessary.

> In rewriting the guide we are attempting to bring into sharper focus and detail the difference in the kind and detail of information to be required of an applicant with an established operating history as distinguished from the applicant which is a newly formed entity....

This history suggests that for established utilities with substantial operating records, close scrutiny of financial qualifications was not viewed as necessary to assure that financial considerations did not compromise safety.

The statement of considerations accompanying the final rule and Appendix C states:

> Although the Commission's safety determinations required for the issuance of facility licenses are based upon extensive and detailed technical review, an applicant's financial qualifications can also contribute to his ability to meet his responsibilities on safety matters. 33 Fed. Reg. 9704.

As will be seen, much of the controversy in this case concerns just how this declared relationship between financial qualifications and safety applies in practice to a regulated public utility.

B. The Review of Financial Qualifications in This Case

Before a case proceeds to hearing, the NRC staff prepares its analysis of the applicant's financial qualifications, based on extensive data submitted by the applicant. Here, the NRC staff, assisted by a consultant, considered the information and the proposed financial plan submitted by each of the applicants and concluded they had demonstrated the requisite financial qualifications.[15]

The transcript of the Seabrook hearing documents an exhaustive examination of the financial qualifications issue: six days of testimony and cross-examination were devoted to the issue; the transcript of this portion of the hearing occupies more than 1,300 pages, exclusive of exhibits; ten expert witnesses appeared. Appearing in support of the applicants' qualifications were the senior financial analyst of the NRC staff and the consultant who together prepared the staff evaluation; the financial vice-president of PSCO; and a vice-president of PSCO's financial consulting firm. The intervenor NECNP presented in opposition to the application a professor of business administration and a professor of economics. Intervenor Donald B. Ross called an insurance company investment officer and officials of three other utility participants. The witnesses were cross-examined extensively.

[15]This analysis appears in the record in Supplement No. 3 to the Safety Evaluation Report.

The witnesses presented detailed testimony on such areas as: construction costs; sources of funds; the health of the utility industry generally and of the applicants in particular; the state of the bond market and the likely marketability of PSCO bonds under different assumptions; the reasonableness of PSCO's assumptions with regard to the projections of other applicants; the history of rate actions by the New Hampshire Public Utilities Commission (PUC); the upturn in the market price of PSCO stock following the favorable PUC action in December 1974 granting PSCO a 14% return on equity; and financing practices in the utility industry, including allowance for funds used during construction (AFUDC) and construction work in progress (CWIP). The financial qualifications inquiry here appears to have been the most searching examination of this question in the history of commercial power reactor licensing. The testimony of the witnesses presented by the applicants and the staff supported the conclusion of a "reasonable assurance" regarding financial qualifications. Intervenors' witnesses disputed that conclusion, contending not that the necessary funds could not be raised, but that the applicants would experience difficulty in raising them.

D. The Decision of the Licensing Board

The Licensing Board rendered its decision authorizing issuance of construction permits for the Seabrook facility in June 1976. The three members of the Board were in agreement on detailed findings of fact leading to the conclusion that the applicants were financially qualified to construct the facility. 3 NRC 857.

The Licensing Board's Supporting Opinion included a discussion of the major facts and reasoning underlying its conclusion. It noted that the controversy centered on the ability of PSCO to raise some $800,000,000, a sum twice the total assets of the company as of December 31, 1974. The Board observed that while PSCO had raised a comparable proportion of its assets in a comparable period of time—167% of its assets in the eight-year period 1967 through 1974—the company had then enjoyed a Moody's bond rating of A. In February 1974, Moody's had derated PSCO's bonds to Baa, and PSCO's common stock, like that of many other utilities, had declined to substantially below book value between 1973 and 1975. During that time, the company had been involved in a protracted rate proceeding.

The Licensing Board also noted, however, that during the previous two years an unusual combination of tight money, recession, inflation, and the energy crisis had increased fuel costs and other expenses rapidly and had impaired utilities' fund-raising for all purposes, including plant construction.

It also observed that PSCO's earnings had begun to improve since the approval of its requested rate increase. The Board concluded that "the preponderance of the expert testimony in this case is that the necessary funds will be forthcoming from the market although the cost of money may be higher than originally projected to PSCO."[16] 3 NRC at 917.

The Licensing Board hearings on the financial qualifications issue concluded in June 1975. In December of that year, Northeast Utilities, the parent company of Connecticut Light and Power Company, announced its intention to sell its entire 11.98% share of the Seabrook project. At the same time, the United Illuminating Company indicated its desire to sell half of its 20% interest in Seabrook. On the basis of these developments SAPL-Audubon moved to reopen the evidentiary proceedings on financial qualifications, need for power, and the overall cost-benefit balance for the facility.

In February 1976, the Licensing Board granted the motion with regard to need for power, noting that Northeast Utilities had publicly stated that one reason for its decision to sell its share of Seabrook was "changes ... in the long-range capacity and energy needs of NU's service area and of New England as a whole." Memorandum and Order at 8. The Board reserved judgment on whether to reopen the cost-benefit balance issue pending the outcome of the need for power inquiry. As to financial qualifications, the Licensing Board declined to reopen stating that it found no evidence that the applicants could not meet their financial obligations for the Seabrook project. It further reasoned that the Commission's regulations, under which any change in ownership requires an amendment to the construction permit and is subject to full adjudication, provided adequate protection of the public interest.

E. The Appeal Board's Divided Decision

1. The Majority View

The Board majority, Chairman Rosenthal and Member Buck, affirmed the Licensing Board's conclusion that the applicants were financially qualified. The majority observed that central elements in the intervenors' contentions were the undisputed facts that in February 1974 the Moody's

[16]Whereas PSCO had originally projected that it would issue bonds at 8%, its revised source of funds sheet raised this figure to 12%.

rating of PSCO bonds fell from A to Baa,[17] and that between 1974 and 1976, the price of the company's stock declined to substantially below book value. The Board noted, however, that the Licensing Board had recognized these facts, as well as the fund-raising efforts which would be required of PSCO. Balanced against these considerations were favorable factors, including the company's fund-raising ability as demonstrated between 1967 and 1974; the higher rate of return allowed the company by the New Hampshire PUC's decision; the "possibility" that PSCO would regain its A rating from Moody's; and the extensive sales of Baa utility bonds in the first months of 1975. The majority quoted with approval the Licensing Board's discussion of the financial condition of utilities and the improving economic and regulatory climate. 6 NRC at 76.

The majority discussed at some length the intervenors' attack on the Licensing Board's decision, insofar as it had given weight to the prospect of future rate increases. The majority declared that:

> These claims lose sight of one undeniable fact: the applicants here are public utilities which are under an obligation to render a public service and which are regulated by state regulatory bodies. Those bodies have considered and approved the Seabrook facility.... Given these considerations, it is scarcely likely that the PUC would stand in the way of the establishment of those rates necessary to enable Public Service to fulfill the obligations imposed upon it by its nuclear facility licenses. 6 NRC at 77.

The Appeal Board majority also pointed to the recent history of the New Hampshire PUC in granting rate relief to PSCO. In the circumstances, the Board concluded that:

> ... it was not improper for the applicants to have supported their showing of financial qualifications *in part* by relying on future, not-yet-obtained rate increases. And it was not error for the Licensing Board to

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[17]The Board cited Moody's explanation of its rating system:

Bonds which are rated A possess many favorable investment attributes and are to be considered as upper medium grade obligations. Factors giving security to principal and interest are considered adequate but elements may be present which suggest a susceptibility to impairment sometime in the future.

Bonds which are rated Baa are considered as medium grade obligations, *i.e.*, they are neither highly protected nor poorly secured. Interest payments and principal security appear adequate for the present but certain protective elements may be lacking or may be characteristically unreliable over any great length of time. Such bonds lack outstanding investment characteristics and in fact have speculative characteristics as well. ALAB-422, 6 NRC 33, at 76, n. 49.

have *accorded weight* to the prospect of such future rate increases. 6 NRC at 78 (emphasis added).

The Appeal Board majority next considered the intervenors' claim that the increased cost of the project and the two utilities' plans to sell portions of the facility indicated that applicants would face greater difficulty than earlier anticipated in financing Seabrook. The majority observed:

> This all well may be true. But it does not perforce undermine the conclusion below that the applicants are financially qualified.... Certainty need not be shown and all contingencies need not be foreseen. 6 NRC at 79.

The majority noted that none of the intervenors' witnesses had contended that, even with rising capital costs, the applicants would be *unable* to obtain the required funds. Reviewing the record before the Licensing Board, the majority noted that while one witness for NECNP had foreseen problems for the utility in raising funds, he had declined to predict that funds could not be raised. The Board found that his testimony, like that of the intervenors' other two witnesses on the financial qualifications issue, was that fund-raising would be more "difficult and expensive" than had been projected by the applicants. The Board continued:

> That being so, it is unnecessary for us to consider here the particular strengths and weaknesses of each witness' testimony. For the financial qualifications inquiry contemplated by the Commission's regulations centers upon whether the funds can be obtained and not on the price of or difficulty in obtaining them. 6 NRC at 79.

The Appeal Board majority also considered and rejected intervenor contentions, earlier rejected by the Licensing Board, that developments following the hearing warranted a reopening of the financial qualifications inquiry.[18]

[18] These developments were the announcement of two utilities' plans to sell portions of the Seabrook facility and alleged inconsistencies between the testimony of a PSCO witness before the Licensing Board and his subsequent testimony to the FPC and to a committee of the New Hampshire legislature. As to the sale of ownership interests, the Board found no suggestion that either of the two utilities in question intended to breach its obligation under the Joint Ownership Agreement to continue financial participation in Seabrook "unless and until" the Commission issued a license amendment approving the substitution of other participants. Nor did the record suggest that either utility was not financially qualified to meet its obligations, should it be unable to find a financially qualified purchaser. The majority analyzed the alleged inconsistent statements in some detail and, while rebuking the practice, determined that they did not "undercut the conclusions we have reached on the basis of the record adduced below."

2. Member Farrar's Dissenting Views

Dissenting from the ruling of the majority on financial qualifications, Member Farrar viewed that holding as adopting the "singular principle ... that a large utility company which has received the approval of its State regulatory agency should, on that ground alone, be conclusively presumed by this Commission to be financially qualified." 6 NRC 106. He found a "superficial appeal" in the principle assertedly adopted by the majority, stating that in the case of a nonnuclear facility, he would be willing to endorse it. But, as he viewed the matter, "this is a nuclear power plant, and that makes a difference." 6 NRC at 108.

Stating that the majority's position rendered the financial qualifications inquiry "virtually meaningless," Mr. Farrar declared that an applicant's duty to prove itself capable of constructing the plant in a manner consistent with the Commission's safety goals

> means that there is a need to avoid a situation in which financial pressures on an applicant become so pervasive as to influence the manner in which the plant is constructed. If the struggle to obtain funds becomes too difficult, even the most safety-conscious utility company might succumb and, in its efforts to reduce costs, end up cutting corners in constructing the plant.

His assessment of the evidence in this case showed that "at best, the lead applicant would have a long, difficult and costly struggle" obtaining the outside capital necessary to finance its share of the plant. As he saw it, "an applicant must show that it will be able to obtain funds in ready enough fashion to avoid the likelihood that temporary shortages may compromise safety [footnote omitted]. The applicants have not shown this here. It invites disaster to overlook it." 6 NRC at 110.

Mr. Farrar went on to assert that the Licensing Board erred in refusing to reopen the record to examine the announced desire of the two Connecticut utilities to sell interests aggregating 22% of Seabrook. This development, in his view, "cried out for further investigation," since it was "not unheard of" even for parties able to honor their contractual agreements to decide that it was in their interest not to do so. 6 NRC at 110.

F. Contentions of the Parties

In their briefs and at oral argument, the NRC staff argued for affirmance of ALAB-422, contending that the decision of the Appeal Board majority rested not only on assumptions as to the likelihood of favorable rate action by the New Hampshire PUC but also on the extensive record before

the Licensing Board, including the staff's analysis of the applicants' financial qualifications. In effect, staff takes the position that "reasonable assurance" of obtaining the funds necessary for construction means that the applicant has demonstrated that it has a reasonable financing plan.

The applicant also urged affirmance on similar bases, and on the theory that public utility commissions must be presumed to discharge their duties responsibly (*i.e.*, granting rate increases when justified), and that for regulated public utilities, the financial qualifications inquiry should therefore focus solely on regulatory climate.[19] The fact that a utility is publicly regulated would therefore be sufficient proof of its financial qualifications, unless the state public utilities commission were shown to be derelict in its duty to grant needed rate increases.[20] Arguing against a linkage of financial qualifications and safe construction, the applicants contended that attempts by a utility to cut corners on safety-related construction would be both contrary to its long-run financial interests and certain of detection by the Commission's inspectors.[21]

Intervenors NECNP, SAPL-Audubon, and Massachusetts urge us to reverse the Appeal Board majority. All three agree with Mr. Farrar that applicants have failed to demonstrate their financial qualifications to build the plant, focusing much of their attack on the weight accorded by the majority to the prospect of favorable rate action by the New Hampshire PUC. Pointing to difficulties PSCO has experienced in the past in obtaining rate relief from the PUC, they contend that no weight whatsoever may be accorded to the prospect of future rate increases. The intervenors argue, in essence, that our present regulation assumes a direct and significant relationship between the safety of an applicant's construction practices and its financial condition, and that therefore only a financially strong utility—its stability to be demonstrated with considerable certitude—should be found qualified to build a nuclear power plant.[22]

G. Financial Qualifications on the Record of this Case

The divergent contentions must be measured against our existing regulation. Given the record in this case, we need not define the precise relationship between safety and financial qualifications for we are satisfied that the applicants' financial condition presently provides "reasonable assurance of obtaining the necessary funds." Further exploration of these generic

[19]Applicant's brief at 12, n.9, and 25.
[20]Transcript of oral argument at 70.
[21]Applicant's brief at 23.
[22]Transcript of oral argument at 18.

issues—presumably applicable to all commercial nuclear plants—should be undertaken in rulemaking, with its broader opportunities for interested public and industry participation.

The "reasonable assurance" requirement of 10 CFR §50.33 does, however, contemplate actual inquiry into the applicants' financial qualifications. It is not enough that the applicant is a regulated public utility. On the other hand, given the history of the present rule and the relatively modest implementing requirements in Appendix C,[23] a "reasonable assurance" does not mean a demonstration of near certainty that an applicant will never be pressed for funds in the course of constructon. It does mean that the applicant must have a reasonable financing plan in the light of relevant circumstances.

As we noted earlier, the statement of considerations accompanying adoption of the present regulation stated that "an applicant's financial qualifications can ... contribute to his ability to meet his responsibilities on safety matters." While unexceptionable in the abstract, this proposition is less compelling in the case of a regulated public utility engaged in a construction project which is itself subject to high safety standards and ongoing inspection. No facts in the rulemaking record underlying the present regulation either support or negate the asserted link between financial qualifications and safety. Nor is there evidence in the present record that the applicants would be likely to engage in substandard construction should they ever run short of funds.

In the absence of any demonstrated direct connection between financial qualifications and safety in the utility industry—either generally or in this case in particular—we are left with the essentially speculative claims of the parties. It is not enough to say, as the applicant suggests, that failure to adhere to rigid safety standards is unlikely because this would be contrary to the applicant's self-interest. To be sure, applicants have a near-term interest in avoiding possible civil penalties and adverse publicity arising out of safety violations, and a long-term interest in building a safe, reliable plant. Nevertheless, nuclear safety regulation is premised on a system of multiple and redundant safety measures. The "reasonable assurance" requirement was adopted to assure that financial conditions did not compromise the applicant's clear self-interest in safety.

Counsel for Massachusetts expressed concern not so much with deliberate efforts to depart from safety standards, but rather with financial difficulties that might lead utility personnel, as a matter of human nature, to view potential safety problems with less seriousness than might otherwise be the case.[24] However, recent experience does not suggest that a utility

[23]See text accompanying n. 10, *supra*.

[24]Transcript of oral argument at 150.

short of funds will cut corners on safety. In the past few years, many utilities in the process of constructing nuclear facilities have experienced unforeseen financial difficulties. Common responses have been to slow down construction or to suspend construction altogether.[25] Such a response is not surprising in view of the fact that the sums involved in the process of building a nuclear power plant, even over a relatively short segment of the whole process, can run to the tens of millions, amounts far exceeding the comparatively small sums a utility might expect to save by cutting corners in construction.

These speculative and conflicting considerations do not support our reading the stringent test of financial qualifications urged by the intervenors and Mr. Farrar into the present regulation. And apart from the seemingly tenuous link between safety and financial qualifications, particularly for a large regulated utility, other considerations lead us to believe that a utility cannot provide more than a reasonable assurance that funds will be available through the course of a multiyear construction project. The number of variables—such as interest rates, the state of the stock and bond markets, the regulatory climate and the cost of fuel—that operate over the period required to construct a nuclear plant make financial forecasting over a ten-year period uncertain.

The resulting limited usefulness of the financial qualifications inquiry underscores the importance of ongoing inspections of reactor construction projects. Our Office of Inspection and Enforcement monitors the quality assurance programs of licensees and samples of the actual work performed by contractors and subcontractors. The Commission's inspection force has increased substantially over the past several years. On the basis of inspector field reports, the Commission can bring and has brought construction to an immediate halt when deficient practices indicated a safety problem.[26] The Commission is presently prepared to implement a plan under which resident NRC inspectors will be assigned to plants in the later stages of construction and to operating facilities. The quality and extensiveness of the Inspection and Enforcement effort is such that any significant pattern of unsafe cost-cutting should be detectable and would be dealt with appropriately.

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[25]See Nuclear Power Plant Licensing: Opportunities for Improvement, NUREG-0292 (June 1977) at 3-1; C. Behrens, The Role of Licensing in Nuclear Power Plant Construction Times, Congressional Research Service (October 20, 1977).

[26]In *Consumers Power Company,* in which a licensee objected that the Director of Regulation had acted illegally in halting construction upon finding a pattern of deficient cadwelding, the Commission declared that where the public health, interest, or safety is involved, "a show cause proceeding—contemplating possible suspension, revocation or other appropriate action following a hearing—may be instituted without notice, and the order may be made effective immediately pending the hearing." CLI-74-3, 7 AEC 7, 10 (1974).

We need not undertake here any further examination of the nature and extent of the relationship between financial qualifications and safety, nor need we attempt a more precise determination of the standards by which financial qualifications should be judged. We are, however, directing the staff to initiate a rulemaking proceeding in which the factual, legal, and policy aspects of the financial qualifications issue may be reexamined.

Our determination that the generic issues raised in this proceeding require further exploration does not prevent our resolution of the case before us. Our review of the extensive record summarized earlier persuades us that the Licensing Board and the Appeal Board majority were correct in finding that the applicants possessed the requisite "reasonable assurance" of the funds necessary to construct the Seabrook facility. Based on our review of the original and revised source of funds sheets and the prospect of future rate increases, we believe that the Licensing Board was correct in finding that the applicants' financial plans should generate the necessary construction funds. Although the bond rating of the lead applicant has fallen to Baa, there is no evidence that a bond offering at that rating would be unsaleable.[27] The witnesses who testified were in general agreement that the lead applicant would be able to raise the funds necessary to build the plant, although the cost of financing would be higher than it had originally projected. And the cost record shows, among other things, that the New Hampshire Public Utilities Commission has granted the lead applicant a 14% rate of return on equity and has indicated its present intention to provide PSCO with the rate relief it needs in order to build the plant. We conclude that on the record before us, taken as a whole, the applicants have reasonable assurance of obtaining the funds necessary to build the plant, within the meaning of present requirements.

Our holding today rests on the factual record of this case, which does justify consideration of the prospect of future rate increases. Although speculative, this factor is no more speculative than numerous other factors, such as future interest rates, which should be taken into account. Though this factor received inordinate emphasis in the majority opinion, the Appeal Board discussed other elements in the record as well, notably the applicant's bond ratings and its fund-raising history.

The division between the majority and dissent focused in part on the concept of "difficulty." The majority asserted concern should center on "whether the funds can be obtained and not on the price of or difficulty in obtaining them." 6 NRC at 79. The dissent countered that difficulty in raising funds was precisely the circumstance in which corner-cutting was likely to occur. 6 NRC at 108.

[27] It was pointed out at oral argument that twelve other utilities licensed by the Commission are rated Baa by Moody's. Transcript of Oral Argument at 76.

Both majority and dissent presumably would agree that at a certain point, an applicant could face so much difficulty in obtaining funds that the likelihood of its being able to finance the plant would fall below the level of "reasonable assurance." They appear to differ on what is "reasonable"; the majority would establish a low threshold to satisfy the "reasonable assurance" standard, while the dissent urges an exacting standard. As we have indicated, we believe that the correct approach falls between the majority and dissent. Anticipated difficulties in raising funds are relevant to the reasonable assurance determination, but a showing of some potential difficulty would not necessarily preclude that determination, all other relevant factors being taken into account.

Shortly before oral argument, counsel for SAPL-Audubon wrote to the Commissioners, enclosing a document consisting of excerpts of testimony before the New Hampshire PUC by a PSCO executive who had earlier testified before the Licensing Board. SAPL-Audubon asserted that this material had a bearing on the applicants' financial qualifications. At oral argument, the Commission indicated that it would treat the letter as a motion to file the material and that counsel for the applicants and the other parties would have an opportunity to comment on that motion and to offer additional material as they saw fit. The applicants' response urged that no additional material should be accepted, but that if the SAPL-Audubon submission were accepted, the applicants' submission should be received as well. As attachments, the applicants included the October 25, 1977, decision of the Connecticut Public Utilities Control Authority on Connecticut Light and Power Company's request for a rate increase, an affidavit of an official of CL&P's parent company, Northeast Utilities, and the testimony of a PUC staff witness before the New Hampshire PUC. We are granting the motions for leave to file, and we have considered the material proffered by both SAPL-Audubon and the applicants in our resolution of the financial qualifications issue.

The excerpted testimony submitted by SAPL-Audubon demonstrates that the company is eager to show the New Hampshire PUC that a rate increase is required, and believes that an upgrading of its bond rating would substantially facilitate its effort to finance the plant. The applicants' reply indicates that the PUC staff advocates granting in full PSCO's request for permission to include construction work in progress in the rate base.[28] In

[28]Moreover, the PUC staff believes that PSCO meets the Federal Power Commission's "severe financial stress" tests for allowing inclusion of construction work in progress in the rate base. The submission also makes clear that a finding of "severe financial stress," as the term is defined by the Federal Power Commission, need not preclude a finding that a utility is "financially qualified," as defined by NRC. In the November 8, 1976, decision that concluded

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our view, these submissions are largely cumulative of material already in the record, both as to the means by which financing might be facilitated and as to regulatory climate. Accordingly, our finding that the applicants possess the requisite financial qualifications is not altered by the additional material.

These submissions raise questions, however, with respect to the two Connecticut utilities, Connecticut Light and Power and United Illuminating, which wish to dispose of interests in the plant. The October 25 decision of the Connecticut Public Utilities Control Authority, which granted Connecticut Light and Power a lower rate increase than it had requested, recommended that the company puruse all possibilities available to it for selling its 12% interest in Seabrook.[29] The Northeast Utilities affidavit states that Connecticut Light and Power will conform to the Seabrook Joint Ownership Agreement as long as it remains a participant; that it has entered into or is entering into agreements with various New England utilities for the sale of all its interest in Seabrook; and that when NU offered its interest in Seabrook to all New England utilities presently, or eligible to become, members of the New England Power Pool, the offer was oversubscribed. The affidavit did not specify the companies with which those contracts had been or would be concluded.[30]

Any transfer of ownership would require Commission approval.[31] We will await the filing of an application for a license amendment to consider the issue whether future applicants are financially qualified. In the event that the Connecticut PUC issues a further order related to the two utilities,

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its rulemaking proceeding on construction work in progress, the FPC explained "severe financial stress" as follows: "The financial circumstances that we contemplate are those in which it would be clearly detrimental to utility wholesale customers if some amount of CWIP were not permitted in rates base.... Such a circumstance might arise, for example, where the exigencies of the utility's construction program are such as to reduce its interest coverage to such an extent that additional capital cannot be raised at reasonable rates and that to attract capital would require a rate of return on equity substantially in excess of the cost of equity capital to otherwise similar electric utilities. Under such circumstances, it would be to the benefit of the consumer if the additional earnings necessary to attract capital were permitted by way of a return on CWIP rather than by way of an inflated return on the traditional rate base since the former treatment would eventually be reflected in a lower rate base ... while the latter would not." Docket No. RM 75-13.

[29]Docket No. 770319 at 32.

[30]Under Section 23.1 of the Joint Ownership Agreement, before any interest in the facility may be offered for sale, PSCO and United Illuminating "must have first been afforded in writing an opportunity to purchase the interest involved separately or in the aggregate on equal or better terms than those of the offer of sale and have declined such opportunity." The affidavit does not indicate the terms of the offer to the New England utilities generally or of the offer presumably first made to PSCO and UI.

[31]See Section 184 of the Atomic Energy Act, 42 U.S.C. 2234.

or that either utility independently withdraws from the project without disposing of its shares, the lead applicant shall advise the Commission's staff of its plans for dealing with the changed circumstances.[32]

As described above, there is pending before the New Hampshire PUC a PSCO request for a rate increase and for the inclusion of construction work in progress in the rate base. The company has made it clear that it views the PUC's action on its request as critical to its plans for constructing Seabrook. Accordingly, we also direct the lead applicant to report promptly to the staff all orders entered by the PUC with regard to this rate proceeding, indicating any changes in financial planning to which the PUC's action may give rise. The staff shall duly report to the Commission on its findings and proposed course of action with regard to any such change in circumstances.

II. EFFECT OF EPA DETERMINATIONS OF AQUATIC IMPACTS

The second issue on which we granted review was the Appeal Board's decision to give binding effect to certain findings of EPA made pursuant to Section 316 of the Federal Water Pollution Control Act ("FWPCA"). The EPA Administrator found that the once-through cooling system he approved for Seabrook was, as required by the FWPCA, adequate to "assure the protection and propagation of a blanced, indigenous population of fish, shellfish, and wildlife in and on" the ocean waters near Seabrook. June 17, 1977, Decision at 35. The Appeal Board read this conclusion as a finding that "the marine environment impacts of once-through cooling are small." 6 NRC at 71. The Board accepted those findings "without independent inquiry of our own into their record foundation," *id.*, and without itself resolving the conflict on precisely this issue between the Licensing Board's majority and dissent, *id.* The Appeal Board then concluded that this "small" effect of the once-through cooling system was not enough either to tilt the ultimate cost-benefit balance against the facility or to require the choice of an alternative site. *Id.*

The narrow question presented is whether the Commission may accept and use without independent inquiry EPA's determination of the magnitude of the marine environmental impacts from the cooling system in

[32]Appendix C specifically contemplates that:

> The Commission may, from time to time, request the applicant or licensee ... to submit additional or more detailed information respecting its financial arrangements and status of funds if such information is deemed necessary to determine an applicant's financial qualifications for a license or a licensee's financial qualifications to continue the conduct of the activities authorized by the licensee ....

striking an overall cost-benefit balance for the facility. Our conclusion is that we may and in this case should. The alternative suggested by the intervenors would be for the Commission to allow relitigation of an issue already ventilated before the EPA, possibly leading to different determinations concerning aquatic impacts, even though we are bound to accept the cooling system prescribed by EPA with which those impacts are associated. We cannot believe that Congress contemplated such a procedure. In its brief to us, the NRC staff seemed to argue that if the Appeal Board relied solely on EPA's determination of the magnitude of the aquatic impacts, it should be affirmed. Staff brief at 24. During oral argument staff espoused a somewhat different position, stating that the Board's decision could be affirmed either because the Board had independently evaluated the magnitude of the aquatic impacts,[33] or because the independent evaluation that was done by staff and by the Licensing Board was adequate to satisfy our NEPA obligation despite the Appeal Board's failure to make that analysis itself.[34] The explicit language of ALAB-422 cited above refutes the first contention staff raised in argument; the second contention, that staff and Licensing Board environmental analysis alone without final adjudicatory consideration and review satisfies our NEPA obligations, is one we need not decide in view of our decision herein to rely on the EPA findings.

Since an understanding of the statutory framework governing the relationship between the Commission and EPA in the area of nuclear power plant cooling systems is central to consideration of this issue, it is helpful to restate part of the Appeal Board's discussion of this subject in ALAB-366.[35] By virtue of NEPA and the FWPCA, both this Commission and EPA have significant roles to play in the overall effort to regulate the impact of nuclear generating facilities on the aquatic environment. The 1972 amendments to the FWPCA gave EPA a more expansive role in protecting water quality than any Federal agency previously had. At the same time, in furtherance of the expressed policy of the FWPCA to reduce "needless duplication and unnecessary delays at all levels of government,"[36] they significantly reduced the scope of obligations this Commission had been discharging under NEPA.

Under Section 402 of the FWPCA, EPA may issue a permit allowing discharge of a pollutant if the discharge complies with certain standards. Heat is included as a pollutant under the FWPCA. The most important EPA heat standards are set pursuant to Section 301, under which, by 1983,

[33]Transcript at 105-06, 108.

[34]Transcript at 117, 118-19.

[35]See 5 NRC 39 at 48-58.

[36]Section 101(f) of the FWPCA, 33 U.S.C. 1251(f).

EPA must set effluent limitations based on the "best available technology economically achievable."[37] With respect to thermal pollution, EPA also has authority to insure that intake locations reflect the best technology available for minimizing adverse environmental impact.[38]

Congress recognized that EPA's general standards governing heat discharges might be more restrictive than necessary in particular cases. Accordingly, Section 316(a) of the Act permits the Administrator to grant an exemption from Section 301 standards if an applicant has shown to his satisfaction that the 301 standards are more stringent than necessary to assure the protection and propagation of a balanced indigenous population of shellfish, and wildlife at the site. EPA's current policy is that unless a 316(a) exemption is obtained, there may be essentially no discharge of heat from cooling water condensers, thus requiring closed-cycle cooling and the use of cooling towers for plants such as Seabrook.

The major change the FWPCA made in this Commission's NEPA responsibilities is contained in Section 511(c). As the Appeal Board said in ALAB-366, 5 NRC 39, *supra,* at 51-52 (footnotes omitted):

> In order to establish a different role for this Commission with respect to water pollution matters than that mandated by *Calvert Cliffs,* Congress provided that nothing in NEPA was to be deemed to authorize this Commission either (1) "to review an effluent limitation or other requirement established pursuant to" the FWPCA or "the adequacy of any certification under Section 401 of" the FWPCA; or (2) "to impose ... any effluent limitation other than any such limitation established pursuant to the FWPCA...."
>
> The meaning of section 511(c)(2) can perhaps best be understood by examining how, in light of it and in ideal circumstances, the responsibilities of the two agencies are to mesh in passing upon an applicant's proposal. As Senator Baker explained in introducing the floor amendment which was the forerunner of section 511(c)(2), duplication was to be avoided by leaving to EPA and the states the decision as to the water pollution control criteria to which a facility's cooling system would be held. This Commission would not then be free to ignore considerations of aquatic impact; it would have to consider them, but only as part of its overall "balancing judgment" on whether "it is in the public interest" to grant the requested permit. In other words, this Commission still must consider any adverse environmental impact that would accrue from operation of the facility in compliance with EPA-imposed stand-

[37] Section 301(b)(2)(A), 33 U.S.C. 1311(b)(2)(A).
[38] Section 316(b), 33 U.S.C. 1326(b).

ards; but it cannot go behind either those standards or the determination by EPA or the state that the facility would comply with them.[39]

The relationship of EPA and this Commission in the present setting may be summarized thus: EPA determines what cooling system a nuclear power facility may use and NRC factors the impacts resulting from use of that system into the NEPA cost-benefit analysis.

Viewed against the statutory framework, the board's reliance on the EPA findings was clearly correct. The FWPCA reflects a Congressional judgment that the primary repository of expertise on water pollution questions generally, and on the environmental impacts of heat specifically, should be the EPA. Indeed, the legislative history of the FWPCA indicates that agencies such as NRC should *not* develop expertise "with respect to water quality considerations." Legislative History of the FWPCA Amendments of 1972 at 139 (Remarks of Senator Baker).[40]

When this case was last before us, we emphasized that a finding of environmental acceptability made by a competent State authority after environmentally sensitive hearings was entitled to "substantial weight" in the conduct of our NEPA analysis. 5 NRC 503, *supra,* at 527. Here the justification for reliance on the EPA findings is much stronger. EPA is a sister Federal agency with expertise in the subject area, and it is being relied on for determination of a single entirely factual issue which Congress has specifically entrusted to it.

But perhaps the strongest reason for accepting as conclusive the EPA determinations of aquatic impact is to avoid protracted relitigation of these factual issues. Where litigants have one full and fair opportunity to contest a particular issue, they need not be given a second opportunity to reopen the whole matter before another tribunal where the same issue is relevant.[41] The

[39]See also 5 NRC 39, *supra,* at 52, n. 20.

Massachusetts argues that the position taken on this issue by the Appeal Board and affirmed by us is inconsistent with the analysis of the Commission's NEPA obligations the Board outlined in the above-cited portions of ALAB-366. The Board explicitly did "consider any adverse environmental impact that would accrue from operation ...," but, since it properly accepted EPA's determination that the magnitude of that impact was slight, its consideration of that impact did not lead it to reject the Seabrook application. 6 NRC 33, *supra,* at 71.

[40]*Cf. U.S. Energy Research and Development Administration* (Clinch River Breeder Reactor Plant), CLI-76-13, 4 NRC 67, 83-84 (1976).

[41]Our position on this issue is consistent with the approach recently taken by the Civil Aeronautics Board (CAB) in a similar situation. The Department of Transportation had conducted a full NEPA analysis of a proposal to permit a limited number of Concorde flights to this country and had approved the proposal. Thereafter, the CAB was asked to undertake a second environmental analysis of those flights. The CAB noted that all environmental issues

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Board quoted *United States* v. *Utah Construction and Mining Company,* 384 U.S. 394, 421-22 (1966), for the proposition that where another agency has acted

> "in a judicial capacity and resolve[d] disputed issues of fact properly before it which the parties have had an adequate opportunity to litigate," we will not hesitate to give *res judicata* or collateral estoppel effect to its findings "to enforce repose." ALAB-422 at 75.

As we recently noted, "[a]lthough these judicially developed doctrines are not fully applicable in administrative proceedings ... the considerations of fairness to parties and conservation of resources embodied in them are relevant here." *Houston Lighting and Power Company, et al.* (South Texas Project, Units 1 and 2), CLI-77-13, 5 NRC 1303, 1321 (1977). See K. Davis, Administrative Law Treatise, § 18.02 at 360 (3rd ed. 1972).

The EPA regulations provide for a formal adjudicatory hearing before the Regional Administrator on the issue of aquatic impact. SAPL-Audubon, the intervenor seeking to litigate such impact questions here, requested and received such a hearing. EPA's regulation gave SAPL-Audubon the right to raise contentions, to present witnesses, and to cross-examine witnesses presented by EPA and by the applicant. See 40 CFR §125.36 (1976). Apart from these familiar procedural rights, where one agency has given collateral estoppel effect to the findings of another agency, the courts have focused on the nature and purpose of the two proceedings, the relative expertise of the agencies involved, and other relevant policy considerations. See generally *Utah Construction, supra* at 422; *FTC* v. *Texaco,* 555 F.2d 862, 879-81, 893-94, 923-35 (D.C. Cir. 1977)(*en banc*)(majority, concurring and dissenting opinions); *Safir v. Gibson,* 432 F.2d 137, 148 (2nd Cir.)(Friendly, Ch. J.), *certiorari denied,* 400 U.S. 942 (1970). Here the aquatic impacts were crucial to EPA's Section 316 determination. Under that provision, EPA had to approve a cooling intake system which would reflect the "best technology available for minimizing adverse environmental impact," and a discharge system that would not imbalance the marine populations. EPA's cooling system decision therefore not only is sensitive

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relating to the Concorde flights had previously been fully considered by DOT. Expressing the view that for it to conduct further duplicative proceedings "would serve no useful purpose," the Board held that such a proceeding was not required by NEPA. *Petition of Environmental Defense Fund, Inc.,* CAB Order 76-4-21 at 3 (April 6, 1976). Like the EPA decision on which we rely here, the Department of Transportation decision relied on by the CAB was under judicial review at the time.

to aquatic impacts, it is controlled by them. In these circumstances, we should not go behind EPA's determinations unless compelled to do so.[42]

SAPL-Audubon is appealing aspects of the EPA Administrator's review of the Regional Administrator's decision. For the reasons already set forth, we will nevertheless rely on determinations reached in that proceeding subject to possible reconsideration following its judicial review.

SAPL-Audubon argues that the Appeal Board's reliance on the EPA decision, without circulation for comment of a supplement to the impact statement discussing changed locations of the seawater intakes, violates NEPA. There is no reason in this case why a supplement should have been recirculated after the EPA decision. The CEQ guidelines provide that an agency may "at any time" supplement or amend an EIS and that recirculation for comment depends on the particular circumstances. 40 CFR §1500.11(b). In our view, the change from the inshore to the offshore location for the cooling system intakes does not present an appropriate case for recirculating for further comments. First, since the decision as to intake location is solely within EPA's jurisdiction, and since as discussed above the Commission is bound by EPA's determination of the magnitude of the associated impacts, any comments could not have been used by the Commission either as a basis for considering possible changes in the location or as a basis for reevaluating the magnitude of those impacts. Moreover, the Administrator found that the effect of moving the intake from the inshore to the offshore location "... will further minimize any potential environmental effects." EPA Administrator's June 17 Decision at 24. While circulation of a supplement may well be appropriate or necessary where the change in the proposed action has significant aggravating environmental impacts, there is no reason for a supplement when, as here, the change

[42]Intervenors argue that our action here—accepting EPA's determination of the magnitude of aquatic impacts instead of ourselves determining it—is in conflict with the spirit if not the letter of *Calvert Cliffs' Coordinating Committee* v. *AEC*, 449 F.2d 1109 (D.C. Cir. 1971). We reject that argument for two reasons. First, the "spirit" of the *Calvert Cliffs'* decision means to us that we must consider all environmental factors in the course of making our own environmentally sensitive decision on licensing a proposed facility. *See* 449 F.2d *supra* at 1122. This the Appeal Board did. Neither the spirit nor the letter of *Calvert Cliffs'* demands that the magnitude of each of those impacts be measured or determined solely by NRC personnel as long as they are fairly and accurately determined. The second reason is that the only language in *Calvert Cliffs'* that contemplated the Commission's rejecting an EPA decision—by imposing a stricter effluent limitation—has been specifically overruled by Congress in Section 511(c)(2) of the FWPCA.

Our action in this case rests on the nature and extent of the EPA proceedings. In future cases where EPA has made the necessary factual findings for approval of a specific once-through cooling system for a facility after full administrative proceedings, we expect our adjudicatory boards to do as we have done today. There is no question before us as to how to treat other EPA actions reached through other proceedings, and we express no view in that regard.

mitigates such impact.[43] *Cf. Environmental Defense Fund* v. *Froehlke,* 368 F. Supp. 231, 237 (W.D. Mo. 1973), *aff'd.* 497 F.2d 1340 (8th Cir. 1974).

III. ALLEGED APPEAL BOARD DISTORTIONS OF THE RECORD

In its petition for review, NECNP asserted that the Appeal Board "distort[ed] the meaning of the testimony, and thus, its rulings are in error." In our Order granting review we invited NECNP to provide us with "specific instances where testimony distorted by the Appeal Board resulted in erroneous rulings ...." With one possible exception relating to the seismic issue, NECNP's response does not provide any specific instances to support its claim. Indeed, although NECNP repeats its "distortion" claims and adds charges of "stretching" and "skew[ing]," the section of its brief devoted to this issue offers no citation to the record made before the Licensing Board. Without such citations we cannot test the validity of NECNP's claims.

The Commission's regulations explicitly provide that the Commission or the Appeal Board has authority to modify or set aside findings made by the Licensing Board. 10 CFR §§2.740(b), 2.785. This accords with well-established principles of administrative law. 5 U.S.C. 558; Attorney General's Manual on the Administrative Procedure Act (1947) at 83. None of the distortions offered by NECNP involves issues as to the credibility of witnesses, the one area where the reviewing body's fact-finding power may be somewhat limited. In the absence of specific explanations of how the record was allegedly distorted and of record citations from the NECNP in support of its distortion claims, both of which were contemplated by our Order granting review, further consideration of those claims is unwarranted.

We leave aside the extensive discussion of the Appeal Board's treatment of Dr. Chinnery's seismic testimony. Since we do not yet have before us Mr. Farrar's dissenting opinion on the seismic issue, we have decided to reserve judgment until we are able to consider that issue with the views of the entire Appeal Board before us. We note in that regard that Mr. Farrar has assured us resolution of his concerns will not be foreclosed by construction taking place in the near future. 6 NRC 33, *supra,* at 106.

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[43] In the course of its argument SAPL implies that 10 CFR §51.52(b)(3), providing that the FES is deemed modified by subsequent decisions of our adjudicatory tribunals, violates NEPA. Two courts of appeal have approved of that rule. The Court of Appeals for the District of Columbia Circuit has approved of our practice as not departing "from either the letter or the spirit of [NEPA]." *Citizens for Safe Power* v. *NRC,* 524 F.2d 1291, 1294 n. 5 (D.C. Cir. 1975). See also *Ecology Action* v. *AEC,* 492 F.2 998, 1001-02 (2nd Cir. 1974), where Judge Friendly recognized that omissions from an FES can be cured by subsequent consideration of the issue in an agency hearing.

IV. PRESUMPTIVE VALIDITY OF THE SUPPLEMENTAL INITIAL DECISION

We also asked the parties to discuss whether the Appeal Board erred in treating the July 7, 1977, Supplemental Initial Decision ("SID") of the Licensing Board as presumptively valid. Both NECNP and SAPL raise arguments similar to those made by Mr. Farrar in his dissent to ALAB-423; namely, that when viewed against the background of the original Initial Decision and in light of alleged weaknesses in it, the SID is a "fit candidate for reversal" and should not have been relied upon in lifting the stay at Seabrook.

When we granted review of this issue, it was central to the resumption of construction at Seabrook. In ALAB-416, 5 NRC 1438, 1440 (June 29, 1977), decided before the SID, the Appeal Board held that the permits had to remain suspended at least until the Licensing Board ruled on the issues presented in the SID. In ALAB-423, 6 NRC 115, *supra,* at 117, decided after the SID, the Appeal Board majority cited issuance of the SID as one of the recent developments supporting reinstatement of the permits. Subsequent to our grant of review, however, we directly addressed the resumption of construction issue in the context of NECNP's stay motion[4] and the presumptive validity issue thereby lost its significance.

The decision of the Appeal Board is affirmed. The Commission staff is directed to prepare and present to us a proposal which can serve as the basis for initiating the rulemaking described above.

It is so ORDERED.

By the Commission

Samuel J. Chilk
Secretary of the Commission

Dated at Washington, D.C.,
this 6th day of January 1978.

[4]Under our recently adopted certiorari and stay rules, 10 CFR §§2.786 and 2.788, if a party is aggrieved by an Appeal Board decision denying a stay, that party should file stay papers with us pursuant to 10 CFR §2.788(a) rather than seeking review of the Board decision under §2.786(b). If the Board makes a decision on the merits and also rules on a stay in the same decision, both procedures should be employed if a party seeks both a stay and review.

Decision-Making on Mega-Projects

Cost–Benefit Analysis, Planning and Innovation

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TRANSPORT ECONOMICS, MANAGEMENT AND POLICY

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8. Evolving strategy: risk management and the shaping of mega-projects[1]

Roger Miller and Donald R. Lessard

8.1 INTRODUCTION AND OVERVIEW

Project management is often equated with methods that decompose a project into discrete elements, determine their sequencing, and track their completion. Our review of large-scale engineering projects reveals a different reality. In the early stages in particular, project management consists of a series of shaping episodes, first to explore if there is a project, then to recruit participants and explore potential bases of collaboration among them, then to flesh out a holistic proposal – a script for the project if you will – then to advocate and negotiate more precisely the shape of the project and the roles of the various parties, and finally to reach closure and a final agreement. It is at this point that traditional 'decomposing' project management begins. Along the way, projects are often abandoned, or the process returns to an earlier stage because of obstacles encountered or new insight or interests that develop.

Rather than a 'Microsoft Project', the more apt metaphor is a sequence of real options, each of which is shaped and then either exercised or abandoned. In fact, as is often the case with cutting-edge practice, managers have been successful at creating value through the development and exercise of sequential options without explicitly framing the process in options terms, and without explicitly valuing these options since the emphasis is on whether there is a positive value option that justified going forward rather than determining an exact price.

The real-options framework is based on the same logic as that of financial options as developed by Black and Scholes (1974). It recognises that the decisions that determine project cash flows are made sequentially over many episodes. The key insight of this approach is that uncertainty or volatility may actually increase the value of a project, as long as flexibility is preserved and resources are not irreversibly committed. As a result, the economic value of a project when it is still relatively unformed is often greater than the discounted present value of the expected future cash flows.

Value is increased through the creation of options for subsequent sequential choices and exercising these options in a timely fashion. Thus sponsors seek projects that have the potential for large payoffs under particular institutional and technical circumstances. Our study illustrates the rich varieties of mechanisms through which these options are shaped and exercised over the life of the project – the real management that is integral to real options.

Large engineering projects (LEPs) are high-stakes games characterised by substantial irreversible commitments, skewed reward structures when they are successful, and high probabilities of failure. Their dynamics also change over time. The journey from initial conception to ramp-up and revenue generation takes ten years on average. While the 'front end' of a project – project definition, concept selection, and planning – typically involves less than one-third of the total elapsed time and expense, it has a disproportionate impact on outcomes, as most shaping actions occur during this phase. During the ramp-up period, the reality of market estimates and the true worth of the project are revealed. Sponsors may find that actual conditions are very different from expectations, but only a few adaptations are possible. Once built, most projects have little flexibility in use beyond the original intended purpose. Managing risks is thus a real issue.

The purpose of this chapter is to sketch out the various components of risk and outline ranges of strategies for coping with risks and turbulence based on an assessment of 60 projects as part of the IMEC (International Program in the Management of Engineering and Construction) study. Furthermore, we propose the elements of a governance system to master their evolutionary dynamics. The main finding is that successful projects are not selected but shaped. Rather than choosing a specific project concept from a number of alternatives at the outset based on projections of the full sets of benefits, costs and risks over the project's lifetime, successful sponsors start with project ideas that have the potential to become viable. These sponsors then embark on shaping efforts to influence risk drivers ranging from project-related issues to broader governance. The seeds of success or failure of individual projects are thus planted early and nurtured over the course of the shaping period as choices are made. Successful sponsors, however, do not escalate commitments, and they abandon quickly when they recognise that projects have little possibility of becoming viable.

Two other key concepts related to risk that emerge from the study are governability – the creation of relationships that allow a project to be reconstituted and proceed even after major changes in project drivers and the resulting payoffs to the various parties involved – and turbulence – the tendency for risks to compound dramatically once things begin going off track. In our view, projects are dynamic, iterative and often chaotic systems: project-management architectures must reflect this. While they

tend to resemble a spiral more than the classic waterfall, even this metaphor may be too orderly. Projects are better viewed as evolutionary and path-dependent systems composed of episodes displaying different dynamics.

These findings apply equally, albeit in somewhat different ways, to the three distinct classes of risk (in terms of their causes) encountered in most projects: those emanating from the dynamics of the project itself (technical and operational risks); those associated with the markets with which the project interacts (market risks); and those related to the political, social and economic setting of the project (institutional/social risks).

In this chapter, we first discuss the IMEC project and the sample of projects that underlie it. Our focus is mostly on front-end choices. We then describe the nature of risks encountered in projects and assess the various strategies that successful projects employ to cope with these risks. Using these descriptions, we highlight the extent to which project management in the face of risk is a sequence of shaping episodes, and then we draw conclusions.

8.2 THE IMEC STUDY AND LARGE ENGINEERING PROJECTS

The IMEC study grew out of the noted difficulties in project delivery that became public (Miller and Lessard, 2001). As long as governments and businesses were content to rely on traditional financing, governance and methods, there was no need for innovative approaches. However, as public financing became tight and many projects become more financially, politically and socially complex, methods that had served their purpose in the past were no longer sufficient.

IMEC was thus set up to understand the changes that were occurring. To our knowledge, there had been no recent attempts to study, evaluate and present a systematic analysis of the new approaches to large projects except the initiatives of the UK Treasury Board (HM Treasury, 2006), Bent Flyvbjerg and his colleagues on mega-projects and risks (Flyvbjerg et al., 2003) and the book by Thomas Hughes, *Rescuing Prometheus* (Hughes, 1998). To counter the objection that each project is unique and that generalisations are therefore impossible, we decided to undertake grounded research to understand what leads to success or failure, using a sample of 60 LEPs. The goal was to identify the practices that, in the experience of executives involved in projects, really made a difference. The IMEC study was distinctive in several ways. First, it was an international field study. The study sums up the collective experience from Europe, North and South America, and Asia. In general, seven to eight participants – sponsors, bankers, contractors, regulators, lawyers, analysts and others – were

interviewed for each of the 60 projects. Second, it involved systemic and strategic perspectives. Particular emphasis was placed on front-end development decisions, but execution and initial ramp-up to operation were also studied. Calling upon a range of disciplines, the IMEC study focused on themes such as coping with uncertainty through risk analysis, institution shaping and strategies. Finally, projects were selected from a range of domains. The 60 projects included 15 hydroelectric dams, 17 thermal and nuclear power plants, 6 urban transport facilities, 10 civil infrastructure investments, 4 oil platforms, and 8 technology initiatives.

Projects differ substantially in terms of the intensity of the social/institutional, technical and market-related risks that they pose to sponsors (see Figure 8.1 for the IMEC sample). For instance, oil platforms are technically difficult, but they typically face few institutional risks because they are built far from public attention and bring high direct benefits to their sponsors and affected parties. Hydroelectric power projects tend to be moderately difficult in so far as engineering is concerned, but very difficult in terms of social acceptability. Nuclear power projects pose high technical risks but still higher social and institutional risks. Road and tunnel systems present very high levels of risk, as rock formations usually hide big surprises and markets are difficult to predict when user fees are applied. Market risks faced by roads, bridges and tunnels are especially high when private sponsors build them under concessionary schemes. Urban transport projects that meet real needs pose average market and social/institutional risks. However, they pose technical risks, as they often involve underground geological work that affects costs. R&D projects present scientific challenges but face fewer social acceptability and market difficulties, as they can be broken into smaller testable investments.

8.3 THE NATURE OF RISKS IN PROJECTS

Risk is the possibility that events, their resulting impacts and their dynamic interactions will turn out differently than anticipated. Risk is typically viewed as something that can be described in statistical terms, while uncertainty is viewed as something that applies to situations in which potential outcomes and causal forces are not fully understood. In this chapter, both risks and uncertainties will be referred to as risks. Risks are multidimensional and thus need to be unbundled for a clear understanding of causes, outcomes and drivers.

In the IMEC study, managers were asked to identify and rank the risks they faced in the early front-end period of each project (Miller and Lessard,

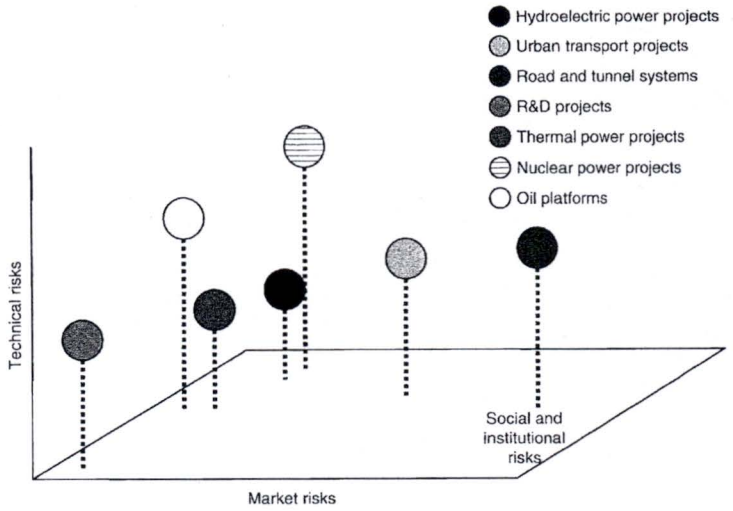

Figure 8.1 A taxonomy of LEPs in the IMEC sample

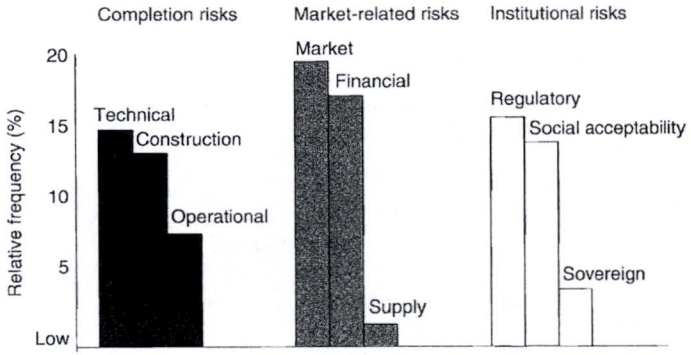

Figure 8.2 Major risks in LEPs, IMEC study

2001). Market-related risks dominated in terms of mentions (41.7 per cent), followed by technical risks (37.8 per cent), and institutional and sovereign risks (20.5 per cent). Figure 8.2 illustrates the frequency of mentions of the risks that managers identified as important in their projects.

Market-related Risks

The ability to forecast demand varies widely, thus creating high levels of risk. The output of oil projects is a fungible commodity sold in highly integrated world markets: probabilistic forecasts are possible. In contrast, many road projects face a specific set of customers; however, users of highways, tunnels, bridges, airports and ports often have alternatives, and forecasting behaviour is extremely difficult. Failures to reach traffic volume seriously threaten business models.

The market for financial inputs depends on prior risk management.[2] Unless all risks have been addressed by sponsors, financial markets are hard to convince. Many projects that offer an adequate prospective return are unable to go forward because of the parties' inability to work out acceptable risk-sharing arrangements. Supply risks are similar to market risks: both involve price and access uncertainties. Supply may be secured through contracts, open purchases, or ownership.

Completion Risks

Projects face technical risks that reflect their engineering difficulties and degrees of innovation: some of these risks are inherent in the designs employed. Construction risks refer to the difficulties that sponsors, prime contractors and contractors may face in the actual building of the project. Execution risks refer to issues that arise from errors or conflicts in the task breakdown, schedule and so on.[3] Operational risks refer to the possibility that the project will not function as expected – for example, that the availability, capacity, or operating efficiency will turn out to be lower than anticipated.

Institutional Risks

The ability of projects to access key resources or to appropriate the returns from operations in order to repay debts and recoup and profit from investments depends on the laws, regulations and norms that govern the appropriability of returns, property rights and contracts. Some countries are governed under constitutional frameworks and the rule of law, while others are led by powerful political parties or clans. Institutional risks refer to unexpected changes in these rules and norms that somehow alter the project payoffs. They are typically seen as greatest in emerging economies – countries whose laws and regulations are incomplete and in a state of flux – although the risks associated with community opposition to projects (the NIMBY phenomenon) or changes in environmental regulations may be as great or greater in highly developed countries.

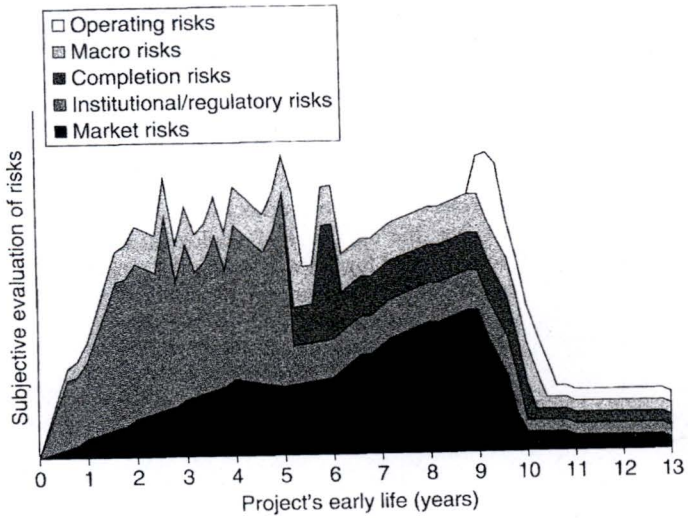

Figure 8.3 The evolution of risks over a project's life

Regulations concerning pricing, entry, unbundling and other elements are presently undergoing major changes in many countries, thus opening opportunities. Social-acceptability risks refer to the likelihood that sponsors will meet opposition from local groups, economic-development agencies and influential pressure groups. Sovereign risks, in turn, involve the likelihood that a government will decide to renegotiate contracts, concessions, or property rights.

Many of these risks emerge only over time. Emerging opportunities or risks may call for changes in project configurations. Benefits may outweigh costs but the reverse can also be true. Projects that appeared sound at one point in time all of a sudden become ungovernable. Events burst out and interact to create turbulence. Figure 8.3 illustrates the evolution of risks that emerge and challenge sponsors. Many risks are linked to the life cycle of the project: regulatory risks, for instance, diminish very soon after permits are obtained, while technical risks drop as engineering experiments are performed.

Turbulence

While strictly speaking not an additional category of risk, one aspect of risk that we observed in many projects was turbulence. Turbulence refers to

the way that consequences of events are compounded in unforeseen ways, even if the initial event lies within a range of possibilities that was known in advance, but often more seriously in the case of events that are truly 'surprises'. In the face of such difficulties, some parties have a tendency to leave projects or minimise their losses, perhaps at the expense of other participants. Moves and countermoves lead to a vortex that causes project demise. Without a set of institutional and governance devices to contain degradation, otherwise viable projects sink into deadlocks. In the case of a major civil transportation project, the discovery of geological conditions that were different from those planned for but well within the range of possibilities and did not represent that large a change in overall project economics, for example, allowed opponents to raise multiple issues that ultimately caused the collapse of the entire project.

Opportunity Failures and Oversights

Opportunity failures refer to the risk of missing a good opportunity to improve value or to reduce costs due to error, inadvertence, or even design. While an opportunity failure may be seen as a risk event resulting from a completion or social/institutional cause, the accumulation of such oversights in a project may itself become a cause of a governance crisis. Failures to capture opportunities do not threaten a project's continuity when the public or private sponsors remain unaware of what could have been achieved. When, however, there is a consensus that too many opportunities have been lost, the sponsor or other key players may lose legitimacy in the eyes of others, and the fabric of agreements required to sustain the project breaks down.

Oversight risks are particularly salient when projects are constructed using the traditional mode of contracting, in which the sponsors define expectations in detail and call for bids for execution: since these arrangements typically have no mechanisms for responding to opportunities and changes in circumstances, they generate oversights. In contrast, new modes of governance that rely on partnerships or relational contracts may allow the incorporation of changes and trigger innovative solutions that reduce the likelihood of such oversights.

8.4 APPROACHES TO MANAGING RISK IN LARGE ENGINEERING PROJECTS

Theoretical perspectives on structuring and coping with risks range from narrow, technical analysis to systemic political and institutional approaches.

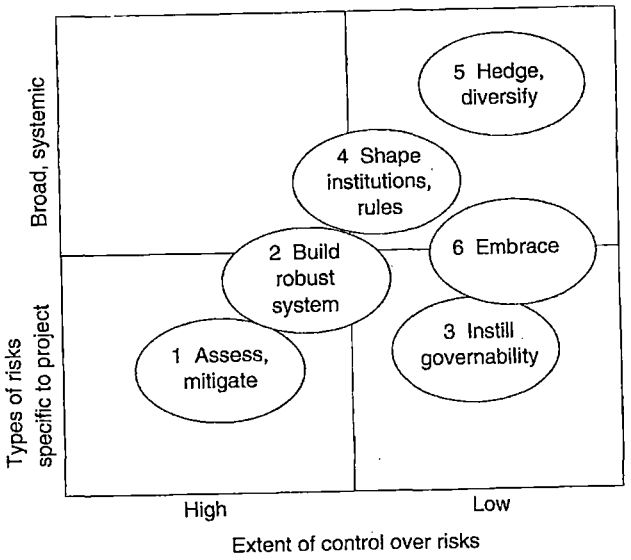

Figure 8.4 Strategies to cope with risk

In the course of the IMEC study, we have observed many innovative approaches to risk management. Sponsors, we have found, strategise to influence outcomes by using six main risk-management techniques: 'decisioneering' to assess and mitigate risks; building robust strategic systems; instilling governability; shaping institutions; hedging and diversifying risks through portfolios; and embracing risks.

Figure 8.4 illustrates the applicability of these strategies to types of risks classified along two axes: the extent to which the risks are controllable and the degree to which they are specific to the project or inherent to the economic system and thus affecting large numbers of actors. When risks are specific to the project and controllable – that is, endogenous – the usual prescription is to mitigate with risk-management approaches. However, if one party has comparative advantage in such mitigation, due to possessing more information regarding the risk or control over the outcomes, the prescription is to shift these risks to that party through contract. When risks are poorly defined but at least partially under the control of affected parties, governments, or regulators, transforming them through institutional influence is the way for sponsors to gain some control. When risks

apply broadly but are not under the control of any of the parties, the preferred approach is to transfer them through hedging transactions when markets exist or through insurance when it is priced efficiently. Sponsors must be prepared to embrace the remaining risk, and typically enhance their ability to do so by diversifying exposure through forming portfolios of projects, or equivalently, syndicating out parts of some projects to balance their overall exposure.

Classic Decisioneering Approaches to Assessing and Controlling Risks

Decisioneering approaches view projects as initiatives that can be planned under conditions of calculable risks. Careful analyses of trade-offs between costs and risks, it is argued, can yield good approximations for the appropriate timing of investment in projects. Accelerating a project will increase development costs to the point that there is a danger of sinking it. Proceeding with prudence increases the danger of missing the opportunity that the project aims to capture.

This perspective, typical of much of the project-management literature (Cleland and Ireland, 2006) assumes an environment in which the range of issues facing a project is more or less constant and current quantitative trends can be easily extrapolated into the future. Decisioneering approaches can be grouped into two basic streams. The first are quantitative sensitivity analyses that investigate the impact that possible deviations in some variables, such as anticipated costs, may have on financial performance. The second are probabilistic approaches – using scenario analysis, decision trees, or influence diagrams – that provide more sophisticated alternatives to sensitivity analysis and, in some cases, link the assessment of risk to choices and actions. Sensitivity analysis and similar approaches are helpful for making go/no-go decisions by eliminating the projects with high anticipated performance variability. However, because they focus on aggregate variables, they are less useful for the concrete and detailed shaping of a strategic system through specific choices and actions.

Building Robust Strategic Systems

Sponsors of projects deal with anticipated risks, constraints and issues by creating strategic systems with scope. Large-scale projects potentially face several classes of risks: sponsorship/development, market, social acceptability, regulatory and political, financial, execution and operation. A large portion of the risks are addressed through project-specific strategies to reduce the odds of negative events or the maximal negative impact that such events may have on the project. We identified five classes of strategies

Table 8.1 Devices used in building strategic systems

Information search	Research and studies Expert judgements Debates, scenarios, risk seminars Multidisciplinary strategy teams
Network building and co-optation	Early involvement of financiers, operators and others Public–private partnerships Alliance of owners sharing equity Partnerships with suppliers/contractors Coalitions with affected parties
Structures of incentives, and contracts	Risks/decision rights allocation Type and number of contracts Incentives/penalties Frame agreements Methods of contractor selection
Project/design configuration	Select geographical location/site Complementary investments and linkages Contract flexibility, ability to restructure Flexible/modular technical solutions Flexible contracts/contractual options
Influence and bold actions	Educate regulator, rating agencies, and others Side payments: compensation, add-ons Pre-emptive action, signals Climate of optimism Windows of opportunity Signal probity (e.g. bidding) Seek and improve on legal requirements Change laws and regulations

(summarised in Table 8.1): information/selection, co-optation, allocation, design and action.

'Information/selection strategies' refer to the approaches that managers use to gather information about the project and its environment, as well as to shape and approve the project concept, and to identify and decide on the best strategies. We identified three classes of information/selection strategies: studies, private search and relational probing. 'Studies' refers to 'impersonal' and 'objective' information-gathering approaches such as comparative costs

estimates, forecasts, tests and simulations. In this class, selection emphasises theoretical models and bureaucratic procedures. The 'private search' class involves the use of a network of personal contacts to obtain 'privileged' information; it often requires a history of previous joint work and trust. Selection takes the form of early commitment to and relentless but flexible pursuit of a single opportunity. 'Relational probing' refers to lengthy face-to-face interactions with potential participants, such as banks, regulators, clients, suppliers, engineering and construction firms, operators and affected parties, during which the information emerges and the concept is directly tested. Like personal searches, relational probing strategies proactively uncover flaws or risks and focus on meeting potential opponents and critics of the project, rather than supporters. Selection relies on iterative discussion and negotiation to expose unworkable alternatives and stimulate the emergence of a better project concept. The information/selection approach used will influence the extent to which risks are identified and the quality of the solutions and strategies that will be produced.

'Co-optation strategies' secure a basic set of 'core competencies', such as technical and construction skills, which will increase the odds for success in critical areas of project execution and ensure access to 'resources' such as markets, financing and even public support. The first step in co-optation is deciding which resources can be provided by the owner's business units or subsidiaries. Some projects, however, require bringing independent participants on board through 'partnership' links – as co-owners, joint-venture partners, or equity investors. Alternatively, resources can be co-opted through contracts and formal agreements such as project financing and tax treaties. Then again, access to some resources may be achieved through informal 'engagement' links with communities and other stakeholders in order to obtain their support.

'Allocation strategies' refer to the detailed ways in which rights, responsibilities, rewards and risks are apportioned between participants through pricing, transfer, penalty, incentive and other contractual clauses. Parties to a contract delimit their respective responsibility areas – what each of them has to provide to the other party, when, and under what conditions. For instance, a joint venture between an electric utility and an independent firm contains agreements that stipulate that the utility provides a site for the gasification plant and guarantees the supply and quality of coal, demineralised water and auxiliary power. The utility has the obligation to accept all the synthetic gas that meets the quality requirements and owns all the by-products that result from the gasification process. Failure to supply the required quantities reliably triggers the payment of penalties.

Price-determination formulas are another frequently used allocation strategy. Cost-reimbursement contracts allocate risks to the owner; fixed-price contracts transfer the cost-overrun risk to the contractor. In cost-incentive and performance-based price-determination schemes, the owners and contractors share the risks and rewards. In many power plant projects the price of the turnkey contract increases if the contractors deliver the plant early or if performance tests reveal that real plant capacity is larger than specified capacity. Other risk-allocation strategies limit the negative consequences for one of the parties to a contract. For instance, utilities often include clauses that allow them to cancel contracts with independent developers if regulators do not allow them to fully recover the contract costs from their customers. Economic-dispatch formulas can be designed to pass on the additional costs resulting from operating a power plant at suboptimal capacity to the electric utility that purchases the power and dispatches the plant.

'Design strategies' involve the use of technical, organisational, scheduling and financial choices to reduce the likelihood and impact of risks. One spectacular example of a technical solution used mainly for political risks is the building of power plants on barges that can be towed away from the host country in case of difficulties. Other examples are technical solutions that reduce the supply risk by providing fuel flexibility and economic development initiatives to gain the support of local communities.

'Action strategies' include confronting opponents using legal or informational means; persuading other participants and stakeholders such as banks, rating agencies, regulators, politicians, publics and opponents; making gestures that legitimate the project in the eyes of the regulators or the communities; developing alternatives to be used if the preferred course of action is blocked by an adverse event; and taking pre-emptive steps to signal commitments. For instance, faced with the prospect of social opposition, the owners of the ITA power plant project in Brazil established a public relations centre in the community and organised town-hall meetings at which the project was explained. Opposition weakened and the population became an ally of the project. Traditionally, engineering firms design projects under a cost-reimbursement contract, and construction is contracted using fixed-price or unit-price contracts. More recently, engineering–procurement–construction and turnkey contracts group these activities together to better align incentives between engineering and construction. BOT (build–operate–transfer)-like schemes, which make a single firm or consortium responsible not only for developing, designing and building the project but also for operating it for a long period of time, propose an even more radical way of aligning incentives. Finally, participant selection procedures may range from invited negotiations to open and public calls for bids.

Instilling Governability

Diligent sponsors do not sit idle, waiting for the probabilities to yield a 'win' or a 'loss', but work hard to influence outcomes and turn the selected initial option into a success. They shepherd their choices in light of changing conditions and often succeed against the odds. Governability is enabled by instilling a series of properties in projects: cohesion, reserves, flexibility and generativity (Miller and Floricel, 2005). These four properties are often contradictory, so a balance must be sought. For instance, strong inter-organisational bonds increase cohesion but limit flexibility. Hierarchical links create inefficiencies, while long-term contracts bring rigidities. Short-term contracts do not provide sufficient stabilisation of the future to induce adequate investment. Increasing flexibility through design and incentives may reduce the efficiency of the project.

'Cohesion' is the property that results in participants' staying with the project and solving the problems caused by turbulence, instead of exiting as crises erupt. The main sources of cohesion are the bonds between project participants resulting from co-optation strategies and informal links created during project execution or early operation. Still other bonds are the result of collateral ties between the organisations participating in a project.

Inadequate cohesion leads to disintegration. Cohesion emerged quite unexpectedly as the basic governability property: one cannot govern a project that is disintegrating; flexibility is clearly not enough. To support cohesion reserves can be built into the institutional arrangements surrounding it. In fact, ownership is the dominant factor in building reserves. Co-optation and sharing, used to deal with anticipated risks, also build in the ability to respond to turbulence. Reserves are frequently incorporated into execution budgets and schedules; contingency allowances in budgeted costs are a common practice for dealing with cost and schedule variability. Finally, reserves can be designed into projects through redundancies and slack resources.

'Flexibility' is the property that enables a project to be restructured as choices, actions and commitments, which initially stabilised the future, change when unexpected events occur. Flexibility can be achieved by using strategies that do not produce long-term constraints, offer other avenues for action, or reduce the costs of restructuring and pursuing alternatives. These costs can be reduced through co-optation and design strategies that emphasise modularity, in which no element of the project is critical by itself. Contractual structures associated with co-optation and allocation strategies are among the main sources of lack of flexibility. The same long-term contracts that reduce market and fuel-supply risks in independent

projects may block efforts to respond to new market realities. Contracts often create rigidity at the interface between owner and contractor: as contractors stick to specifications, changes required by the owner will be very expensive.

'Generativity' is the ability to develop creative responses to situations that appear difficult. Response generation presupposes correct sensing and interpretation, as well as the time and attention needed to produce constructive rather than destructive debates. Co-optation strategies, especially those that bring in participants with different competencies, may help. Having many points of view and access to different networks also means that adverse developments will probably be detected earlier and different perspectives will be brought into the discussion. For instance, unlike projects financed on the balance sheet, project financing brings banks, investment advisers, rating agencies and consulting engineers to the heart of project debates. Creative individuals bring in new perspectives from outside the circle of managers who normally participate in the project. With their different experiences, they can sense danger and propose innovative solutions. On the other hand, numerous participants and contractual interfaces hamper creativity, especially when parties focus on contracts instead of problem-solving.

Shaping Institutional Arrangements

Sponsors attempting to anchor projects often find that laws and regulations are incomplete. Many projects serve to unlock new models of project delivery (for example, the first BOTs were developed in the 1980s). One-third of the projects analysed by IMEC required at least one change in laws and rules. Concession rights, property rights, economic regulations, or foreign-investment rules needed to be modified. More than one-quarter required or accompanied changes in property rights: land rights, water rights, monopoly on or improvements to BOT and concession frameworks. Changes to laws and regulations in capital markets were also frequent. A few projects called for new environmental frameworks.

The main function of institutional arrangements is to help anchor projects in their economic and political contexts, and ensure that investments will be repaid and social utility provided. Unless they are solidly anchored, projects will be at the mercy of shifting interests, caprices and opportunistic moves. Sponsors will seek institutional arrangements to buttress LEPs.

Stabilisation of the long-term future to enable investments

Legal and regulatory frameworks, such as sector regulations and concession frameworks, help to reduce risks by minimising opportunities for

clients, communities, or governments to attempt to capture revenues after the investment is sunk. The goal is to create the prospect of secure streams of funds in the long term to cope with the various uncertainties that can affect the project. To secure streams of revenues, the approach throughout most of the twentieth century has been to assign sponsorship and ownership to network operators. Recently, power-purchase agreements, in which the regulator or the state forces network operators to sign long-term supply contracts with independent producers, have been used as a tool for providing revenue flows. Concessions by the state to sponsors also provide a framework for future revenues but are less secure.

Flexibility to face turbulence

During the front-end development of projects, when agreements are negotiated and commitments made, managers develop specific strategies to cope with foreseeable risks; they cannot, however, develop specific ways to cope with 'surprise' events. Turbulence is likely to arise given the long time span required for development. Flexibility is provided by elements of institutional arrangements that enable projects to undergo rescheduling, restructuring, or bankruptcy. The flexibility provided by institutional arrangements helps many projects survive unforeseen events.

Enhancing the legitimacy of projects, participating organisations and agreements

Many projects face opposition from interest groups. Laws, regulations and practices that create well-structured assessment frameworks enable sponsors and interest groups to air their views through public hearings, and even to oppose decisions through appeal procedures. Public-bidding frameworks structure the orderly selection of 'fit' sponsors and provide legitimacy. Practices such as inviting representatives of the public into planning and design meetings and proactively consulting conservationist groups and environmental regulators help to find credible solutions and reduce the likelihood of protest.

Frameworks for structuring voice, decision-making and public trade-offs make it possible to choose public transportation systems, erect power plants and, in some countries, build nuclear facilities. To manage social-acceptability risks in siting of power plants in Japan, for instance, the Three Power Source Laws System was put in place by the Japanese Ministry of International Trade and Industry. This framework structures public consultations and hearings across the country; the population is consulted on choice of eventual sites for projects and their technical features.

Portfolios, Insurance and Hedging

The principle of diversification is applied in projects in many different ways. In many projects, three applications were observed. First, sponsors of risky projects likely to face turbulence from disturbances caused by economic crises or government behaviours build a diversified portfolio across sectors and jurisdictions to balance risks and cash flows. Positive variations in a few compensate for negative outcomes in others. While sponsors may be able to influence some behaviour, these risks – particularly those of overall macro-economic conditions or general policy changes – are by and large beyond the control of project participants. Diversification generally is the sole option. Second, sponsors may hedge against possible losses due to currency fluctuations or commodity exposures by employing financial derivatives or other structures to shift these exposures to 'the market at large', which by definition possesses the maximum diversification potential and hence should demand the lowest premium for bearing such risks. Third, sponsors may protect themselves against political risks by investing in many countries, finding partners in each country, or buying insurance against expropriation. They may also engage in shaping or influencing behaviours by incorporating legitimate stakeholders and/or by being sure that they deliver value to those in control.[4]

Embracing Residual Risks

Of course, not all risks can be mitigated, shaped to sponsors' advantage, or transferred to others through contracts or market transactions. Successful project sponsors and other strategic players understand which risks must be taken in order to seek 'the prize' associated with the project. Through experience, they have developed a clear sense of their comparative advantage in bearing various risks, reflecting their financial strength (their capital base, diversification, access to capital markets, and financial sophistication), their understanding of particular risk domains, and their influence over the relevant events or consequences of those events. In areas where uncertainty is high, sponsors seek partners with comparative advantages in bearing risks.

Efficient risk management requires matching risks and responses, all within a dynamic iterative system. This is typically done through an iterative 'layering process', as depicted in Figure 8.5. For any given risk that is identified, there is a pecking order of responses – for example, mitigating or shaping for risks that are controllable to some extent; applying the principle of comparative advantage to determine who best should bear them given the ability to control coupled with the financial capacity to bear the

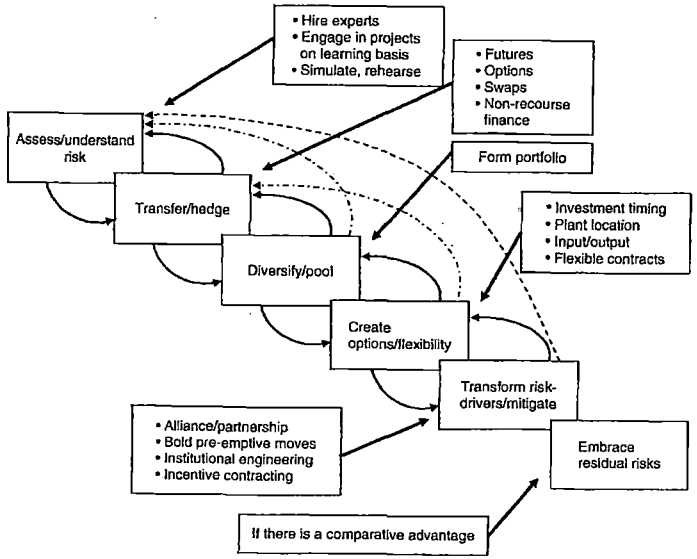

Figure 8.5 The layering process

risk; hedging in the case of risk that can easily be transacted in financial markets; and pooling or diversification for risks that cannot be shaped or traded.

8.5 GOVERNING PROJECTS AS EVOLUTIONARY SYSTEMS

In this section, we will outline a governance framework to manage projects while recognising that they are essentially evolutionary and messy. The actual decision-making processes observed in the projects studied in IMEC were indeed messy, and often chaotic. Projects are often launched by promoters who need to charm potential participants and feel compelled to build convincing but less-than-reality-grounded stories. Expenditures are allocated to soft issues such as opinion research, public affairs and announcements that lay bare issues of politics and power. Decisions are never final but are remade, recast and reshaped. Confrontations often bring deadlocks.

This messiness, as opposed to clear-cut decision-making, has led many observers to argue that LEPs are basically unmanageable, and that success is a matter of luck and improvisation. In reality, projects are better viewed as evolutionary systems where messy decision processes can be structured by a governance framework that combines discipline with creative responses.

Performance of Projects

Traditional perspectives on project management measure performance in terms of meeting projected costs, deadlines and functionality. However, project sponsors buy benefits not artefacts: they evaluate projects by the value and satisfaction they create. Should one adopt an evolutionary perspective, performance becomes the output of processes over which control varies from strong to minimal. Achieved results may be different from initial expectations for a number of reasons:

- The internal governance framework of the sponsoring organisation may have led to initial estimates that were off the mark, wrong, or deceptive, as managers were unwilling to allocate the resources necessary to build solid estimates or tell the truth.
- Capabilities of sponsors or consultants to shape projects or respond to crises may have been inadequate or have faltered. Exogenous or endogenous events may have required competencies that parties did not have.
- Exogenous unexpected events beyond the control of sponsors or partners may have generated turbulence that was difficult to master.
- Sponsors may have changed priorities mid-course, set new goals, or cut budgets, thus triggering endogenous turbulence.
- Bold moves to profit from emerging technical or market opportunities may have led to overruns but with increased benefits. Overall satisfaction may be high, together with a perception of bad management.

Should one adopt an evolutionary perspective, the performance of projects becomes not a comparison with goals stated many years ago but the output of processes of shaping, countermoves and facing emerging risk. The project that has been built differs from the original concept because of unexpected events, imposed redesigns or voluntary changes in the concept.

Progressive Issue Resolution Through Shaping Episodes

Rather than evaluating projects at the outset based on projections of the full sets of benefits and costs over their lifetime, competent sponsors view

and shape them in evolutionary perspectives. They start with initial concepts that have the possibility of becoming viable. They then embark on shaping efforts to refine, reconfigure and eventually agree on acceptable concepts. Sponsors cut their losses quickly when a concept has little possibility of becoming viable.

Shaping episodes start with broad hypotheses about what nested problems and risks need to be addressed and what resources are necessary to achieve progress. The shaping process combines deliberate actions with responses to emergent situations. Various intertwined issues have to be resolved one by one by sponsors alone or in cooperation with partners or co-specialised firms. Progress typically involves 'buying in' some stakeholders and 'buying off' others. In some cases, the expectations of stakeholders can be specified in advance. In many cases, though, it is not clear how to accommodate various interests; the leading sponsor uses the front-end period to identify mutual-gains trajectories.

Episodes start with momentum-building, continue with the countering of opposing forces, and iterate until closure can be achieved. As shaping progresses, new options are opened and old ones are closed. At closure, clients and partners agree to commit, thus losing degrees of freedom.

Momentum building

Momentum is built by imagining concepts, promoting legitimacy and selling a project configuration such that partners, affected parties and governments accept what is proposed. Risk seminars and decision conferences are used to shape the value proposition and identify risks. To ensure that investments are protected against opportunistic behaviours, risk-sharing agreements will be developed. To gain legitimacy, consent from affected parties and approval by governments will be sought.

Meeting countering forces

The countering forces that come into play over time can easily sidetrack weak sponsors into wrong choices or lead inexperienced ones to kill good ideas. In each shaping episode, the forces of criticisms and counteractions will be at work. Opponents will call for realism. Experts will challenge cost estimates and risk potentials. Sponsors will respond and take actions that may plant the seeds of later failure or success. In situations of antagonism or when desire to collaborate is mixed with the intention to oppose, parties learn opponents' values, communicate promises and make veiled or overt threats to arrive eventually at meetings of minds.

Sponsors sometimes believe their own overly optimistic assumptions. Weak analyses, incomplete research and the need to show progress lead to the rejection of valid criticisms. Excessive realism, in contrast, leads to

scepticism and to the eventual rejection of good opportunities. What is basically a good concept is painted negatively and rejected. Unfavourable judgements drive away parties whose contribution is critical. Doubts, negative stories and emergent problems set in motion self-fulfilling prophecies.

Sponsors often yield to the temptations of unreasonable commitments because they are unaware of particular risks. Blindness generally comes from the inability to form coalitions that confront distinct but relevant viewpoints. Regulatory agencies may refuse to grant permits or change rules during project shaping. Only projects whose leaders and sponsors have the resources, willingness and competencies to counteract destructive forces survive.

Closure

Eventually, imperfectly coordinated but stabilised understandings move toward temporary agreements that are enforceable. Each shaping episode ends with a process of closure that suggests either abandoning the whole project or accepting a temporary agreement on a concept configuration.

Closure takes many forms: memorandum of understanding, business case, negotiated agreement, formal public commitment, sets of formal contracts, and so on. The dangers associated with closure are that choices can be made too early or too late, too rigidly or too flexibly. Missing the boat – rejecting a good opportunity – is just as real a possibility as selecting a bad option or pursuing the wrong project. Premature closure locks a project on a rigid configuration, narrow sets of agreements, or irreversible choices that limit degrees of freedom for the future.

When exogenous or endogenous forces are strong, the agreed-upon closure may be reopened at the start of another shaping episode. For example, emerging technical opportunities may call for reopening IT projects or infrastructure projects. When this occurs, assessing costs against benefits is necessary. Similarly, changes in the business models may call for reconfiguration of the agreement. Figure 8.6 pictures the shaping effort as going up a hill through coalition-building, problem-solving and risk management in the face of counter-dynamics such as cynicism, false expectations and feedback effects.

Projects as Paths of Interdependent Shaping Episodes

Projects are rarely shaped in one over-arching episode. Instead, multiple and interdependent episodes are necessary to resolve issues and arrive at a closure that, though reopenable, can be agreed upon. Episodes are not stages that logically flow from one to the other, but distinct shaping dynamics that are autonomous yet path-dependent. Figure 8.7 illustrates the path

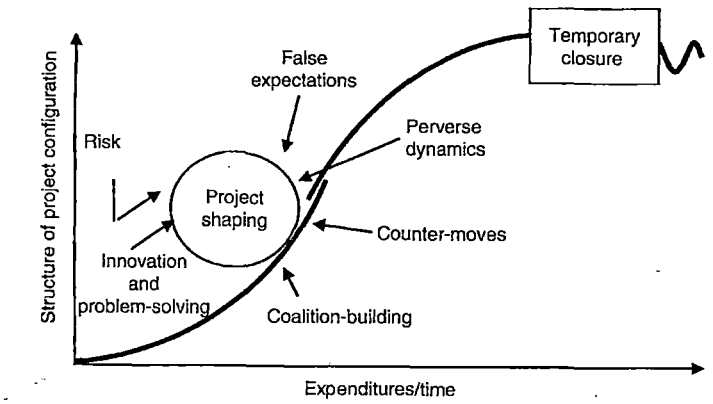

Figure 8.6 Stages in project shaping

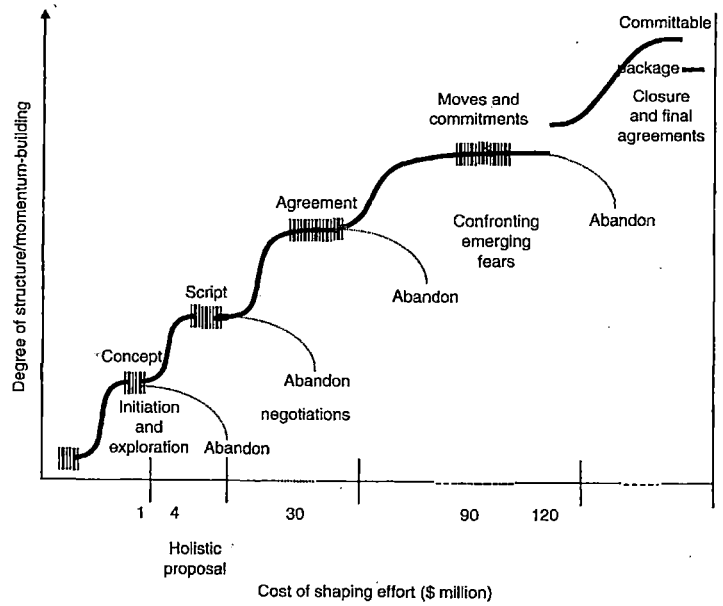

Figure 8.7 A project as a series of shaping episodes

of early front-end shaping episodes for a bridge project that was examined in great detail. Five episodes characterised the progression from initial hypothesis to formal contracts and construction fund release. We will present these episodes in a generic manner:

Initiation and exploration

The initiation episode is usually short (six months to a year) and closes when a credible party conveys to others that the project concept has relevance and should be sponsored. The credible party states openly that it is ready to allocate funds and lead debates on the ways and means of shaping and financing the idea. In the IMEC sample, project ideas were initiated by network operators (32 per cent), entrepreneurial firms (20 per cent), political leaders (20 per cent), technical entrepreneurs (12 per cent) and owners of rights (8 per cent).

Resources of a few million dollars are used to shape the project concept during this episode. Exploratory searches are conducted internally or in collaboration with external parties. In the IMEC sample, the dominant modes of exploration were a team in symbiosis with external consultants (16 per cent); open idea competition (20 per cent), strategic-planning groups (30 per cent), and entrepreneur design (28 per cent). Conceptual closure is achieved when independent studies confirm the viability of the concept. The output is a series of documents sketching out ideas but with an emphasis on technical issues. The most common form is a position paper presented to legitimate authorities, such as ministers or boards of directors.

Development of holistic proposals

The leading sponsors start with 'horseback' assumptions and proceed to develop holistic proposals covering financial and technical parameters, social acceptability, environmental challenges, and regulatory decisions and permits. The central concern is to maintain a perspective that avoids blindness to risks. Sponsors build fully developed scripts addressing pertinent risks and providing concrete solutions. Holistic proposals are presented as business cases to investors or public authorities. Preparing such proposals is expensive: from a few to many tens of millions of dollars. Entrepreneurial sponsors are often unable to fund such efforts.

Extended negotiations

Assuming that a version of the holistic proposal has been selected, the leader works with selected bidders to clear out assumptions concerning risks, revenues, costs, guarantees, engineering design and other factors. Assumptions often need to be reworked. Many sketched relationships have to be made operational. Numerous issues skipped earlier are discovered

and require solutions. Such issues may include definition of property rights to protect sponsors; development of guarantees to protect clients from completion risks faced by sponsors; negotiation of terms of guarantees and covenants to protect banks and investors; determination of the public contribution in the case of projects in which toll revenues are insufficient; determination of pricing structures and conditions of the concession; and identification of rules, regulations and laws that will have to be modified to provide security to the project.

When a government is the sponsor, negotiations of agreements have to meet additional criteria of transparency, probity and accountability. Negotiations often extend over many years because different departments have distinct requirements and expectations. Many winners of competitions, having sketched beautiful holistic proposals, are dismayed when they have to restart negotiations after winning a bid and spend $15–20 million just to work out issues that they thought were resolved.

Confronting emerging fears

As information is made public, pressure groups are triggered. Facing social and environmental fears is a very expensive affair. Sponsors have to bind themselves through actions to gain consent. Promises to engage in future actions are insufficient. Concrete moves to meet expectations and solve social and environmental issues have to be made.

If parties are unable to forge agreements, they must wait for court or government decisions. The presence of public social- and environmental-assessment frameworks is extremely important here in helping to solve dilemmas. Delays are the inevitable consequence of such formal assessments, but the public framework builds legitimacy and forces parties either to make trade-offs or to kill the project.

Closure on a Committable Package

Commitment on a final package can take place when all major issues have been resolved. In many projects, sponsors have spent a few hundred million dollars to shape a holistic proposal, gain consent, solve social and environmental issues, and build agreements. Once the slow front-end shaping process closes on a committable package, the sprint to engineering, procurement and construction may then begin.

The costs of shaping projects and planning to meet risks can be high. For simple projects, around 2–3 per cent of the overall costs will be spent in planning activities. However, for socially complex projects up to 35 per cent of the total costs will be spent in shaping the concept, ensuring good-quality coordination between players and investing to master risks. Leadership tends to be different in each episode. During the initiation period, entrepreneurs or

political officials tend to be leaders until a credible client accepts the project as a viable idea. In developing proposals and negotiations, two leaders, the owner and the sponsor/developer, interact. During construction, leadership is shared between the owner and contractors.

Sometimes, the reopening of closure is so powerful that shaping has to return to early conceptualisation. For example, during the construction of the Tucurui dam in Brazil, the extent of rain was such that prior estimates about the flow of water had to be revised and all designs redone during construction. Similarly, progress in clinical research may lead doctors to openly question assumptions embedded in the design of a university hospital.

Governance Frameworks for Shaping Projects as Evolutionary Systems

Various governance arrangements for developing projects have been tried. The rational model for project planning emerged in the twentieth century to replace the entrepreneurial approach. Belief in formal analysis was, and still is, the central pillar of the rational approach. Successful projects are portrayed as the product of advanced planning by experts who carefully weigh forecasts, alternatives and contracts. Project failures are seen largely as resulting from planning errors. Although many studies showed that large projects did not always conform to the rational-system model, the ideal lives on.

The approach proposed here combines rational planning with evolutionary shaping as progress is made on facing issues, risks and opportunities. Governance frameworks can be built at the project level but also at the institutional level to provide the scaffolding around which the various issues of projects can be shaped.

Governance means setting up a structure – a set of decision-making processes and methods for accumulating of knowledge to ensure that creativity and discipline are brought to bear. In conjunction with analytical planning, debates and discussions about risks, value creation and opportunities to reopen projects are kept alive. They make sure that risks are not defined as cost contingencies but that risk-management systems are put in place to trigger the negative feedback loops necessary to counteract the positive loops. The reopening of closed agreements will be subjected to cost–benefit tests.

Participants

Building a structure to shape projects through their multiple episodes requires deciding what parties will be involved. The structure must identify the multiple perspectives from which the project may be viewed, and the multiple tests that it should be subjected to. If the project team is staffed

only with internal technical experts, projects will be configured in technical terms. In contrast, if the project office includes external parties, experienced contractors, lawyers representing opponents, and professional managers with a systemic perspective, risks and opportunities will be addressed. Sponsors who become blind to particular risks do so because they have not brought distributed and differentiated expertise and viewpoints. They fail to form coalitions that can identify the major issues, put in place mechanisms to address them, and not allow commitments to get out of step with the resolution of key risks.

Using a mountain-climbing metaphor, competent public or private sponsors do not rush to climb the mountains that they are best equipped to climb. Rather, they seek to select, equip and train a climbing party. In fact, the game consists in identifying projects that stretch capabilities but that, because of their complexity and risk, offer substantial value and benefits to clients in spite of the costs involved.

Processes

Governance processes set up decision-making frameworks to make sure all the right questions are being asked, to initiate research activities to develop answers, and to outline the hurdles that the project must clear. Large multinational firms have often put in place complex frameworks composed of five or six decision gates in which most issues are addressed. Governmental frameworks are usually less complex, with a few decision moments.

For example, the system instituted by the Royal Ministry of Finance of Norway (see Chapter 9 in this book) includes three gates at which the project concept is tested. Project concepts are developed technically by the relevant ministries but must answer the following questions: what is the value for clients and opponents? Is value created properly shared? What are markets estimates? How will the project be financed? Could it be built using alternatives? What are the major risks and how will they be dealt with? Where are the forgotten costs, especially in risk mitigation? How do estimates compare with other projects in the world? Have competing options such as public–private partnerships been analysed? The initial concept is assessed internally. However, holistic proposals are evaluated in cooperation with external expert evaluators (Samset et al., 2006).

Methods for accumulating knowledge

Without comparative knowledge about costs, contracts, risks and so on, it is very difficult to shape projects. Sponsors who get involved sporadically in large projects find themselves starting anew and building on high levels of ignorance. The accumulation of knowledge has to be organised on a systematic and continuous basis. Sponsors should internally and in cooperation with

others build knowledge bases on construction cost estimates, risk-bearing costs, contractual forms, practices for introducing innovation, financial methods for business modelling, and learned best practices.

Powerful sponsors such as governments and large firms may even shape the environments in which projects will be developed. They may decide that ultimate users, engineering contractors or project management firms must build up their capabilities to create value and share knowledge. Improved capabilities will make it possible to answer questions better and work cooperatively to develop superior solutions by engaging in generative thinking and search for innovative solutions.

8.6 CONCLUSION: CREATION AND EXERCISE OF OPTIONS

As we have shown, the succession of shaping episodes that form the front-end process to cope with risks can be reinterpreted as a sequence of creating, shaping, and the exercising or abandoning of real options. Decisions that determine project cash flows are made sequentially over many episodes, and value is often created or preserved in the face of a great deal of uncertainty by ensuring flexibility and limiting irreversible commitments until a final closure is reached, and then 'sprinting' to the finish as quickly as possible. In fact, this process of exploration, shaping, closure and sprinting takes place many times in the complex projects we have reviewed. Value is increased through the creation of options for subsequent sequential choices, and exercising these options in a timely fashion. Thus sponsors seek projects that have the potential for large payoffs under particular institutional and technical circumstances. The study in this chapter illustrates the rich varieties of mechanisms through which these options are shaped and exercised over the life of the project – the real management that is integral to real options.

NOTES

1. This chapter is based primarily on Miller and Lessard (2001) and the underlying IMEC study. However, it also reflects the insights that the two authors have gained from their separate journeys over the last six years. Miller has gone on to define and lead the MINE study, a large-scale project focusing on innovation games based at Ecole Polytechnique de Montréal. Lessard has continued his work on large-scale projects in the oil-and-gas sector as faculty director of the BP Projects Academy and the Major Projects Research Program at MIT.
2. The term 'financial risk' is often used overly broadly to refer to risks with financial consequences – essentially everything. For us, the term applies only to events that have some underlying financial cause.

3. Schedule risk also is often used to identify a risk that has an impact on the schedule. Here, we refer to schedule risks only when they are a cause and not just a consequence. Of course, in episodes of turbulence a schedule impact may become a cause of further unravelling, and hence the distinction becomes less clear.
4. For an excellent recent study of how sponsors deal with political risk in major projects, see Wells and Ahmed (2007).

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Survival of the unfittest: why the worst infrastructure gets built—and what we can do about it

Bent Flyvbjerg*

Abstract The article first describes characteristics of major infrastructure projects. Second, it documents a much neglected topic in economics: that *ex ante* estimates of costs and benefits are often very different from actual *ex post* costs and benefits. For large infrastructure projects the consequences are cost overruns, benefit shortfalls, and the systematic underestimation of risks. Third, implications for cost–benefit analysis are described, including that such analysis is not to be trusted for major infrastructure projects. Fourth, the article uncovers the causes of this state of affairs in terms of perverse incentives that encourage promoters to underestimate costs and overestimate benefits in the business cases for their projects. But the projects that are made to look best on paper are the projects that amass the highest cost overruns and benefit shortfalls in reality. The article depicts this situation as 'survival of the unfittest'. Fifth, the article sets out to explain how the problem may be solved, with a view to arriving at more efficient and more democratic projects, and avoiding the scandals that often accompany major infrastructure investments. Finally, the article identifies current trends in major infrastructure development. It is argued that a rapid increase in stimulus spending, combined with more investments in emerging economies, combined with more spending on information technology is catapulting infrastructure investment from the frying pan into the fire.

Key words: infrastructure, cost overruns, benefit shortfalls, cost–benefit analysis, optimism bias, agency issues, reference class forecasting

JEL classification: H43, H54, R42

I. Introduction

In mid-2008, *The Economist* called current spending on infrastructure the 'biggest investment boom in history' (*The Economist*, 7 June 2008, p. 80). Spending was the largest it had ever been as a share of world GDP. When the fiscal crisis deepened and became global during the autumn to winter of 2008–9, this could have ended the infrastructure boom, as banks and capital funds radically cut back on their lending. But the opposite appears to have happened.

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Reductions in private funds have been offset by hundreds of billions of public dollars for stimulus spending. Heads of state, led by US president Barach Obama and China Premier Wen Jiabao, have singled out investment in infrastructure as a key means to create jobs and keep the economy from slumping. China was first mover when its State Council, in November 2008, passed a $586 billion stimulus plan, mainly for investment in infrastructure. In February 2009 the USA followed suit, with Congress passing President Obama's $787 billion new New Deal. India has a $475 billion plan, and the UK, Germany, France, and many other nations have made similar arrangements.

With so much money in the pipeline—and with the health of the global economy riding on the success of infrastructure investment—the efficiency of infrastructure delivery is particularly important at present. If done right the investment boom could become a boon, because infrastructure investment is appealing in many ways: it creates and sustains employment; there is a large element of domestic inputs relative to imports; it improves productivity and competitiveness by lowering producer costs; it benefits consumers through higher-quality services; and it improves the environment when infrastructures that are environmentally sound substitute for infrastructures that are not (Helm, 2008, p. 1).

But there is a big 'if' here. Because if done wrong the thrust may become a bust, with boondoggles worse than any seen yet, weakening the economy instead of improving it. Unfortunately the conventional way of delivering major infrastructure shows a dismal performance record. In what follows, I document the record, explain why it is so poor, and finally describe measures that may help current stimulus spending become effective, instead of adding to the financial and economic failures that litter the field of infrastructure investment.

But first, let's see what the characteristics of major infrastructure are.

II. Characteristics of major infrastructure

Major infrastructure projects generally have the following characteristics.[1]

- Such projects are inherently risky owing to long planning horizons and complex interfaces.
- Technology and design are often non-standard.
- Decision-making, planning, and management are typically multi-actor processes with conflicting interests.
- Often there is 'lock in' or 'capture' of a certain project concept at an early stage, leaving analysis of alternatives weak or absent.
- The project scope or ambition level will typically change significantly over time.
- Statistical evidence shows that such unplanned events are often unaccounted for, leaving budget and time contingencies sorely inadequate.
- As a consequence, misinformation about costs, benefits, and risks is the norm throughout project development and decision-making, including in the business case.
- The result is cost overruns and/or benefit shortfalls during project implementation.

[1] By 'major projects' I here mean the most expensive projects that are built in the world today, typically at costs per project from around a hundred million to several billion dollars.

Table 1: Inaccuracy of transportation project cost estimates by type of project, in constant prices

Type of project	No. of cases	Avg. cost overrun %	Standard deviation
Rail	58	44.7	38.4
Bridges and tunnels	33	33.8	62.4
Road	167	20.4	29.9

Cost overruns in the order of 50 per cent in real terms are common for major infrastructure, and overruns above 100 per cent are not uncommon. Demand and benefit forecasts that are wrong by 20–70 per cent compared with actual development are common.

Table 1 shows more detailed cost data for transportation infrastructure projects. Transportation is used as an example here and elsewhere in the article because the best data exist for transportation and because there is not enough space to present data for all project types. It should be mentioned, however, that comparative research shows that the problems identified for transportation apply to a wide range of other project types including ICT systems, buildings, aerospace projects, defence, mega-events such as the Olympics and the World Cup, water projects, dams, power plants, oil and gas extraction projects, mining, large-scale manufacturing, big science, and urban and regional development projects (Flyvbjerg *et al.*, 2003, pp. 18–19; Altshuler and Luberoff, 2003; Priemus *et al.*, 2008; Flyvbjerg *et al.*, 2002, p. 286; Flyvbjerg, 2005*a*).

The dataset in Table 1 shows cost overrun in 258 projects in 20 nations on five continents. All projects for which data were obtainable were included in the study.[2] For rail, average cost overrun is 44.7 per cent measured in constant prices from the build decision. For bridges and tunnels, the equivalent figure is 33.8 per cent, and for roads 20.4 per cent. The difference in cost overrun between the three project types is statistically significant (Flyvbjerg *et al.*, 2002). The large standard deviations shown in Table 1 are as interesting as the large average cost overruns. The size of the standard deviations demonstrates that uncertainty and risk regarding cost overruns in infrastructure are large, indeed.

The following key observations pertain to cost overruns in transportation infrastructure projects:

- nine out of 10 projects have cost overrun;
- overrun is found across the 20 nations and five continents covered by the study;
- overrun is constant for the 70-year period covered by the study; cost estimates have not improved over time.

Table 2 shows the inaccuracy of travel demand forecasts for rail and road infrastructure. The demand study covers 208 projects in 14 nations on five continents. All projects for which data

[2] The data are from the largest database of its kind. All costs are construction costs measured in constant prices. Cost overrun, also sometimes called 'cost increase' or 'cost escalation', is measured according to international convention as actual outturn costs minus estimated costs in percentage of estimated costs. Actual costs are defined as real, accounted construction costs determined at the time of project completion. Estimated costs are defined as budgeted, or forecasted, construction costs at the time of the decision to build. For reasons explained in Flyvbjerg *et al.* (2002) the figures for cost overrun presented here must be considered conservative. Ideally financing costs, operating costs, and maintenance costs would also be included in a study of costs. It is difficult, however, to find valid, reliable, and comparable data on these types of costs across large numbers of projects. For details on methodology, see Flyvbjerg *et al.* (2002).

Table 2: Inaccuracy in forecasts of rail passenger and road vehicle traffic

Type of project	No. of cases	Avg. inaccuracy %	Standard deviation
Rail	25	−51.4	28.1
Road	183	9.5	44.3

were obtainable were included in the study.[3] For rail, actual passenger traffic is 51.4 per cent lower than estimated traffic on average. This is equivalent to an average overestimate in rail passenger forecasts of no less than 105.6 per cent. The result is large benefit shortfalls for rail. For roads, actual vehicle traffic is on average 9.5 per cent higher than forecasted traffic. We see that rail passenger forecasts are biased, whereas this is less the case for road traffic forecasts. The difference between rail and road is statistically significant at a high level. Again the standard deviations are large, indicating that forecasting errors vary widely across projects (Flyvbjerg *et al.*, 2005; Flyvbjerg, 2005*b*).

The following observations hold for traffic demand forecasts:

- 84 per cent of rail passenger forecasts are wrong by more than ±20 per cent;
- nine out of 10 rail projects have overestimated traffic;
- 50 per cent of road traffic forecasts are wrong by more than ±20 per cent;
- the number of roads with overestimated and the number with underestimated traffic is about the same;
- inaccuracy in traffic forecasts is found in the 14 nations and five continents covered by the study;
- inaccuracy is constant for the 30-year period covered by the study; forecasts have not improved over time.

We conclude that if techniques and skills for arriving at accurate cost and traffic forecasts have improved over time, these improvements have not resulted in an increase in the accuracy of forecasts.

We also conclude that cost overruns and benefit shortfalls are a problem because: (i) they lead to a Pareto-inefficient allocation of resources, i.e. waste; (ii) they lead to delays and further cost overruns and benefit shortfalls; (iii) they destabilize project management; and (iv) the problem is getting bigger, because projects get bigger.

III. Implications for cost–benefit analysis

Cost–benefit analyses and social and environmental impact assessments are typically at the core of documentation and decision-making for major infrastructure projects. Such analyses are based on cost and traffic forecasts like those described above. But if we combine the data in Tables 1 and 2, we see that for rail an average cost overrun of 44.7 per cent combines

[3] Following international convention, inaccuracy is measured as actual traffic minus estimated traffic in percentage of estimated traffic. Rail traffic is measured as number of passengers; road traffic as number of vehicles. The base year for estimated traffic is the year of decision to build. The forecasting year is the first full year of operations. Two statistical outliers are not included here. For details on methodology, see Flyvbjerg (2005*b*).

with an average traffic shortfall of 51.4 per cent.[4] For roads, an average cost overrun of 20.4 per cent combines with a fifty–fifty chance that traffic is also wrong by more than 20 per cent. With errors and biases of such magnitude in the forecasts that form a basis for cost–benefit analyses, such analyses will also, with a high degree of certainty, be strongly misleading. 'Garbage in, garbage out', as the saying goes.

As a case in point, consider the Channel tunnel, the longest underwater rail tunnel in Europe, connecting France and the UK. This project was sold as highly beneficial both financially and economically. At the initial public offering, Eurotunnel, the private owner of the tunnel, lured investors by telling them that 10 per cent 'would be a reasonable allowance for the possible impact of unforeseen circumstances on construction costs'.[5] In fact, costs went 80 per cent over budget for construction and 140 per cent for financing, measured in real terms from the decision date. Revenues have been half of those forecasted. As a consequence the project has proved non-viable, with an internal rate of return on the investment that is negative, at −14.5 per cent. However convenient for the users of the service—who are heavily subsidized—the Channel tunnel detracts from the economy instead of adding to it. An economic and financial *ex post* evaluation of the project, which systematically compared actual with forecasted costs and benefits, concluded that 'the British Economy would have been better off had the Tunnel never been constructed' (Anguera, 2006, p. 291).

But perhaps the Channel tunnel was just a piece of bad luck? Perhaps the next similar project did better? Not so. The next major tunnel was the Danish Great Belt rail tunnel, the second-longest underwater rail tunnel in Europe, opened 3 years after the Channel tunnel. Here construction cost overrun was 120 per cent in real terms, and the project proved non-viable even before it opened. Only by cross-subsidizing the tunnel with revenues from a nearby motorway bridge was it possible to pay for the tunnel. Danish legislators—and the government and the EU Commission—are officially against cross-subsidies. But in this case they were happy and quick to use the remedy to sweep a major embarrassment under the carpet: the fact that actual benefits would never come even close to covering actual costs for the tunnel, although taxpayers had been told the exact opposite when they were asked to underwrite the billion-dollar debt of the project.

The Channel and Great Belt tunnels are both examples of a phenomenon I focus on below: 'survival of the unfittest'. From an economic point of view the projects should never have been built, at least not in the form they were. They survived because benefit–cost ratios presented to investors and legislators were hugely inflated, deliberately or not. The UK, France, and Denmark are rich countries and can afford to build financial and economic disasters like this. But it is important to understand that countries do not become rich by doing so. They do so when they have become rich.

It is easy to make long lists of projects with similar cost and/or benefit problems (Flyvbjerg, 2005*a*). To mention only a few, in America Boston's Big Dig, LA's subway, San Francisco's Bay Bridge, Denver's new International Airport, and the New Woodrow Wilson Bridge in Washington, DC come to mind, not to speak of the rebuilding of Iraq. In Britain, the London Tube public–private partnership, the West Coast Main Line upgrade, the Railtrack fiscal collapse, the Millennium Dome, the Scottish parliament building, the Humber Bridge, and the cost overruns on the 2012 London Olympics have been major boondoggles. Other nations, and even cities, have their own long lists of underperforming projects.

[4] For each of 12 urban rail projects, we have data for both cost overrun and traffic shortfall. For these projects average cost overrun is 40.3 per cent; average traffic shortfall is 47.8 per cent.

[5] Quoted from 'Under Water Over Budget,' *The Economist*, 7 October 1989, 37–8.

This does not show the uselessness of cost–benefit analysis as such, needless to say. But if informed decisions are the goal, then conventional *ex ante* cost–benefit analysis must be supplemented with empirical *ex post* risk analysis focused on documented uncertainties in the estimates of costs and benefits that enter into cost–benefit analysis. For a given major infrastructure project, this would constitute a kind of empirical due diligence of its cost–benefit analysis, something that is rarely carried out today.

Given the data presented above, a key recommendation for decision-makers, investors, and voters who care about what Williams (1998) calls 'honest numbers' is that they should not trust the budgets, patronage forecasts, and cost–benefit analyses produced by promoters of major infrastructure projects. Independent studies should be carried out and, again, such studies should be strong on empirically based risk assessment. Until now it has been difficult or impossible to carry out such assessments, because empirically grounded and statistically valid figures of risk did not exist. With the study documented above, this has changed and empirical risk assessment and management has begun (Flyvbjerg, 2006). In addition to sound data, institutional checks and balances that would enforce accountability in actors towards risk are also necessary, as we will see below.

In economics, large inaccuracies in forecasting have recently led to discussions of the necessity of 'firing the forecaster' (Akerlof and Shiller, 2009, p. 146). Below, I argue that this may be letting forecasters off too easily. Some forecasts are so grossly misrepresented that we need to consider not only firing the forecasters but suing them, too—perhaps even having a few serve time.

IV. Explaining cost overruns and benefit shortfalls

Three main types of explanation exist that claim to account for cost overruns and benefit shortfalls in major infrastructure projects: technical, psychological, and political-economic.

Technical explanations account for cost overruns and benefit shortfalls in terms of imperfect forecasting techniques, inadequate data, honest mistakes, inherent problems in predicting the future, lack of experience on the part of forecasters, etc. This is the most common type of explanation of inaccuracy in forecasts (Ascher, 1978; Morris and Hough, 1987; Wachs, 1990; Flyvbjerg *et al.*, 2002, 2005). Technical error may be reduced or eliminated by developing better forecasting models, better data, and more experienced forecasters, according to this explanation.

Psychological explanations account for cost overruns and benefit shortfalls in terms of what psychologists call the planning fallacy and optimism bias. Such explanations have been developed by Kahneman and Tversky (1979); Kahneman and Lovallo (1993), and Lovallo and Kahneman (2003). In the grip of the planning fallacy, managers make decisions based on delusional optimism rather than on a rational weighting of gains, losses, and probabilities. They overestimate benefits and underestimate costs. They involuntarily spin scenarios of success and overlook the potential for mistakes and miscalculations. As a result, managers pursue initiatives that are unlikely to come in on budget or on time, or to deliver the expected returns. Over-optimism can be traced to cognitive biases, that is, errors in the way the mind processes information. These biases are thought to be ubiquitous, but their effects can be tempered by simple reality checks, thus reducing the odds that people and organizations will rush blindly into unprofitable investments of money and time.

Political-economic explanations see project planners and promoters as deliberately and strategically overestimating benefits and underestimating costs when forecasting the outcomes of projects. They do this in order to increase the likelihood that it is their projects, and not the competition's, that gain approval and funding. Political-economic explanations have been set forth by Flyvbjerg *et al.* (2002, 2005) and Wachs (1989, 1990). According to such explanations planners and promoters purposely spin scenarios of success and gloss over the potential for failure. Again, this results in the pursuit of ventures that are unlikely to come in on budget or on time, or to deliver the promised benefits. Strategic misrepresentation can be traced to agency problems and political and organizational pressures—for instance, competition for scarce funds or jockeying for position—and it is rational in this sense.[6] If we now define a lie in the conventional fashion as making a statement intended to deceive others (Bok, 1979, p. 14; Cliffe *et al.*, 2000, p. 3), we see that deliberate misrepresentation of costs and benefits is lying, and we arrive at one of the most basic explanations of lying that exists: lying pays off or, at least, political and economic agents believe it does. Where there is political pressure there is misrepresentation and lying, according to this explanation, but misrepresentation and lying can be moderated by measures of accountability.

How well does each of the three explanations of forecasting inaccuracy—technical, psychological, and political-economic—account for the data on cost overruns and benefit shortfalls presented earlier? This is the question to be answered below.

Technical explanations have, as mentioned, gained widespread credence among forecasters and project managers (Ascher, 1978; Flyvbjerg *et al.*, 2002, 2005). It turns out, however, that such credence could mainly be upheld because, until now, samples have been too small to allow tests by statistical methods. The data presented above, which come from the first large-sample study in the field, lead us to reject technical explanations of forecasting inaccuracy. Such explanations do not fit the data well. First, if misleading forecasts were truly caused by technical inadequacies, simple mistakes, and inherent problems with predicting the future, we would expect a less biased distribution of errors in forecasts around zero. In fact, we have found with high statistical significance that for four out of five distributions of forecasting errors, the distributions have a mean statistically different from zero. Only the data for inaccuracy in road traffic forecasts have a statistical distribution that seems to fit with explanations in terms of technical forecasting error. Second, if imperfect techniques, inadequate data, and lack of experience were the main explanations of inaccuracies, we would expect an improvement in accuracy over time, since in a professional setting errors and their sources would be recognized and addressed through the refinement of data collection, forecasting methods, etc. Substantial resources have, in fact, been spent over several decades on improving data and methods. Still our data show that this has had no effect on the accuracy of forecasts. Technical factors, therefore, do not appear to explain the data. It is not so-called forecasting 'errors' or their causes that need explaining. It is the fact that, in a large majority of cases, costs are underestimated and benefits overestimated. We may agree with proponents of technical explanations that it is, for example, impossible to predict for the individual project exactly *which* geological, environmental, or safety problems will appear and make costs soar. But we maintain that it is possible to predict the risk, based on experience from other projects, *that* some such problems will haunt a project and how this will affect costs. We also maintain

[6] For an interpretation of strategic misrepresentation in terms of agency problems and rent-seeking behaviour, see Flyvbjerg *et al.* (2009).

that such risk can and should be accounted for in forecasts of costs, but typically is not. For technical explanations to be valid, they would have to explain why forecasts are so consistent in ignoring cost and benefit risks over time, location, and project type.

Psychological explanations better fit the data. The existence of optimism bias in managers and promoters would result in actual costs being higher and actual benefits lower than those forecasted. Consequently, the existence of optimism bias would be able to account, in whole or in part, for the peculiar bias found in most of our data. Interestingly, however, when you ask forecasters about causes for forecasting inaccuracies in actual forecasts, they do not mention optimism bias as a main cause of inaccuracy (Flyvbjerg *et al.*, 2005, pp. 138–40). This could of course be because optimism bias is unconscious and thus not reflected by forecasters. After all, there is a large body of experimental evidence for the existence of optimism bias (Buehler *et al.*, 1994; Buehler *et al.*, 1997; Newby-Clark *et al.*, 2002). However, the experimental data are mainly from simple, non-professional settings. This is a problem for psychological explanations, because it remains an open question whether they are general and apply beyond such simple settings. Optimism bias would be an important and credible explanation of underestimated costs and overestimated benefits in infrastructure forecasting if estimates were produced by inexperienced forecasters, i.e. persons who were estimating costs and benefits for the first or second time and who were thus inexperienced in the realities of major infrastructure development and were not drawing on the knowledge and skills of more experienced colleagues. Such situations may exist and may explain individual cases of inaccuracy. But, given the fact that in modern society it is a defining characteristic of professional expertise that it is constantly tested—through scientific analysis, critical assessment, and peer review—in order to root out bias and error, it seems unlikely that a whole profession of forecasting experts would continue to make the same mistakes decade after decade instead of learning from their actions. Learning would result in the reduction, if not elimination, of optimism bias, which would then result in estimates becoming more accurate over time. But our data clearly show that this has not happened. The profession of forecasters would, indeed, have to be an optimistic—and non-professional—group to keep their optimism bias throughout the 70-year period our study covers for costs, and the 30-year period covered for patronage, and not learn that they were deceiving themselves and others by underestimating costs and overestimating benefits. This would account for the data, but is not a credible explanation. Therefore, on the basis of our data, we are led to reject optimism bias as a primary and single cause of cost underestimation and benefit overestimation.

Finally, political-economic explanations and strategic misrepresentation account well for the systematic underestimation of costs and overestimation of benefits found in the data. A strategic estimate of costs would be low, resulting in cost overrun, whereas a strategic estimate of benefits would be high, resulting in benefit shortfalls. A key question for explanations in terms of strategic misrepresentation is whether estimates of costs and benefits are intentionally biased to serve the interests of promoters in getting projects started. This question raises the difficult issue of lying. Questions of lying are notoriously hard to answer, because by definition a lie consists in making a statement intended to deceive others, and in order to establish whether lying has taken place, one must therefore know the intentions of actors. For legal, economic, moral, and other reasons, if promoters and managers have intentionally cooked estimates of costs and benefits to get a project started, they are unlikely to tell researchers or others formally that this is the case. Despite such problems, two studies exist that succeeded in getting forecasters and managers to talk about strategic misrepresentation, one from the UK (Flyvbjerg and COWI, 2004) and one from the USA (Wachs, 1990).

V. Survival of the unfittest

Flyvbjerg and COWI (2004) interviewed public officials, planners, and consultants who had been involved in the development of large UK transportation infrastructure projects. A planner with a local transportation authority is typical of how respondents explained the basic mechanism of cost underestimation:

> You will often as a planner know the real costs. You know that the budget is too low but it is difficult to pass such a message to the counsellors [politicians] and the private actors. They know that high costs reduce the chances of national funding.

Experienced professionals like the interviewee know that outturn costs will be higher than estimated costs, but because of political pressure to secure funding for projects they hold back this knowledge, which is seen as detrimental to the objective of obtaining funding.

Similarly, an interviewee explained the basic mechanism of benefit overestimation:

> The system encourages people to focus on the benefits—because until now there has not been much focus on the quality of risk analysis and the robustness [of projects]. It is therefore important for project promoters to demonstrate all the benefits, also because the project promoters know that their project is up against other projects and competing for scarce resources.

Competition between projects and authorities creates political and organizational pressures that in turn create an incentive structure that makes it rational for project promoters to emphasize benefits and de-emphasize costs and risks. A project that looks highly beneficial on paper is more likely to get funded than one that does not.

Specialized private consultancy companies are typically engaged to help develop project proposals. In general, the interviewees found that consultants showed high professional standards and integrity. But interviewees also found that consultants appeared to focus on justifying projects rather than critically scrutinizing them. A project manager explained:

> Most decent consultants will write off obviously bad projects but there is a grey zone and I think many consultants in reality have an incentive to try to prolong the life of projects which means to get them through the business case. It is in line with their need to make a profit.

The consultants interviewed confirmed that appraisals often focused more on benefits than on costs. But they said this was at the request of clients and that for specific projects discussed 'there was an incredible rush to see projects realized'.

One typical interviewee saw project approval as 'passing the test' and precisely summed up the rules of the game like this: 'It's all about passing the test [of project approval]. You are in, when you are in. It means that there is so much focus on showing the project at its best at this stage.'

In sum, the UK study shows that strong interests and strong incentives exist at the project-approval stage to present projects as favourably as possible—that is, with benefits emphasized and costs and risks de-emphasized. Local authorities, local developers and land owners, local labour unions, local politicians, local officials, local MPs, and consultants all stand to benefit from a project that looks favourable on paper and they have little incentive actively to avoid bias in estimates of benefits, costs, and risks. National bodies, such as certain parts of the Department for Transport and the Ministry of Finance who fund and oversee projects, may

have an interest in more realistic appraisals, but so far they have had little success in achieving such realism, although the situation may be changing with the initiatives to curb bias set out in HM Treasury (2003) and UK Department for Transport (2006).

Wachs (1986, 1990) found similar results for transit planning in the USA. Taken together, the UK and US studies both account well for existing data on cost underestimation and benefit overestimation. Both studies falsify the notion that in situations with high political and organizational pressure the underestimation of costs and overestimation of benefits is caused by non-intentional technical error or optimism bias. Both studies support the view that in such situations promoters and forecasters intentionally use the following formula in order to secure approval and funding for their projects:

$$\text{underestimated costs} + \text{overestimated benefits} = \text{funding}$$

Using this formula, and thus 'showing the project at its best' as one interviewee said above, results in an inverted Darwinism, i.e the survival of the unfittest. It is not the best projects that get implemented, but the projects that look best on paper. And the projects that look best on paper are the projects with the largest cost underestimates and benefit overestimates, other things being equal. But the larger the cost underestimate on paper, the greater the cost overrun in practice. And the larger the overestimate of benefits, the greater the benefit shortfall. Therefore the projects that have been made to look best on paper in this manner become the worst, or unfittest, projects in reality, in the sense that they are the very projects that will encounter most problems during construction and operations in terms of the largest cost overruns, benefit shortfalls, and risks of non-viability. They have been designed like that, as disasters waiting to happen.

VI. The outside view

When contemplating what project managers can do to help reform come about, we need to distinguish between two fundamentally different situations: (i) project managers consider it important to get estimates of costs, benefits, and risks right; and (ii) project managers do not consider it important to get estimates right, because optimistic estimates are seen as a necessary means to getting projects started. The first situation is the easier one to deal with and, here, better methodology will go a long way in improving project management. The second situation is more difficult, and more common for political projects as we saw above. Here, better governance with changed incentives is essential in order to reward honesty and punish deception, where today's incentives often do the exact opposite.

Thus two main measures of reform are (i) better methods for estimating costs, benefits, and risks, and (ii) improved governance. Better methods are covered in this section, improved governance in the next.

If project managers genuinely consider it important to get estimates of costs, benefits, and risks right, it is recommended they use a promising new method called 'reference class forecasting' to reduce inaccuracy and bias. This method was originally developed to compensate for the type of cognitive bias in human forecasting that Princeton psychologist Daniel Kahneman found in his Nobel prize-winning work on bias in economic forecasting (Kahneman, 1994; Kahneman and Tversky, 1979). Reference class forecasting has proven more accurate than conventional forecasting. It was used in project management in practice for the first time in 2004 (Flyvbjerg and COWI, 2004); in 2005 the method was officially

endorsed by the American Planning Association (2005); and since then it has been used by governments and private companies in the UK, the Netherlands, Denmark, Switzerland, Australia, and South Africa, among others.

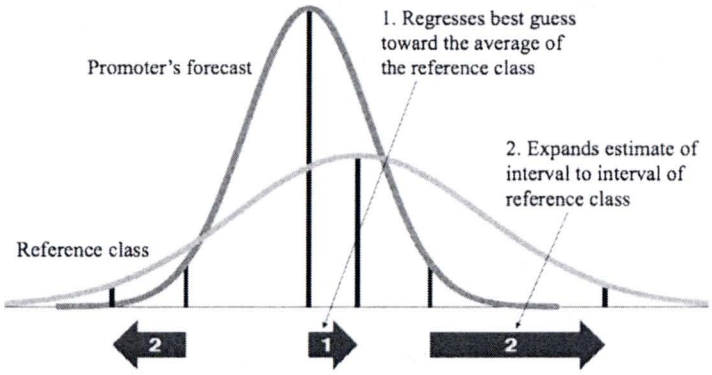
For reasons of space, here I present only an outline of the method, based mainly on Lovallo and Kahneman (2003) and Flyvbjerg (2006). Reference class forecasting consists in taking a so-called 'outside view' on the particular project being forecasted. The outside view is established on the basis of information from a class of similar projects. The outside view does not try to forecast the specific uncertain events that will affect the particular project, but instead places the project in a statistical distribution of outcomes from this class of reference projects. Reference class forecasting requires the following three steps for the individual project:

(i) identification of a relevant reference class of past projects. The class must be broad enough to be statistically meaningful but narrow enough to be truly comparable with the specific project;
(ii) establishing a probability distribution for the selected reference class. This requires access to credible, empirical data for a sufficient number of projects within the reference class to make statistically meaningful conclusions; and
(iii) comparing the specific project with the reference class distribution, in order to establish the most likely outcome for the specific project.

Daniel Kahneman relates the following story about curriculum planning to illustrate reference class forecasting in practice (Lovallo and Kahneman, 2003, p. 61). Some years ago, Kahneman was involved in a project to develop a curriculum for a new subject area for high schools in Israel. The project was carried out by a team of academics and teachers. In time, the team began to discuss how long the project would take to complete. Everyone on the team was asked to write on a slip of paper the number of months needed to finish and report the project. The estimates ranged from 18 to 30 months. One of the team members—a distinguished expert in curriculum development—was then posed a challenge by another team member to recall as many projects similar to theirs as possible and to think of these projects as they were in a stage comparable to their project. 'How long did it take them at that point to reach completion?', the expert was asked. After a while he answered, with some discomfort, that not all the comparable teams he could think of ever did complete their task. About 40 per cent of them eventually gave up. Of those remaining, the expert could not think of any that completed their task in less than 7 years, nor of any that took more than ten. The expert was then asked if he had reason to believe that the present team was more skilled in curriculum development than the earlier ones had been. The expert said no, he did not see any relevant factor that distinguished this team favourably from the teams he had been thinking about. His impression was that the present team was slightly below average in terms of resources and potential. The wise decision at this point would probably have been for the team to break up, according to Kahneman. Instead, the members ignored the pessimistic information and proceeded with the project. They finally completed the project 8 years later, and their efforts went largely wasted—the resulting curriculum was rarely used.

In this example, the curriculum expert made two forecasts for the same problem and arrived at very different answers. The first forecast was the inside view; the second was the outside view, or the reference class forecast. The inside view is the one that the expert and the other team members adopted. They made forecasts by focusing tightly on the case at hand, considering its objective, the resources they brought to it, and the obstacles to its completion. They constructed in their minds scenarios of their coming progress and extrapolated current

Figure 1: What reference class forecasting does, in statisticians' language

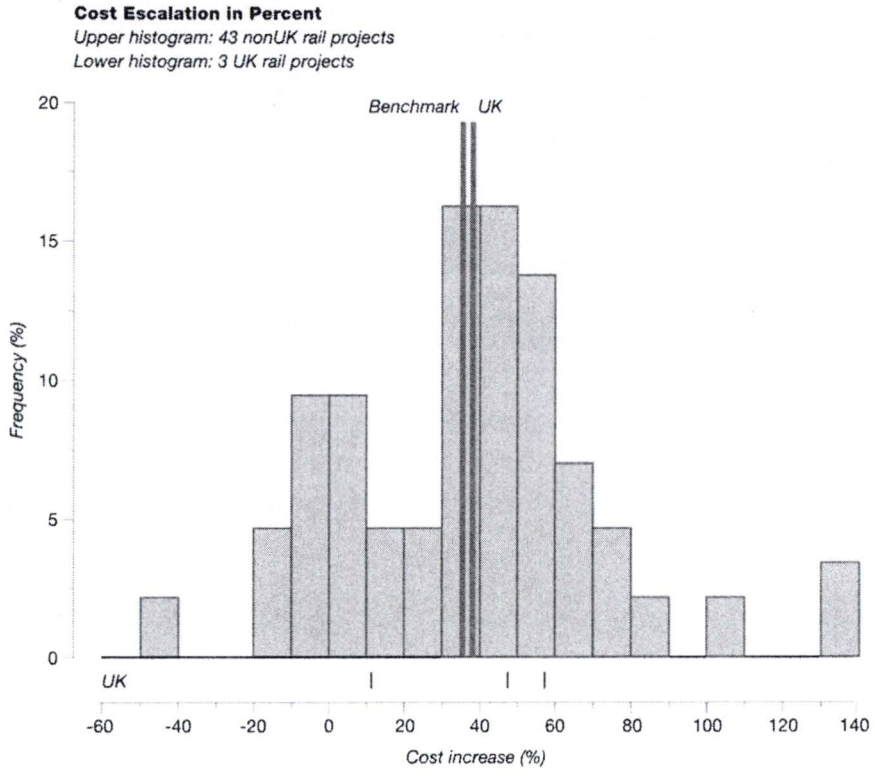


trends into the future. The resulting forecasts, even the most conservative ones, were overly optimistic. The outside view is the one provoked by the question to the curriculum expert. It completely ignored the details of the project at hand, and it involved no attempt at forecasting the events that would influence the project's future course. Instead, it examined the experiences of a class of similar projects, laid out a rough distribution of outcomes for this reference class, and then positioned the current project in that distribution. The resulting forecast, as it turned out, was much more accurate.

Figure 1 shows what reference class forecasting does in statisticians' language. First, reference class forecasting regresses the best guess of the conventional forecast—here the project promoters' forecast, indicated by the darker curve—towards the average of the reference class. The distribution of outcomes in the reference class is indicated by the lighter curve. Second, reference class forecasting expands the estimate of interval in the conventional forecast to the interval of the reference class.

With an example from infrastructure provision, planners in a city preparing to build a new subway would, first, establish a reference class of comparable projects. This could be the relevant rail projects from the sample described in Table 1. Through statistical and other analyses the planners would establish which projects to include in the reference class, i.e. projects that were, indeed, comparable to the one being planned and to each other. Second, if the planners were concerned, for example, with getting construction cost estimates right, they would then establish the distribution of outcomes for the reference class regarding the accuracy of construction cost forecasts. Figure 2 shows what this distribution looks like for a reference class relevant to building subways in the UK, developed by Flyvbjerg and COWI (2004, p. 23) for the UK Department for Transport. Third, the planners would compare their subway project to the reference class distribution. This would make it clear to the planners that unless they have reason to believe they are substantially better forecasters and planners than their colleagues who did the forecasts and planning for projects in the reference class, they are likely grossly to underestimate construction costs. Finally, planners would then use this knowledge to adjust their forecasts for more realism. Figure 3 shows what such adjustments are for the UK situation. More specifically, Figure 3 shows that for a forecast of construction costs for a rail project, which has been planned in the manner that such projects are usually planned (i.e. like the projects in the reference class), this forecast would have to be adjusted upwards by 40 per cent, if investors were willing to accept a risk of cost overrun of 50 per cent. If investors were willing to accept a risk of overrun of only 10 per cent, the uplift would have to be 68 per cent. For a rail project initially estimated at, say £4 billion, the uplifts for the

Figure 2: Inaccuracy of construction cost forecasts for rail projects in reference class (average cost increase is indicated for non-UK and UK projects, separately; constant prices)



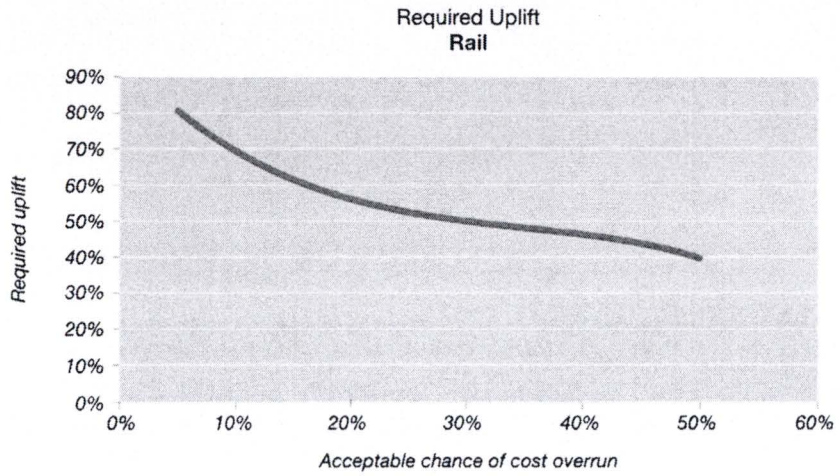
Source: Flyvbjerg and COWI (2004).

50 and 10 per cent levels of risk of cost overrun would be £1.6 billion and £2.7 billion, respectively.

The first instance of reference class forecasting in practice was done in 2004 for capital costs of the proposed Edinburgh Tram Line 2 (Flyvbjerg, 2006). An initial cost estimate of £320m made by planners was adjusted for optimism bias and acceptable risk, using the probability distribution in Figure 3. This resulted in a new cost estimate of £400m, including contingencies to insure against cost overruns at the 80 per cent level, i.e. with a 20 per cent risk of overrun. If the Scottish Parliament, which was underwriting the investment, were willing to accept a risk of overrun of 50 per cent, then the cost estimate including contingencies could be lowered to £357m. Insurance is expensive, here as elsewhere, and the marginal cost of insurance against cost overruns increases as the level of acceptable risk decreases, as seen in Figure 3. Since the Edinburgh Tram, many other infrastructure projects have been subjected to reference class forecasting, Crossrail in London being the most expensive at a cost of £16 billion ($23 billion).

The contrast between inside and outside views has been confirmed by systematic research (Gilovich *et al.*, 2002). The research shows that when people are asked simple questions requiring them to take an outside view, their forecasts become significantly more accurate.

Figure 3: Required adjustments to cost estimates for UK rail projects as function of the maximum acceptable level of risk for cost overrun (constant prices)



Source: Flyvbjerg and COWI (2004).

However, most individuals and organizations are inclined to adopt the inside view in planning major initiatives. This is the conventional and intuitive approach. The traditional way to think about a complex project is to focus on the project itself and its details, to bring to bear what one knows about it, paying special attention to its unique or unusual features, trying to predict the events that will influence its future. The thought of going out and gathering simple statistics about related cases seldom enters a manager's mind. This is the case in general, according to Lovallo and Kahneman (2003, pp. 61–2). And it is certainly the case for cost and benefit forecasting in large infrastructure projects. Despite the many forecasts my team and I have reviewed, before the Edinburgh Tram forecast, which is based on our research, we had not come across a single genuine reference class forecast of costs and benefits. Neither had Daniel Kahneman, who first conceived the idea of the reference class forecast.

While understandable, managers' preference for the inside view over the outside view is unfortunate. When both forecasting methods are applied with equal skill, the outside view is much more likely to produce a realistic estimate. That is because it bypasses cognitive and political biases, such as optimism bias and strategic misrepresentation and cuts directly to outcomes. In the outside view managers and forecasters are not required to make scenarios, imagine events, or gauge their own and others' levels of ability and control, so they cannot get all these things wrong. Surely the outside view, being based on historical precedent, may fail to predict extreme outcomes, that is, those that lie outside all historical precedents. But for most projects, the outside view will produce more accurate results. In contrast, a focus on inside details is the road to inaccuracy.

The comparative advantage of the outside view is most pronounced for non-routine projects, understood as projects that managers in a certain locale have never attempted before—such as building an urban rail system in a city for the first time, or launching a completely new product to the market. It is in the planning of such new efforts that the biases toward optimism and strategic misrepresentation are likely to be largest. To be sure, choosing the right reference

class of comparative past projects becomes more difficult when managers are forecasting initiatives for which precedents are not easily found, for instance the introduction of new and unfamiliar technologies. However, many major infrastructure projects are both non-routine locally and use well-known technologies. Such projects are, therefore, particularly likely to benefit from the outside view and reference class forecasting.

VII. Getting governance right

In this section we consider the situation where project managers and other influential actors do not find it important to get estimates of costs, benefits, and risks right and where managers, therefore, do not help to clarify and mitigate risks but, instead, generate and exacerbate them. Here project managers are part of the problem, not the solution.

This situation may need some explication, because it may sound to many like an unlikely state of affairs. After all, it may be agreed that project managers and other professionals involved in major infrastructure provision ought to be interested in being accurate and unbiased in their work. It is even stated in the Project Management Institute (PMI)'s Code of Ethics and Professional Conduct (PMI, 2006, pp. 4, 5) that project managers should 'provide accurate information in a timely manner' and they must 'not engage in or condone behaviour that is designed to deceive others'. Economists, engineers, planners, and others involved in major infrastructure provision have similar codes of conduct. But there is a dark side to their work, which is remarkably underexplored in the literature (Flyvbjerg, 1996).

On the dark side, project managers and planners 'lie with numbers'. as Wachs (1989) has aptly put it. They are busy not with getting forecasts and business cases right and following the PMI Code of Ethics but with getting projects funded and built. And accurate forecasts are often not an effective means for achieving this objective. Indeed, accurate forecasts may be counterproductive, whereas biased forecasts may be effective in competing for funds and securing the go-ahead for a project. 'The most effective planner,' says Wachs (1989, p. 477), 'is sometimes the one who can cloak advocacy in the guise of scientific or technical rationality.' Such advocacy would stand in direct opposition to PMI's ruling that project managers should 'make decisions and take actions based on the best interests of society' (PMI, 2006, p. 2).

Nevertheless, seemingly rational forecasts that underestimate costs and overestimate benefits have long been an established formula for project approval as we saw above. Forecasting is here mainly another kind of rent-seeking behaviour, resulting in a make-believe world of misrepresentation which makes it extremely difficult to decide which projects deserve undertaking and which do not. The consequence is, as even one of the industry's own organs, the Oxford-based Major Projects Association, acknowledges, that too many projects proceed that should not. One might add that many projects do not proceed that probably should, had they not lost out to projects with 'better' misrepresentation (Flyvbjerg *et al.*, 2002).

In this situation, the question is not so much what project managers can do to reduce inaccuracy and risk in forecasting, but what others can do to impose on project managers the checks and balances that would give managers the incentive to stop producing biased forecasts and begin to work according to their Code of Ethics. The challenge is to change the power relations that govern forecasting and project development. Better forecasting techniques and appeals to ethics will not do here; organizational change with a focus on transparency and accountability is necessary.

As argued in Flyvbjerg *et al.* (2003), two basic types of accountability define liberal democracies: (i) public-sector accountability through transparency and public control; and (ii) private-sector accountability via competition and the market mechanism. Both types of accountability may be effective tools to curb misrepresentation in project management and to promote a culture which acknowledges and deals effectively with risk, especially where large amounts of taxpayers' money are at stake and for projects with significant social and environmental impacts, as is common with major infrastructure projects.

(i) Transparency and public control

In order to achieve accountability through transparency and public control, the following would be required as practices embedded in the relevant institutions (the full argument for the measures may be found in Flyvbjerg *et al.* (2003, chs 9–11)).

- National-level government should not offer discretionary grants to local agencies for the sole purpose of building a specific type of project (a.k.a. 'categorical grants'). Such grants create perverse incentives. Instead, national government should simply offer 'block grants' to local governments, and let local political officials spend the funds however they choose to, but make sure that every dollar they spend on one type of project reduces their ability to fund another.
- Cost–benefit analysis and other types of *ex ante* appraisal should be shifted from promoters to more neutral ground, for instance with the Treasury, in order to reduce risks of agency problems.
- Forecasts and business cases should be made subject to independent peer review. Where projects involve large amounts of government funds, such review may be carried out by national or state auditing offices, such as the General Accounting Office in the USA or the National Audit Office in the UK, who have the independence and expertise to produce such reviews.
- Forecasts should be benchmarked against comparable forecasts, for instance using reference class forecasting as described in the previous section.
- For publicly funded projects, forecasts, peer reviews, and benchmarkings should be made available for public scrutiny, including by the media, as they are produced, including all relevant documentation.
- Public hearings, citizen juries, and the like should be organized to allow stakeholders and civil society to voice criticism and support of forecasts. Knowledge generated in this way should be integrated in project management and decision-making.
- Scientific and professional conferences should be organized where forecasters would present and defend their forecasts in the face of colleagues' scrutiny and criticism.
- Projects with inflated benefit–cost ratios should be reconsidered and stopped if recalculated costs and benefits do not warrant implementation. Projects with realistic estimates of benefits and costs should be rewarded.
- Professional and occasionally even criminal penalties should be enforced for managers and forecasters who consistently and foreseeably produce deceptive forecasts (Garett and Wachs, 1996).

When I first began suggesting, in lectures for project managers, promoters, and forecasters, that deception and criminal penalties may be concepts relevant to our professions, I would get headshakes, sighs, and the occasional boo. Enron and Iraq changed that, almost overnight.

Today people listen and the literature has become replete with books and articles that hammer out the links between lying, forecasting, and management. For instance, a recent book about risk, the planning fallacy, and strategic misrepresentation bluntly states: 'Anyone who causes harm by forecasting should be treated as either a fool or a liar. Some forecasters cause more damage to society than criminals' (Taleb, 2007, p. 163).

Law-making has followed suit, most prominently with the 2002 Sarbanes–Oxley Act, which stipulates up to 20 years in prison for a knowingly false forecast intended to impede, obstruct, or influence the proper administration of affairs. There is little doubt that penalties like this influence behaviour. The point is that malpractice in project management should be taken as seriously as it is in other professions, e.g. medicine and law. Failing to do this amounts to not taking the profession of project management seriously.

(ii) Competition and market control

In order to achieve accountability via competition and market control, the following would be required, again as practices that are both embedded in and enforced by the relevant institutions.

- The decision to go ahead with a major infrastructure project should, where at all possible, be made contingent on the willingness of private financiers to participate without a sovereign guarantee for at least one-third of the total capital needs.[7] This should be required whether projects pass the market test or not—that is, whether projects are subsidized or not or provided for social justice reasons or not. Private lenders, shareholders, and stock-market analysts would produce their own forecasts or conduct due diligence for existing ones. If they were wrong about the forecasts, they and their organizations would be hurt. The result would be added pressure to produce realistic forecasts and reduced risk to the taxpayer.
- Forecasters and their organizations must share financial responsibility for covering cost overruns and benefit shortfalls resulting from misrepresentation and bias in forecasting.
- The participation of risk capital would not mean that government reduces control of major infrastructure projects. On the contrary, it means that government can more effectively play the role it should be playing, namely as the ordinary citizen's guarantor for ensuring concerns about safety, environment, risk, and a proper use of public funds.

Whether infrastructure projects are public, private, or public–private, they should be vested in one and only one project organization with a strong governance framework and strong contract-writing skills. The project organization may be a company or not, public or private, or a mixture. What is important is that this organization has the capacity to (i) set up and negotiate contracts that will effectively safeguard its interests, including in equity risk allocation, and (ii) enforce accountability *vis-à-vis* contractors, operators, etc. In turn, the directors of the organization must be held accountable for any cost overruns, benefit shortfalls, faulty designs, unmitigated risks, etc. that may occur during project planning, implementation, and operations.

[7] A sovereign guarantee is a guarantee where government takes on the risk of paying back a loan, even if the loan was obtained in the private lending market. The lower limit of a one-third share of private risk capital for such capital to influence accountability effectively is based on practical experience. See more in Flyvbjerg *et al.* (2003, pp. 120–3).

Experience with contract writing is a much-neglected topic, but is particularly important in developing and managing major infrastructure projects. This is because a fundamental asymmetry in experience with and resources allocated to contract writing often applies in the client–contractor relationship for such projects. Clients who decide to do major infrastructure—for instance, a city council deciding to build a new subway or toll road—do so relatively rarely, often only once, or never, in the lifetime of the individual city manager and council member. Learning is therefore impaired for clients, and if you do not know what your interests are, it is difficult to safeguard them. Contractors, on the other hand, who bid for and build such projects, do so all the time. Contractors, therefore, typically know much more than clients about the ins and outs of projects and contracts, including the many risks and pitfalls that apply, plus which lawyers, bankers, and consultants to hire to safeguard their interests most effectively. This asymmetry has brought many a client to grief. A possible way to bring more symmetry into the client–contractor relationship would be for government to establish a central contract-writing unit at the state or national level, which would be in charge of negotiating, on behalf of local and other branches of government, the types of major contracts they do too infrequently to gain real experience. This would concentrate a larger number of contracts in one place, allowing experience—and the negotiating power that comes with it—to accumulate.

Fortunately, better governance along the lines described above has recently become stronger around the world. The Enron scandal and its successors have triggered new legislation and a war on corporate deception that is spilling over into government with the same objective: to curb financial waste and promote good governance. Although progress is slow, good governance is gaining a foothold also in major infrastructure project management.

For example, in 2003 the Treasury of the United Kingdom required, for the first time, that all ministries develop and implement procedures for major projects that will curb what the Treasury calls—with true British civility—'optimism bias'. Funding will be unavailable for projects that do not take into account this bias, and methods have been developed for how to do this (HM Treasury, 2003; Flyvbjerg and COWI, 2004; UK Department for Transport, 2006). In the Netherlands in 2004, the Parliamentary Committee on Infrastructure Projects for the first time conducted extensive public hearings to identify measures that will limit the misinformation about large infrastructure projects given to the Parliament, public, and media (Tijdelijke Commissie Infrastructuurprojecten, 2004). In Boston, the government has sued to recoup funds from contractor overcharges for the Big Dig related to cost overruns. More countries and cities are likely to follow the lead of the UK, the Netherlands, and Boston in coming years; Switzerland and Denmark are already doing so (Swiss Association of Road and Transportation Experts, 2006; Danish Ministry for Transport and Energy, 2006, 2008).

Moreover, with private finance in major infrastructure projects on the rise over the past 15–20 years, capital funds and banks are increasingly gaining a say in the project development and management process. Private capital is no panacea for the ills in major infrastructure project management, to be sure (Hodge and Greve, 2009). But private investors place their own funds at risk, as opposed to governments who place the taxpayer's money at risk. Capital funds and banks can therefore be observed not to automatically accept at face value the forecasts of project managers and promoters. Banks typically bring in their own advisers to do independent forecasts, due diligence, and risk assessments, which is an important step in the right direction. The false assumption that one forecast or one business case (which is also a forecast) may contain the truth about a project is problematized. Instead project managers and promoters are getting used to the healthy fact that different stakeholders have different

forecasts and that forecasts are not only products of objective science and engineering but of negotiation. Why is this more healthy? Because it is more truthful about our ability to predict the future and about the risks involved.

If the institutions with responsibility for developing and building major infrastructures continued to implement, embed, and enforce such measures of accountability effectively, then the misrepresentation in cost, benefit, and risk estimates, which is widespread today, might be mitigated. If this is not done, misrepresentation is likely to continue, and the allocation of funds for major infrastructure is likely to continue to be wasteful, unethical, and sometimes even unlawful.

VIII. Current trends in infrastructure investment

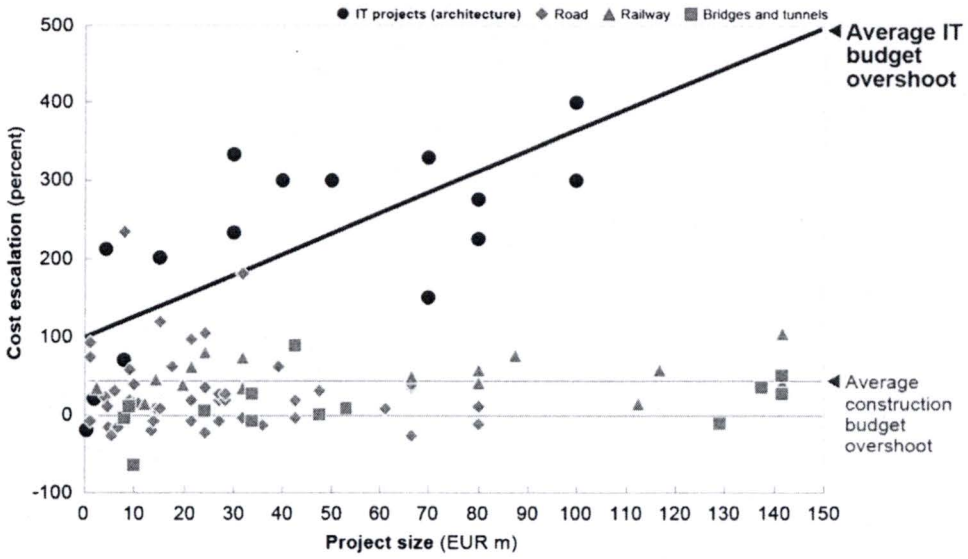
In the introduction to this article, I mentioned that current spending on infrastructure constitutes the biggest investment boom in history, measured as share of world GDP. We also saw above that, even in the best of times, large infrastructure investments have a dismal performance record in terms of cost overruns, delays, and benefit shortfalls. Nine out of ten projects experience cost overrun, and overrun has not diminished for the 70 years for which we have data, to mention but two grim statistics.

Throwing hundreds of billions of extra stimulus dollars at an underperforming business that is already at bubble-like investment levels, is therefore highly risky at best. Nevertheless, this is what China, the USA, and many other countries decided to do with their stimulus packages in 2008 and 2009. Risks include rampant pork-barrel, fast-tracking, bid-rigging, local governments pulling their funds out of on-going projects in anticipation of national funding that may not come or comes late, and projects left unfinished because of cost overruns on stimulus projects that local government cannot finance. The consequences could be dire to the economy, and to public trust in the institutions and people who administer infrastructure spending. Perhaps this is why Macquarie Bank—probably the largest and most experienced infrastructure investor in the world—began reducing its infrastructure portfolio in 2009, moving into energy instead.

Add to this that global infrastructure investments are shifting geographically from developed to emerging economies, where risks of ineffective project delivery are even higher. Over half of infrastructure investments are now taking place in emerging economies. In the past 5 years, China has spent more on infrastructure in real terms than in the whole of the twentieth century. In the past 4 years, China has built as many kilometres of high-speed passenger rail lines as Europe has in two decades. Morgan Stanley predicts that emerging economies will spend $22 trillion in today's prices on infrastructure over the next 10 years. Political risks, risks of corruption, and logistical risks are higher in emerging economies. As a consequence, risks of cost overruns and benefit shortfalls are also higher. A recent study documented that the average cost overrun on rail projects—measured in real terms from the decision date to completion—was 64.6 per cent in emerging economies against 40.8 per cent in North America and 34.2 per cent in Europe (Flyvbjerg *et al.*, 2002, p. 285). Geography matters to project performance. The striking shift in infrastructure investments to emerging economies is therefore placing increased pressure on project delivery.

Finally, information and communication technology (ICT) has fast become a large and rapidly increasing part of more major infrastructure projects. The consequences are often devastating, because large ICT projects appear to perform even worse than other major

Figure 4: Cost overrun in construction projects and IT projects compared.



projects. Recently, a group of ICT experts contacted me to ask how they might learn to manage cost overruns, delays, etc. in ICT projects 'as well as in transportation infrastructure projects'. I laughed out loud because I mistakenly thought they were making a joke. As mentioned above, the evidence is clear that most major transportation infrastructure projects perform poorly. But here is another project type, ICT, that apparently performs so much worse that it can use transportation as a benchmark to be strived for. We did a pilot study, and sure enough, the ICT experts were right: if a major project is not already messed up, injecting a good dose of ICT will do the job (see Figure 4).

As if it were not difficult enough to develop, say, a major new airport, we are now developing airports that depend on major new ICT for their operations, and we pay the price. Hong Kong international airport is a case in point, with initial ICT hiccups so bad that the whole Hong Kong economy suffered. Terminal 5 at London Heathrow is another example. An infrastructure planner recently told me, 'We know how to build large, expensive tunnels by now, but we don't know how to build the ICT safety systems that go into the tunnels; ICT busts us every time.'

Or take Germany's Toll Collect, a consortium of DaimlerChrysler, Deutsche Telekom, and Cofiroute of France responsible for tolling heavy trucks on German motorways for the federal government. The new tolling system was designed to be a showcase for public–private partnership in infrastructure management. Tolling was scheduled to start in January 2003. A year later the project was falling apart. The developers had been too optimistic about the software that would run the system. The government was losing toll revenues estimated to total €6.5 billion ($8.6 billion). For lack of funds, all new road projects in Germany and related public works were put on hold, threatening 70,000 construction jobs. Politicians and media were calling for prosecution of Toll Collect for deceiving the government. Finally, the German transport minister cancelled the contract with Toll Collect and gave the company 2 months to come up with a better plan. By the time tolling at last started, several years delayed,

'Toll Collect' had become a popular byword among Germans used to describe everything wrong with the national economy. Projects like this will not get us out of the current crisis. Quite the opposite.

Examples abound and the advice regarding ICT seems obvious: if you are doing ICT as part of a major project (or as a major project in itself) be sure to get ICT that has been developed and debugged elsewhere and that has a proven track record in daily use. If you decide not to follow this advice (which is common) you should be explicit that you are in essence taking on the development risk of a major new product, which translates into large and unpredictable risks of delays, cost overruns, and benefit shortfalls. Your set-up for risk management and contingencies should then duly reflect this (which is uncommon).

And here's the crunch: not only are clients and managers of major infrastructure projects rushing headlong into risky ICT investments that are really new product development schemes, but a rapidly increasing part of these investments are shifting to emerging economies, which is a source of risk in its own right, as we saw above. Between 2003 and 2008, the share of ICT spending in emerging economies rose by 60 per cent, from 15 to 24 per cent of global ICT spending, according to the OECD.

In sum, the following formula captures the current trends in major infrastructure investment:

(rapid increase in infrastructure spending) + (rapid shift in spending to emerging economies) + (rapid increase in spending on ICT) = (risk to the third degree of financial and economic disasters).

Whether stimulus infrastructure spending will improve or worsen the global economy will be decided by how well we deal with these main trends. Thus the efficiency of project delivery is both particularly important at present and particularly challenged. The major challenges are (i) not to lower standards as the project pipeline rapidly expands, (ii) to navigate the particular risks of doing more projects in emerging economies, and (iii) to harness the bull in a china shop that is ICT in major projects.

Three main ingredients will help meet the challenges. First, we need honestly to acknowledge that infrastructure investment is no easy fix but is fraught with problems. For this purpose, President Obama was immensely helpful when at a 2009 White House Fiscal Responsibility Summit he openly identified 'the costly overruns, the fraud and abuse, the endless excuses' in public procurement as key problems (White House, 2009). *The Washington Post* (24 February 2009) rightly called this 'a dramatic new form of discourse'. Before Obama it was not *comme-il-faut* to talk about overruns, deception, and abuse in relation to infrastructure spending, although they were of epidemic proportions then as now, and the few who did use such language were ostracized. However, we cannot solve problems we cannot talk about. So talking is the first step.

Second, we must arrive at a better understanding and better management of the long, fat tails of financial and economic risks—the abundance of black swans—that apply to infrastructure investment. Risks have so far been as misunderstood and as mismanaged in infrastructure investment as in the financial markets, with equally devastating outcomes. Methods and data for better risk assessment and management were presented above.

Third, incentives need to be put straight, so that bad performance is punished and good performance rewarded, and not the other way around, which is often the case today. Again, methods for how to do this were described above.

IX. Conclusions

This article documents a much neglected topic in economics, namely the fact that *ex ante* estimates of ventures' costs and benefits are often very different from actual *ex post* costs and benefits. The article shows that such differences between estimated and actual outcomes are pronounced for large infrastructure projects, where substantial cost underestimates often combine with equally significant benefit overestimates, rendering cost–benefit analyses of projects not only inaccurate but biased.

The cause of biased cost–benefit analyses is found to be perverse incentives that encourage promoters of infrastructure projects to underestimate costs and overestimate benefits in the business cases for their projects in order to gain approval and funding. But the projects that are artificially made to look best in business cases are the projects that generate the highest cost overruns and benefit shortfalls in reality, resulting in a significant trend for 'survival of the unfittest' for infrastructure projects.

The cure to the problem is enforcing an outside view in the planning of new projects and employing a method called reference class forecasting, based on Daniel Kahneman's Nobel Prize-winning theories of decision-making under uncertainty. However, to be effective such new methodology must be combined with better governance structures with incentives that reward accurate estimates of costs and benefits and punish inaccurate ones.

Finally, stimulus spending has recently resulted in extra money and attention for infrastructure investing. This is placing increased pressure on project delivery. Stimulus spending—together with rapidly increasing spending on infrastructure in emerging economies and on information technology in infrastructure—is driving infrastructure investment from the frying pan into the fire.

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Underestimating Costs in Public Works Projects

Error or Lie?

Bent Flyvbjerg, Mette Skamris Holm, and Søren Buhl

This article presents results from the first statistically significant study of cost escalation in transportation infrastructure projects. Based on a sample of 258 transportation infrastructure projects worth US$90 billion and representing different project types, geographical regions, and historical periods, it is found with overwhelming statistical significance that the cost estimates used to decide whether such projects should be built are highly and systematically misleading. Underestimation cannot be explained by error and is best explained by strategic misrepresentation, that is, lying. The policy implications are clear: legislators, administrators, investors, media representatives, and members of the public who value honest numbers should not trust cost estimates and cost-benefit analyses produced by project promoters and their analysts.

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Comparative studies of actual and estimated costs in transportation infrastructure development are few. Where such studies exist, they are typically single-case studies or they cover a sample of projects too small to allow systematic, statistical analyses (Bruzelius et al., 1998; Fouracre et al., 1990; Hall, 1980; Nijkamp & Ubbels, 1999; Pickrell, 1990; Skamris & Flyvbjerg, 1997; Szyliowicz & Goetz, 1995; Walmsley & Pickett, 1992). To our knowledge, only one study exists that, with a sample of 66 transportation projects, approaches a large-sample study and takes a first step toward valid statistical analysis (Merewitz, 1973a, 1973b).[1] Despite their many merits in other respects, these studies have not produced statistically valid answers regarding the question of whether one can trust the cost estimates used by decision makers and investors in deciding whether or not to build new transportation infrastructure. Because of the small and uneven samples used in existing studies, different studies even point in opposite directions, and researchers consequently disagree regarding the credibility of cost estimates. Pickrell (1990), for instance, concludes that cost estimates are highly inaccurate, with actual costs being typically much higher than estimated costs, while Nijkamp and Ubbels (1999) claim that cost estimates are rather correct. Below we will see who is right.

The objective of the study reported here was to answer the following questions in a statistically valid manner: How common and how large are differences between actual and estimated costs in transportation infrastructure projects? Are the differences significant? Are they simply random errors? Or is there a statistical pattern to the differences that suggests other explanations? What are the implications for policy and decision making regarding transportation infrastructure development?

Four Steps to Understanding Deceptive Cost Estimation

We see four steps in the evolution of a body of scholarly research aimed at understanding practices of cost underestimation and deception in decision making for transportation infrastructure. The first step was taken by Pickrell (1990) and Fouracre, Allport, and Thomson (1990), who provided sound evidence for a small number of urban rail projects that substantial cost underestimation is a problem, and who implied that such underestimation may be caused by deception on the part of project promoters and forecasters. The second step was taken by Wachs (1990), who established—again for a small sample of urban rail projects—that lying, understood as intentional deception, is, in fact, an important cause of cost underestimation. Wachs began the difficult task of charting who does the lying, why it occurs, what the ethical implications are, etc.

The problem with the research in the first two steps is that it is based on too few cases to be statistically significant; the pattern found may be due to random properties of the small samples involved. This problem is solved in the third step, taken with the work reported in this article. Based on a large sample of transportation infrastructure projects, we show that (1) the pattern of cost underestimation uncovered by Pickrell and others is of general import and is statistically significant, and (2) the pattern holds for different project types, different geographical regions, and different historical periods. We also show that the large-sample pattern of cost underestimation uncovered by us lends statistical support to the conclusions about lying and cost underestimation arrived at by Wachs for his small sample.

The fourth and final step in understanding cost underestimation and deception would be to do for a large sample of different transportation infrastructure projects what Wachs did for his small sample of urban rail projects: establish whether systematic deception actually takes place, who does the deception, why it occurs, etc. This may be done by having a large number of forecasters and project promoters, representing a large number of projects, directly express, in interviews or surveys, their intentions with and reasons for underestimating costs. This is a key topic for further research.

In sum, then, we do not claim with this article to have provided final proof that lying is the main cause of cost underestimation in transportation infrastructure projects. We claim, however, to have taken one significant step in a cumulative research process for testing whether this is the case by establishing the best and largest set of data about cost underestimation in transportation infrastructure planning so far seen, by carrying out the first statistically significant study of the issues involved, and by establishing that our data support and give statistical significance to theses about lying developed in other research for smaller, statistically nonsignificant samples.

As part of further developing our understanding of cost underestimation, it would also be interesting to study the differences between projects that are approved on a competitive basis, by voters at an election, and those that are funded through formula-based allocations. One may speculate that there is an obvious incentive to make a project look better, and hence to underestimate costs, in the campaign leading up to an election. A good single-case study of this is Kain's (1990) article about a rail transit project in Dallas. Votes are cast more often for large rail, bridge, and tunnel projects than for road projects. For example, most U.S. highway funds are distributed to states based on a formula (i.e., there is no competitive process). A state department of transportation (DOT) is likely to have a fixed annual budget for construction. The DOT leadership would presumably want fairly accurate cost estimates before allocating the budget. One may speculate that large cost underestimation is less likely in this situation. There are exceptions to this scenario. Sometimes DOT officials want to persuade state legislators to increase their budget. And states occasionally submit bond issue proposals to voters. In Europe, the situation is similar on important points, although differences also exist. This may explain the result found below, that cost underestimation is substantially lower for roads than for rail, bridges, and tunnels, and that this is the case both in the U.S. and Europe. Needless to say, more research is necessary to substantiate this observation.

Finally, we want to emphasize that although the project sample used in this study is the largest of its kind, it is still too small to allow more than a few subdivisions, if comparative statistical analyses must still be possible. Therefore, in further work on understanding cost underestimation, the sample should be enlarged to better represent different types of projects and different geographical locations. As to project types, data for more private projects would be particularly useful in allowing statistically valid comparisons between public and private sector projects. Such comparisons do not exist today, and nobody knows whether private projects perform better or worse than public ones regarding cost underestimation. The sample should also be enlarged to contain data for more fixed-link and rail projects. Such data would allow a better (i.e., a statistically corroborated) comparative understanding of cost underestimation for more specific subtypes of projects such as bridges, tunnels, high-speed rail, urban rail, and conven-

tional rail. Such an understanding is nonexistent today. As to geography, immediate rewards would be gained from data for projects outside Europe and North America, especially for fixed links and roads. But even for Europe and North America, data on more projects are needed to allow better comparative analysis.

Measuring Cost Inaccuracy

The methods used in our study are described in the Appendix. All costs are construction costs. We follow international convention and measure the inaccuracy of cost estimates as so-called "cost escalation" (often also called "cost overrun"; i.e., actual costs minus estimated costs in percent of estimated costs). Actual costs are defined as real, accounted construction costs determined at the time of project completion. Estimated costs are defined as budgeted, or forecasted, construction costs at the time of decision to build. Although the project planning process varies with project type, country, and time, it is typically possible for any given project to identify a specific point in the process as the time of decision to build. Usually a cost estimate was available at this point in time for the decision makers. If not, then the closest available estimate was used, typically a later estimate resulting in a conservative bias in our measure for inaccuracy (see the Appendix). All costs are calculated in fixed prices in Euros by using the appropriate historical, sectoral, and geographical indices for discounting and the appropriate exchange rates for conversion between currencies.

Project promoters and their analysts sometimes object to this way of measuring cost inaccuracy (Flyvbjerg et al., in press). Various cost estimates are made at different stages of the process: project planning, decision to build, tendering, contracting, and later renegotiations. Cost estimates at each successive stage typically progress toward a smaller number of options, greater detail of designs, greater accuracy of quantities, and better information about unit price. Thus, cost estimates become more accurate over time, and the cost estimate at the time of making the decision to build is far from final. It is only to be expected, therefore, that such an early estimate would be highly inaccurate. And this estimate would be unfair as the basis for assessing the accuracy of cost forecasting, or so the objection against using the time-of-decision-to-build estimate goes (Simon, 1991). We defend this method, however, because when the focus is on decision making, and hence on the accuracy of the information available to decision makers, then it is *exactly* the cost estimate at the time of making the decision to build that is of primary interest. Otherwise it would be impossible to evaluate whether decisions are informed or not. Estimates made after the decision to build are by definition irrelevant to this decision. Whatever the reasons are for cost increases after decision makers give the go-ahead to build a project, or however large such increases are, legislators and citizens—or private investors in the case of privately funded projects—are entitled to know the uncertainty of budgets. Otherwise transparency and accountability suffer. We furthermore observe that if the inaccuracy of early cost estimates were simply a matter of incomplete information and inherent difficulties in predicting a distant future, as project promoters often say it is, then we would expect inaccuracies to be random or close to random. Inaccuracies, however, have a striking and highly interesting bias, as we will see below.

Another objection to using cost at the time of decision to build as a basis of comparison is that this supposedly would entail the classical error of comparing apples and oranges. Projects change over the planning and implementation process. When, for instance, the physical configuration of the original Los Angeles Blue Line Light Rail project was altered at substantial cost to comprise grade-crossing improvements, upgrading of adjacent streets, better sidewalks, new fences, etc., the project was no longer the same. It was, instead, a new and safer project, and comparing the costs of this project with the costs of the older, less safe one would supposedly entail the apples-and-oranges error. A problem with this argument is that existing research indicates that project promoters routinely ignore, hide, or otherwise leave out important project costs and risks in order to make total costs appear low (Flyvbjerg et al., in press; Wachs, 1989, 1990). For instance, environmental and safety concerns may initially be ignored, even though they will have to be taken into account later in the project cycle if the project lives on, and the project is more likely to live on if environmental and safety concerns are initially ignored. Similarly, ignoring or underplaying geological risks may be helpful in getting projects approved, and no other risk is more likely to boomerang back and haunt projects during construction. "Salami tactics" is the popular name used to describe the practice of introducing project components and risks one slice at a time in order to make costs appear low as long as possible. If such tactics are indeed a main mechanism in cost underestimation, as existing research indicates, then, clearly, comparing actual project costs with estimated costs at the time of decision to build does not entail the error of comparing apples and oranges but is simply a way of tracking how what was said to be a small, inexpensive apple turned out to actually be a big, expensive one.

Finally, we observe that if we were to follow the objections against using the cost estimate at the time of de-

cision to build as the basis of tracking cost escalation, it would be impossible to make meaningful comparisons of costs because no common standard of comparison would be available. We also observe that this method is the international standard for measuring inaccuracy of cost estimates (Fouracre et al., 1990; Leavitt et al., 1993; National Audit Office & Department of Transport, 1992; Nijkamp & Ubbels, 1999; Pickrell, 1990; Walmsley & Pickett, 1992; World Bank, 1994). This standard conveniently allows meaningful and consistent comparisons within individual projects and across projects, project types, and geographical areas. This standard, then, is employed below to measure the inaccuracy of cost estimates in 258 transportation infrastructure projects worth US$90 billion.

Inaccuracy of Cost Estimates

Figure 1 shows a histogram with the distribution of inaccuracies of cost estimates. If errors in estimating costs were small, the histogram would be narrowly concentrated around zero. If errors in overestimating costs were of the same size and frequency as errors in underestimating costs, the histogram would be symmetrically distributed around zero. Neither is the case. We make the following observations regarding the distribution of inaccuracies of construction cost estimates:

- Costs are underestimated in almost 9 out of 10 projects. For a randomly selected project, the likelihood of actual costs being larger than estimated costs is 86%. The likelihood of actual costs being lower than or equal to estimated costs is 14%.
- Actual costs are on average 28% higher than estimated costs (sd=39).
- We reject with overwhelming significance the thesis that the error of overestimating costs is as common as the error of underestimating costs ($p<0.001$; two-sided test, using the binomial distribution). Estimated costs are biased, and the bias is caused by systematic underestimation.
- We reject with overwhelming significance the thesis that the numerical size of the error of underestimating costs is the same as the numerical size of the error of overestimating costs ($p<0.001$; nonparametric Mann-Whitney test). Costs are not only underestimated much more often than they are overestimated or correct, costs that have been underestimated are also wrong by a substantially larger margin than costs that have been overestimated.

We conclude that the error of underestimating costs is significantly much more common and much larger than the error of overestimating costs. Underestimation of costs at the time of decision to build is the rule rather than the exception for transportation infrastructure projects. Frequent and substantial cost escalation is the result.

Cost Underestimation by Project Type

In this section, we discuss whether different types of projects perform differently with respect to cost underestimation. Figure 2 shows histograms with inaccuracies of cost estimates for each of the following project types: (1) rail (high-speed; urban; and conventional, inter-city rail), (2) fixed link (bridges and tunnels), and (3) road (highways and freeways). Table 1 shows the expected (average) inaccuracy and standard deviation for each type of project.

Statistical analyses of the data in Table 1 show both means and standard deviations to be different with a high level of significance. Rail projects incur the highest difference between actual and estimated costs, with an average of no less than 44.7%, followed by fixed-link projects averaging 33.8% and roads at 20.4%. An F-test falsifies the null hypothesis at a very high level of statistical significance that type of project has no effect on percentage cost escalation ($p<0.001$). Project type matters. The substantial and significant differences among project types indicate that pooling the three types of projects in statistical analyses, as we did above, is strictly not appropriate. Therefore, in the analyses that follow, each type of project will be considered separately.

Based on the available evidence, we conclude that rail promoters appear to be particularly prone to cost underestimation, followed by promoters of fixed-link projects. Promoters of road projects appear to be relatively less inclined to underestimate costs, although actual costs are higher than estimated costs much more often than not for road projects as well.

Further subdivisions of the sample indicate that high-speed rail tops the list of cost underestimation, followed by urban and conventional rail, in that order. Similarly, cost underestimation appears to be larger for tunnels than for bridges. These results suggest that the complexities of technology and geology might have an effect on cost underestimation. These results are not statistically significant, however. Even if the sample is the largest of its kind, it is too small to allow repeated subdivisions and still produce significant results. This problem can be solved only by further data collection from more projects.

We conclude that the question of whether there are significant differences in the practice of cost underesti-

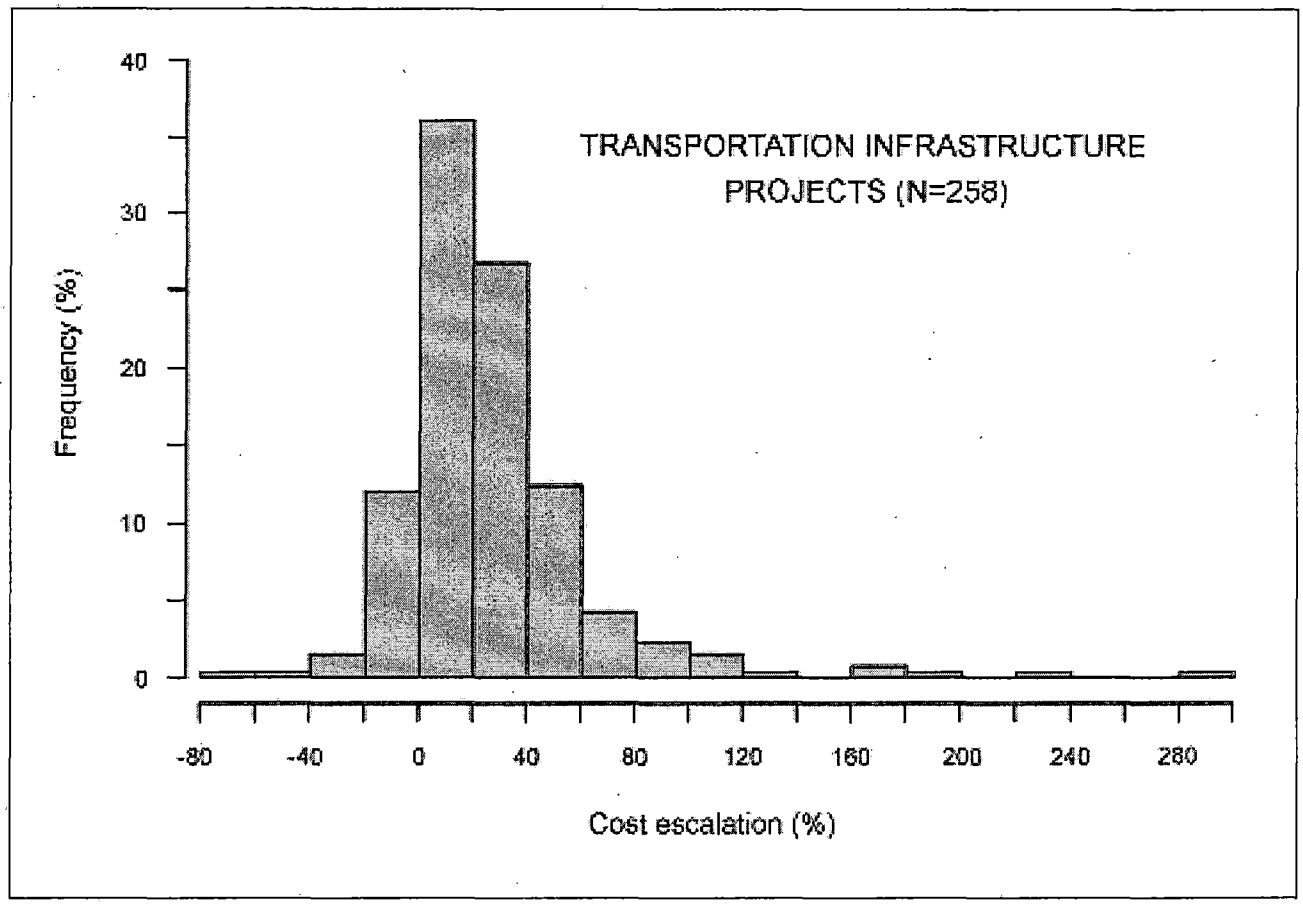

FIGURE 1. Inaccuracy of cost estimates in 258 transportation infrastructure projects (fixed prices).

TABLE 1. Inaccuracy of transportation project cost estimates by type of project (fixed prices).

Project type	Number of cases (N)	Average cost escalation (%)	Standard deviation	Level of significance (p)
Rail	58	44.7	38.4	<0.001
Fixed-link	33	33.8	62.4	<0.004
Road	167	20.4	29.9	<0.001
All projects	258	27.6	38.7	<0.001

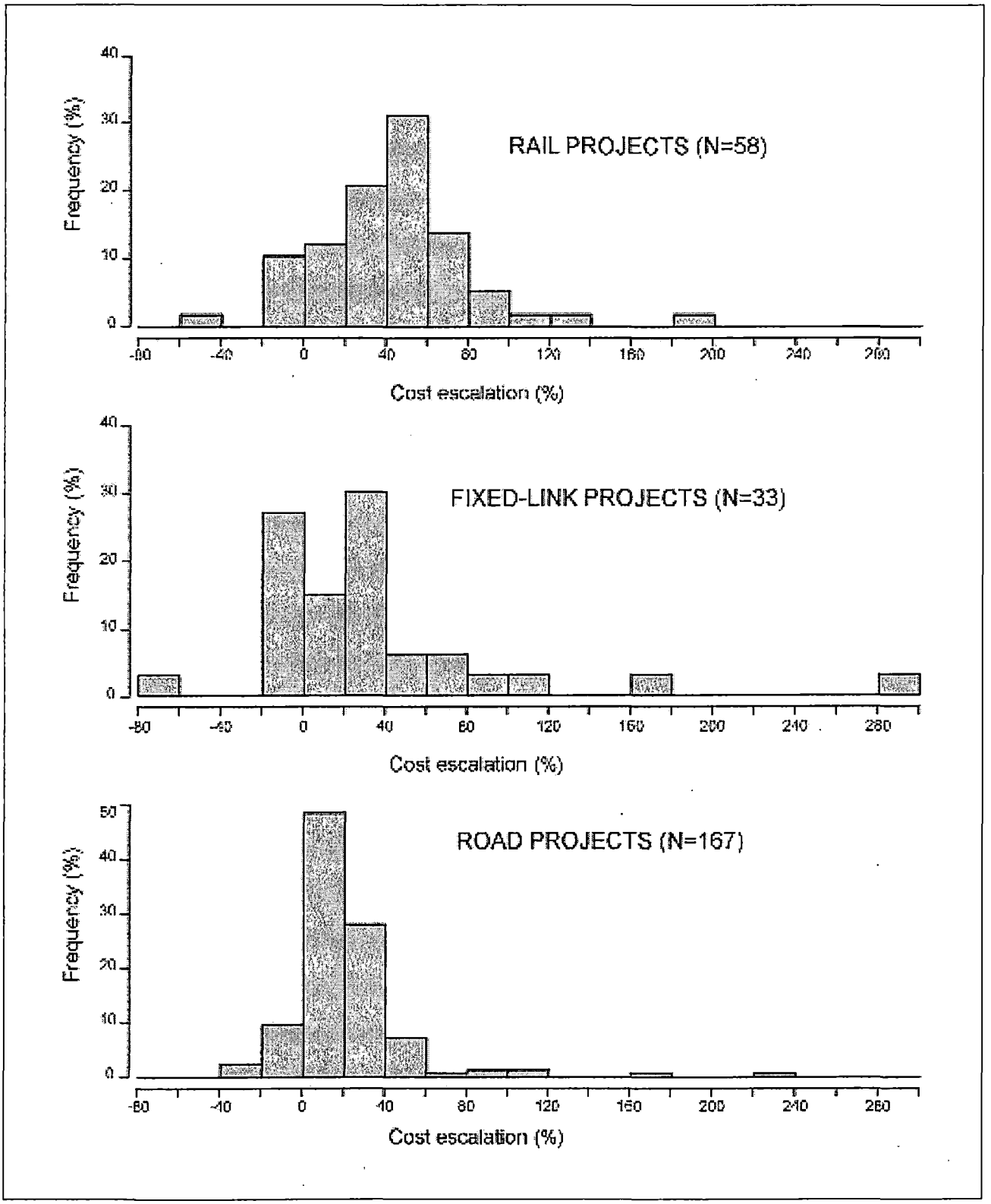

FIGURE 2. Inaccuracy of cost estimates in rail, fixed-link, and road projects (fixed prices).

mation among rail, fixed-link, and road projects must be answered in the affirmative. The average difference between actual and estimated costs for rail projects is substantially and significantly higher than that for roads, with fixed-link projects in a statistically nonsignificant middle position. The average inaccuracy for rail projects is more than twice that for roads, resulting in average cost escalations for rail more than double that for roads. For all three project types, the evidence shows that it is sound advice for policy and decision makers as well as investors, bankers, media, and the public to take any estimate of construction costs with a grain of salt, especially for rail and fixed-link projects.

Cost Underestimation by Geographical Location

In addition to testing whether cost underestimation differs for different kinds of projects, we also tested whether it varies with geographical location among Europe, North America, and "other geographical areas" (a group of 10 developing nations plus Japan). Table 2 shows the differences between actual and estimated costs in these three areas for rail, fixed-link, and road projects. There is no indication of statistical interaction between geographical area and type of project. We therefore consider the effects from these variables on cost underestimation separately. For all projects, we find that the difference between geographical areas in terms of underestimation is highly significant ($p<0.001$). Geography matters to cost underestimation.

If Europe and North America are compared separately, which is compulsory for fixed links and roads because no observations exist for these projects in other geographical areas, comparisons can be made by t-tests (as the standard deviations are rather different, the Welch version is used). For fixed-link projects, the average difference between actual and estimated costs is 43.4% in Europe versus 25.7% North America, but the difference between the two geographical areas is nonsignificant ($p=0.414$). Given the limited number of observations and the large standard deviations for fixed-link projects, we would need to enlarge the sample with more fixed-link projects in Europe and North America in order to test whether the differences might be significant for more observations. For rail projects, the average difference between actual and estimated costs is 34.2% in Europe versus 40.8% in North America. For road projects, the similar numbers are 22.4% versus 8.4%. Again, the differences between geographical areas are nonsignificant ($p=0.510$ and $p=0.184$, respectively).

We conclude, accordingly, that the highly significant differences we found above for geographical location come from projects in the "other geographical areas" category. The average difference between actual and estimated costs in this category is a hefty 64.6%.

Have Estimates Improved Over Time?

In the previous two sections, we saw how cost underestimation varies with project type and geography. In this section, we conclude the statistical analyses by studying how underestimation has varied over time. We ask and answer the question of whether project promoters and forecasters have become more or less inclined over time to underestimate the costs of transportation infrastructure projects. If underestimation were unintentional and related to lack of experience or faulty methods in estimating and forecasting costs, then, a priori, we would expect underestimation to decrease over time as better methods were developed and more experience gained through the planning and implementation of more infrastructure projects.

Figure 3 shows a plot of the differences between actual and estimated costs against year of decision to build

TABLE 2. Inaccuracy of transportation project cost estimates by geographical location (fixed prices).

	Europe			North America			Other geographical areas		
Project type	Number of projects (N)	Average cost escalation (%)	Standard deviation	Number of projects (N)	Average cost escalation (%)	Standard deviation	Number of projects (N)	Average cost escalation (%)	Standard deviation
Rail	23	34.2	25.1	19	40.8	36.8	16	64.6	49.5
Fixed-link	15	43.4	52.0	18	25.7	70.5	0	—	—
Road	143	22.4	24.9	24	8.4	49.4	0	—	—
All projects	181	25.7	28.7	61	23.6	54.2	16	64.6	49.5

for the 111 projects in the sample for which these data are available. The diagram does not seem to indicate an effect from time on cost underestimation. Statistical analyses corroborate this impression. The null hypothesis that year of decision has no effect on the difference between actual and estimated costs cannot be rejected (p=0.22, F-test). A test using year of completion instead of year of decision (with data for 246 projects) gives a similar result (p=0.28, F-test).

We therefore conclude that cost underestimation has not decreased over time. Underestimation today is in the same order of magnitude as it was 10, 30, and 70 years ago. If techniques and skills for estimating and forecasting costs of transportation infrastructure projects have improved over time, this does not show in the data. No learning seems to take place in this important and highly costly sector of public and private decision making. This seems strange and invites speculation that the persistent existence over time, location, and project type of significant and widespread cost underestimation is a sign that an equilibrium has been reached: Strong incentives and weak disincentives for underestimation may have taught project promoters what there is to learn, namely, that cost underestimation pays off. If this is the case, underestimation must be expected and it must be expected to be intentional. We examine such speculation below. Before doing so, we compare cost underestimation in transportation projects with that in other projects.

Cost Underestimation in Other Infrastructure Projects

In addition to cost data for transportation infrastructure projects, we have reviewed cost data for several hundred other projects including power plants, dams, water distribution, oil and gas extraction, information technology systems, aerospace systems, and weapons systems (Arditi et al., 1985; Blake et al., 1976; Canaday, 1980; Department of Energy Study Group, 1975; Dlakwa & Culpin, 1990; Fraser, 1990; Hall, 1980; Healey, 1964; Henderson, 1977; Hufschmidt & Gerin, 1970; Merewitz, 1973b; Merrow, 1988; Morris & Hough, 1987; World Bank, 1994, n.d.). The data indicate that other types of projects are at least as, if not more, prone to cost underestimation as are transportation infrastructure projects.

Among the more spectacular examples of cost underestimation are the Sydney Opera House, with actual costs approximately 15 times higher than those projected, and the Concorde supersonic airplane, with a cost 12 times higher than predicted (Hall, n.d., p. 3). The data also indicate that cost underestimations for other projects have neither increased nor decreased historically, and that underestimation is common in both First- and Third-World countries. When the Suez canal was completed in 1869, actual construction costs were 20 times higher than the earliest estimated costs and 3 times higher than the cost estimate for the year before construction began. The Panama Canal, which was completed in 1914, had cost escalations in the range of 70 to 200% (Summers, 1967, p. 148).

In sum, the phenomena of cost underestimation and escalation appear to be characteristic not only of transportation projects but of other types of infrastructure projects as well.

Explanations of Underestimation: Error or Lie?

Explanations of cost underestimation come in four types: technical, economic, psychological, and political. In this section, we examine which explanations best fit our data.

Technical Explanations

Most studies that compare actual and estimated costs of infrastructure projects explain what they call "forecasting errors" in technical terms, such as imperfect techniques, inadequate data, honest mistakes, inherent problems in predicting the future, lack of experience on the part of forecasters, etc. (Ascher, 1978; Flyvbjerg et al., in press; Morris & Hough, 1987; Wachs, 1990). Few would dispute that such factors may be important sources of uncertainty and may result in misleading forecasts. And for small-sample studies, which are typical of this research field, technical explanations have gained credence because samples have been too small to allow tests by statistical methods. However, the data and tests presented above, which come from the first large-sample study in the field, lead us to reject technical explanations of forecasting errors. Such explanations simply do not fit the data.

First, if misleading forecasts were truly caused by technical inadequacies, simple mistakes, and inherent problems with predicting the future, we would expect a less biased distribution of errors in cost estimates around zero. In fact, we have found with overwhelming statistical significance (p<0.001) that the distribution of such errors has a nonzero mean. Second, if imperfect techniques, inadequate data, and lack of experience were main explanations of the underestimations, we would expect an improvement in forecasting accuracy over time, since errors and their sources would be recognized and addressed through the refinement of data collection, forecasting methods, etc. Substantial resources have

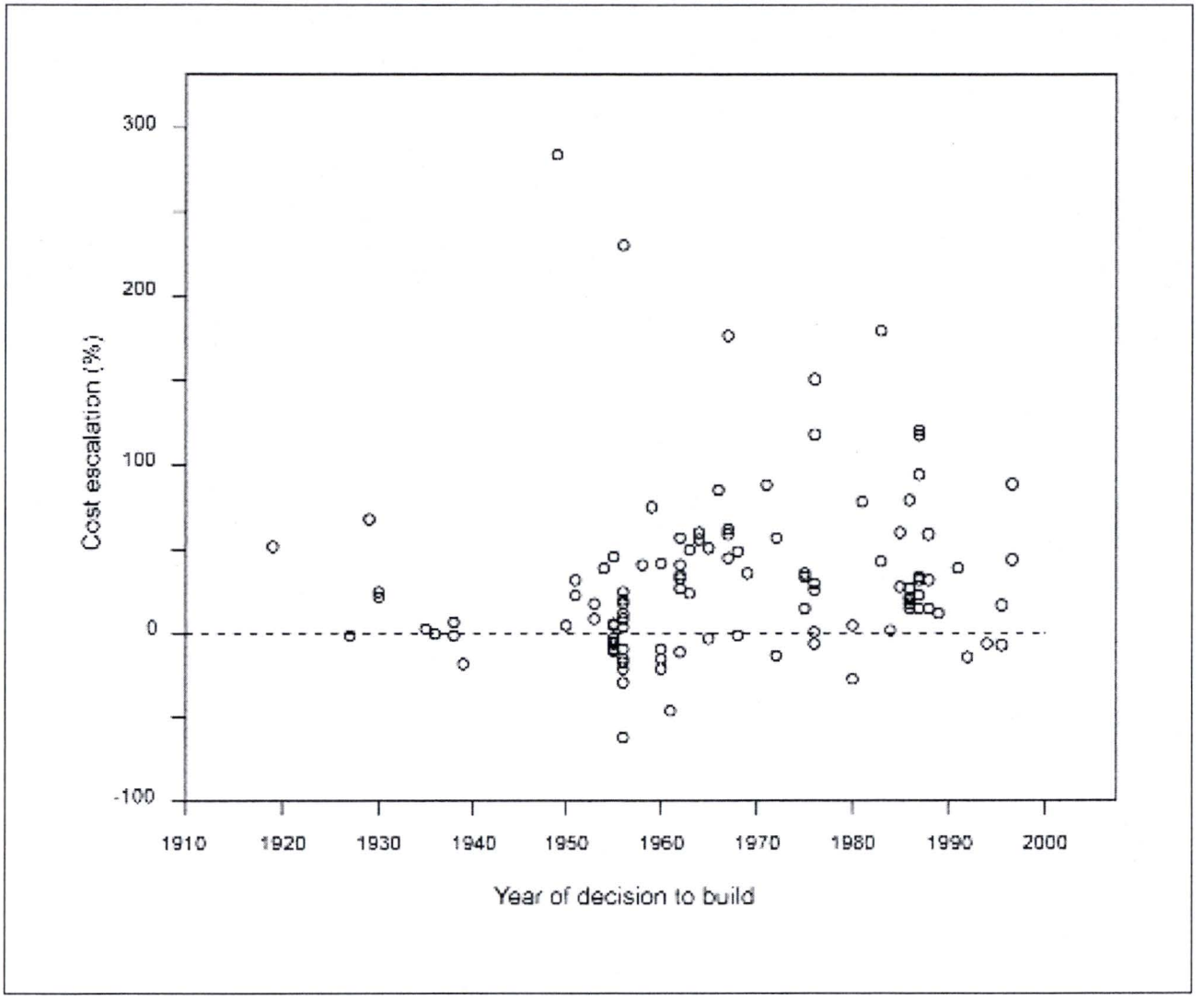

FIGURE 3. Inaccuracy of cost estimates in transportation projects over time, 1910–1998 (fixed prices, 111 projects).

been spent over several decades on improving data and methods. Still our data show that this has had no effect on the accuracy of forecasts. Technical factors, therefore, do not appear to explain the data. It is not so-called forecasting "errors" or cost "escalation" or their causes that need explaining. It is the fact that in 9 out of 10 cases, costs are underestimated.

We may agree with proponents of technical explanations that it is, for example, impossible to predict for the individual project exactly *which* geological, environmental, or safety problems will appear and make costs soar. But we maintain that it is possible to predict the risk, based on experience from other projects, *that* some such problems will haunt a project and how this will affect costs. We also maintain that such risk can and should be accounted for in forecasts of costs, but typically is not. For technical explanations to be valid, they would have to explain why forecasts are so consistent in ignoring cost risks over time, location, and project type.

Economic Explanations

Economic explanations conceive of cost underestimation in terms of economic rationality. Two types of economic explanation exist; one explains in terms of eco-

nomic self-interest, the other in terms of the public interest. As regards self-interest, when a project goes forward, it creates work for engineers and construction firms, and many stakeholders make money. If these stakeholders are involved in or indirectly influence the forecasting process, then this may influence outcomes in ways that make it more likely that the project will be built. Having costs underestimated and benefits overestimated would be economically rational for such stakeholders because it would increase the likelihood of revenues and profits. Economic self-interest also exists at the level of cities and states. Here, too, it may explain cost underestimation. Pickrell (1990, 1992) pointed out that transit capital investment projects in the U.S. compete for discretionary grants from a limited federal budget each year. This creates an incentive for cities to make their projects look better, or else some other city may get the money.

As regards the public interest, project promoters and forecasters may deliberately underestimate costs in order to provide public officials with an incentive to cut costs and thereby to save the public's money. According to this type of explanation, higher cost estimates would be an incentive for wasteful contractors to spend more of the taxpayer's money. Empirical studies have identified promoters and forecasters who say they underestimate costs in this manner and with this purpose (i.e., to save public money; Wachs, 1990). The argument has also been adopted by scholars, for instance Merewitz (1973b), who explicitly concludes that "keeping costs low is more important than estimating costs correctly" (p. 280).

Both types of economic explanation account well for the systematic underestimation of costs found in our data. Both depict such underestimation as deliberate, and as economically rational. If we now define a lie in the conventional fashion as making a statement intended to deceive others (Bok, 1979, p. 14; Cliffe et al., 2000, p. 3), we see that deliberate cost underestimation is lying, and we arrive at one of the most basic explanations of lying, and of cost underestimation, that exists: Lying pays off, or at least economic agents believe it does. Moreover, if such lying is done for the public good (e.g., to save taxpayers' money), political theory would classify it in that special category of lying called the "noble lie," the lie motivated by altruism. According to Bok (1979), this is the "most dangerous body of deceit of all" (p. 175).

In the case of cost underestimation in public works projects, proponents of the noble lie overlook an important fact: Their core argument—that taxpayers' money is saved by cost underestimation—is seriously flawed. Anyone with even the slightest trust in cost-benefit analysis and welfare economics must reject this argument. Underestimating the costs of a given project leads to a falsely high benefit-cost ratio for that project, which in turn leads to two problems. First, the project may be started despite the fact that it is not economically viable. Or, second, it may be started instead of another project that would have yielded higher returns had the actual costs of both projects been known. Both cases result in the inefficient use of resources and therefore in waste of taxpayers' money. Thus, for reasons of economic efficiency alone, the argument that cost underestimation saves money must be rejected; underestimation is more likely to result in waste of taxpayers' money. But the argument must also be rejected for ethical and legal reasons. In most democracies, for project promoters and forecasters to deliberately misinform legislators, administrators, bankers, the public, and the media would not only be considered unethical but in some instances also illegal, for instance where civil servants would misinform cabinet members or cabinet members would misinform the parliament. There is a formal "obligation to truth" built into most democratic constitutions on this point. This obligation would be violated by deliberate underestimation of costs, whatever the reasons may be. Hence, even though economic explanations fit the data and help us understand important aspects of cost underestimation, such explanations cannot be used to justify it.

Psychological Explanations

Psychological explanations attempt to explain biases in forecasts by a bias in the mental makeup of project promoters and forecasters. Politicians may have a "monument complex," engineers like to build things, and local transportation officials sometimes have the mentality of empire builders. The most common psychological explanation is probably "appraisal optimism." According to this explanation, promoters and forecasters are held to be overly optimistic about project outcomes in the appraisal phase, when projects are planned and decided (Fouracre et al., 1990, p. 10; Mackie & Preston, 1998; Walmsley & Pickett, 1992, p. 11; World Bank, 1994, p. 86). An optimistic cost estimate is clearly a low one. The existence of appraisal optimism in promoters and forecasters would result in actual costs being higher than estimated costs. Consequently, the existence of appraisal optimism would be able to account, in whole or in part, for the peculiar bias of cost estimates found in our data, where costs are systematically underestimated. Such optimism, and associated cost underestimation, would not be lying, needless to say, because the deception involved is self-deception and therefore not deliberate. Cost underestimation would be error according to this explanation.

There is a problem with psychological explanations, however. Appraisal optimism would be an important

and credible explanation of underestimated costs if estimates were produced by inexperienced promoters and forecasters, i.e., persons who were estimating costs for the first or second time and who were thus unknowing about the realities of infrastructure building and were not drawing on the knowledge and skills of more experienced colleagues. Such situations may exist and may explain individual cases of cost underestimation. But given the fact that the human psyche is distinguished by a significant ability to learn from experience, it seems unlikely that promoters and forecasters would continue to make the same mistakes decade after decade instead of learning from their actions. It seems even more unlikely that a whole profession of forecasters and promoters would collectively be subject to such a bias and would not learn over time. Learning would result in the reduction, if not elimination, of appraisal optimism, which would then result in cost estimates becoming more accurate over time. But our data clearly shows that this has not happened.

The profession of forecasters would indeed have to be an optimistic group to keep their appraisal optimism throughout the 70-year period our study covers and not learn that they were deceiving themselves and others by underestimating costs. This would account for the data, but is not a credible explanation. As observed elsewhere, the incentive to publish and justify optimistic estimates is very strong, and the penalties for having been overoptimistic are generally insignificant (Davidson & Huot, 1989, p. 137; Flyvbjerg et al., in press). This is a better explanation of the pervasive existence of optimistic estimates than an inherent bias for optimism in the psyche of promoters and forecasters. And "optimism" calculated on the basis of incentives is not optimism, of course; it is deliberate deception. Therefore, on the basis of our data, we reject appraisal optimism as a primary cause of cost underestimation.

Political Explanations

Political explanations construe cost underestimation in terms of interests and power (Flyvbjerg, 1998). Surprisingly little work has been done that explains the pattern of misleading forecasts in such terms (Wachs, 1990, p. 145). A key question for political explanations is whether forecasts are intentionally biased to serve the interests of project promoters in getting projects started. This question again raises the difficult issue of lying. Questions of lying are notoriously hard to answer, because in order to establish whether lying has taken place, one must know the intentions of actors. For legal, economic, moral, and other reasons, if promoters and forecasters have intentionally fabricated a deceptive cost estimate for a project to get it started, they are unlikely to tell researchers or others that this is the case (Flyvbjerg, 1996; Wachs, 1989).

When Eurotunnel, the private company that owns the tunnel under the English Channel, went public in 1987 to raise funds for the project, investors were told that building the tunnel would be relatively straightforward. Regarding risks of cost escalation, the prospectus read:

> Whilst the undertaking of a tunneling project of this nature necessarily involves certain construction risks, the techniques to be used are well proven. . . . The Directors, having consulted the Mâitre d'Oeuvre, believe that 10% . . . would be a reasonable allowance for the possible impact of unforeseen circumstances on construction costs.[2] ("Under Water," 1989, p. 37)

Two hundred banks communicated these figures for cost and risk to investors, including a large number of small investors. As observed by *The Economist* ("Under Water," 1989), anyone persuaded in this way to buy shares in Eurotunnel in the belief that the cost estimate was the mean of possible outcomes was, in effect, deceived. The cost estimate of the prospectus was a best possible outcome, and the deception consisted in making investors believe in the highly unlikely assumption—disproved in one major construction project after another—that everything would go according to plan, with no delays; no changes in safety and environmental performance specifications; no management problems; no problems with contractual arrangements, new technologies, or geology; no major conflicts; no political promises not kept; etc. The assumptions were, in other words, those of an ideal world. The real risks of cost escalation for the Channel tunnel were many times higher than those communicated to potential investors, as evidenced by the fact that once built, the real costs of the project were higher by a factor of two compared with forecasts.

Flyvbjerg, Bruzelius, and Rothengatter (in press) document for a large number of projects that the Everything-Goes-According-to-Plan type of deception used for the Channel tunnel is common. Such deception is, in fact, so widespread that in a report on infrastructure and development, the World Bank (1994, pp. ii, 22) found reason to coin a special term for it: the "EGAP-principle." Cost estimation following the EGAP-principle simply disregards the risk of cost escalation resulting from delays, accidents, project changes, etc. This is a major problem in project development and appraisal, according to the World Bank.

It is one thing, however, to point out that investors, public or private, were deceived in particular cases. It is

quite another to get those involved in the deceptions to talk about this and to possibly admit that deception was intentional, i.e., that it was lying. We are aware of only one study that actually succeeded in getting those involved in underestimating costs to talk about such issues (Wachs, 1986, 1989, 1990). Wachs interviewed public officials, consultants, and planners who had been involved in transit planning cases in the U.S. He found that a pattern of highly misleading forecasts of costs and patronage could not be explained by technical issues and were best explained by lying. In case after case, planners, engineers, and economists told Wachs that they had had to "cook" forecasts in order to produce numbers that would satisfy their superiors and get projects started, whether or not the numbers could be justified on technical grounds (Wachs, 1990, p. 144). One typical planner admitted that he had repeatedly adjusted the cost figures for a certain project downward and the patronage figures upward to satisfy a local elected official who wanted to maximize the chances of getting the project in question started. Wachs' work is unusually penetrating for a work on forecasting. But again, it is small-sample research, and Wachs acknowledges that most of his evidence is circumstantial (Wachs, 1986, p. 28). The evidence does not allow conclusions regarding the project population. Nevertheless, based on the strong pattern of misrepresentation and lying found in his case studies, Wachs goes on to hypothesize that the type of abuse he has uncovered is "nearly universal" (1990, p. 146; 1986, p. 28) and that it takes place not only in transit planning but also in other sectors of the economy where forecasting routinely plays an important role in policy debates.

Our data give support to Wachs' claim. The pattern of highly underestimated costs is found not only in the small sample of projects Wachs studied; the pattern is statistically significant and holds for the project population mean (i.e., for the majority of transportation infrastructure projects). However, on one point, Wachs (1986) seems to draw a conclusion somewhat stronger than is warranted. "[F]orecasted costs always seem to be *lower* than actual costs" (p. 24) he says (emphasis in original). Our data show that although "always" (100%) may cover the small sample of projects Wachs chose to study, when the sample is enlarged by a factor of 20–30 to a more representative one, "only" in 86% of all cases are forecasted costs lower than actual costs. Such trifles—14 percentage points—apart, the pattern identified by Wachs is a general one, and his explanation of cost underestimation in terms of lying to get projects started fit our data particularly well. Of the existing explanations of cost development in transportation infrastructure projects, we therefore opt for political and economic explanations. The use of deception and lying as tactics in power struggles aimed at getting projects started and at making a profit appear to best explain why costs are highly and systematically underestimated in transportation infrastructure projects.

Summary and Conclusions

The main findings from the study reported in this article—all highly significant and most likely conservative—are as follows:

- In 9 out of 10 transportation infrastructure projects, costs are underestimated.
- For rail projects, actual costs are on average 45% higher than estimated costs (sd=38).
- For fixed-link projects (tunnels and bridges), actual costs are on average 34% higher than estimated costs (sd=62).
- For road projects, actual costs are on average 20% higher than estimated costs (sd=30).
- For all project types, actual costs are on average 28% higher than estimated costs (sd=39).
- Cost underestimation exists across 20 nations and 5 continents; it appears to be a global phenomenon.
- Cost underestimation appears to be more pronounced in developing nations than in North America and Europe (data for rail projects only).
- Cost underestimation has not decreased over the past 70 years. No learning that would improve cost estimate accuracy seems to take place.
- Cost underestimation cannot be explained by error and seems to be best explained by strategic misrepresentation, i.e., lying.
- Transportation infrastructure projects do not appear to be more prone to cost underestimation than are other types of large projects.

We conclude that the cost estimates used in public debates, media coverage, and decision making for transportation infrastructure development are highly, systematically, and significantly deceptive. So are the cost-benefit analyses into which cost estimates are routinely fed to calculate the viability and ranking of projects. The misrepresentation of costs is likely to lead to the misallocation of scarce resources, which, in turn, will produce losers among those financing and using infrastructure, be they taxpayers or private investors.

We emphasize that these conclusions should not be interpreted as an attack on public (vs. private) spending on infrastructure, since the data are insufficient to decide whether private projects perform better or worse

than public ones regarding cost underestimation. Nor do the conclusions warrant an attack on spending on transportation vs. spending on other projects, since other projects appear to be as liable to cost underestimation and escalation as are transportation projects. With transportation projects as an in-depth case study, the conclusions simply establish that significant cost underestimation is a widespread practice in project development and implementation, and that this practice forms a substantial barrier to the effective allocation of scarce resources for building important infrastructure.

The key policy implication for this consequential and highly expensive field of public policy is that those legislators, administrators, bankers, media representatives, and members of the public who value honest numbers should not trust the cost estimates presented by infrastructure promoters and forecasters. Another important implication is that institutional checks and balances—including financial, professional, or even criminal penalties for consistent or foreseeable estimation errors—should be developed to ensure the production of less deceptive cost estimates. The work of designing such checks and balances has been begun elsewhere, with a focus on four basic instruments of accountability: (1) increased transparency, (2) the use of performance specifications, (3) explicit formulation of the regulatory regimes that apply to project development and implementation, and (4) the involvement of private risk capital, even in public projects (Bruzelius et al., 1998; Flyvbjerg et al., in press).

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NOTES

1. Merewitz's (1973a, 1973b) study compared cost overrun in urban rapid transit projects, especially the San Francisco Bay Area Rapid Transit (BART) system, with overrun in other types of public works projects. Merewitz's aims were thus different from ours, and his sample of transportation projects was substantially smaller: 17 rapid transit projects and 49 highway projects, compared with our 58 rail projects, 167 highway projects, and 33 bridge or tunnel projects. In addition to issues of a small sample, in our attempt to replicate Merewitz's analysis we found that his handling of data raises a number of other issues. First, Merewitz did not correct his cost data for inflation, i.e., current prices were used instead of fixed ones. This is known to be a major source of error due to varying inflation rates between projects and varying duration of construction periods. Second, in statistical tests, Merewitz compared the mean cost overrun of subgroups of projects (e.g., rapid transit) with the grand mean of overrun for all projects, thus making the error of comparing projects with themselves. Subgroups should be tested directly against other subgroups in deciding whether they differ at all and, if so, which ones differ. Third, Merewitz's two reports (1973a, 1973b) are inconsistent. One (1973a) calculates the grand mean of cost overrun as the average of means for subgroups; that is, the grand mean is unweighted, where common practice is to use the weighted mean, as appears to be the approach taken in the other (1973b). Fourth, due to insufficient information, the p-values calculated by Merewitz are difficult to verify; most likely they are flawed, however, and Merewitz's one-sided p-values are misleading. Finally, Merewitz used a debatable assumption about symmetry, which has more impact for the nonparametric test used than nonnormality has for parametric methods. Despite these shortcomings, the approach taken in Merewitz's study was innovative for its time and in principle pointed in the right direction regarding how to analyze cost escalation in public works projects. The study cannot be said to be a true large-sample study for transportation infrastructure, however, and its statistical significance is unclear.
2. The Maître d'Oeuvre was an organization established to monitor project planning and implementation for the Channel tunnel. It was established in 1985, and until 1988 it represented the owners. In 1988 it was reverted to an impartial position (Major Projects Association, 1994, pp. 151–153).

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APPENDIX

The first task of the research reported in this paper was to establish a sample of infrastructure projects substantially larger than what is common in this area of research, a sample large enough to allow statistical analyses of costs. Here a first problem was that data on actual costs in transportation infrastructure projects are relatively difficult to come by. One reason is that it is quite time consuming to produce such data. For public sector projects, funding and accounting procedures are typically unfit for keeping track of the multiple and complex changes that occur in total project costs over time. For large projects, the relevant time frame may cover 5, 10, or more fiscal years from decision to build, until construction starts, until the project is completed and operations begin. Reconstructing the actual total costs of a public project, therefore, typically entails long and difficult archival work and complex accounting. For private projects, even if funding and accounting practices may be more conducive to producing data on actual total costs, such data are often classified to keep them from the hands of competitors. Unfortunately, this also tends to keep data from the hands of scholars. And for both public and private projects, data on actual costs may be held back by project owners because more often than not, actual costs reveal substantial cost escalation, and cost escalation is normally considered somewhat of an embarrassment to promoters and owners. In sum, establishing reliable data on actual costs for even a single transportation infrastructure project is often highly time consuming or simply impossible.

This state of affairs explains why small-sample studies dominate scholarship in this field of research. But despite the problems mentioned, after 4 years of data collection and refinement, we were able to establish a sample of 258 transportation infrastructure projects with data on both actual construction costs and estimated costs at the time of decision to build. The project portfolio is worth approximately US$90 billion (1995 prices). The project types are bridges, tunnels, highways, freeways, high-speed rail, urban rail, and conventional (interurban) rail. The projects are located in 20 countries on 5 continents, including both developed and developing nations. The projects were completed between 1927 and 1998. Older projects were included in the sample in order to test whether the accuracy of estimated costs improved over time. The construction costs of projects range from US$1.5 million to US$8.5 billion (1995 prices), with the smallest projects typically being stretches of roads in larger road schemes, and the largest projects being rail links, tunnels, and bridges. As far as we know, this is the largest sample of projects with data on cost development that has been established in this field of research.

In statistical analysis, data should be a sample from a larger population, and the sample should represent the population properly. These requirements are ideally satisfied by drawing the sample by randomized lot. Randomization ensures with high probability that factors that cannot be controlled are equalized. A sample should also be designed such that the representation of subgroups corresponds to their occurrence and importance in the population. In studies of human affairs, however, where controlled laboratory experiments often cannot be conducted, it is frequently impossible to meet these ideal conditions. This is also the case for the current study, and we therefore had to take a different approach to sampling and statistical analysis.

We selected the projects for the sample on the basis of data availability. All projects that we knew of for which data on construction cost development were obtainable were considered for inclusion in the sample. Cost development is defined as the difference between actual and estimated costs in percentage of estimated costs, with all costs measured in fixed prices. Actual costs are defined as real, accounted costs determined at the time of completing a project. Estimated costs are defined as budgeted, or forecasted, costs at the time of decision to build. Even if the project planning process varies with project type, country, and time, it is typically possible to locate for any given project a specific point in the process that can be identified as the time of decision to build. Usually a cost estimate was available for this point in time. If not, the closest available estimate was used, typically a later estimate resulting in a conservative bias in our measurement of cost development. Cost data were collected from a variety of sources, including annual project accounts, questionnaires, interviews, and other studies.

Data on cost development were available for 343 projects. We then rejected 85 projects because of insufficient data quality. For instance, for some projects we could not obtain a clear answer regarding what was included in costs, or whether cost data were given in current or fixed prices, or which price level (year) had been used in estimating and discounting costs. More specifically, of those 85 projects, we rejected 27 because we could not establish whether or not cost data were valid and reliable. We rejected 12 projects because they had been completed before 1915 and no reliable indices were available for discounting costs to the present. Finally, we excluded 46 projects because cost development for them turned out to have been calculated before construction was completed and operations begun; therefore, the actual final costs for these projects may be different from the cost estimates used to calculate cost development, and no information was available on actual final costs. In addition to the 85 rejected projects mentioned here, we also rejected a number of projects to avoid double counting of projects. This typically involved projects from other studies that appeared in more than one study or where we had a strong suspicion that this might be the case. In sum, all projects for which data were considered valid and reliable were included in the sample. This covers both projects for which we ourselves collected the data and projects for which other researchers in other studies did the data collection (Fouracre et al., 1990; Hall, 1980; Leavitt et al., 1993; Lewis, 1986; Merewitz, 1973a; National Audit Office, Department of Transport, 1985, 1992; National Audit Office, Department of Transport, Scottish Development Department, & Welsh Office, 1988; Pickrell, 1990; Riksrevisionsverket, 1994; Vejdirektoratet, 1995; Walmsley & Pickett, 1992). Cost data were made comparable across projects by discounting prices to the 1995 level and calculating them in Euros, using the appropriate geographical, sectoral, and historical indices for discounting and the appropriate exchange rates for conversion between currencies.

Our own data collection concentrated on large European projects because too few data existed for this type of project to allow comparative studies. For instance, for projects with actual construction costs larger than 500 million Euros (1995 prices; EUR1=US$1.29 in 1995), we were initially able to identify from other studies only two European projects for which data were available on both actual and estimated costs. If we lowered the project size and looked at projects larger than 100 million Euros, we were able to identify such data for eight European projects. We saw the lack of reliable cost data for European projects as particularly problematic since the Commission of the European Union had just launched its policy for establishing the so-called trans-European transport networks, which would involve the construction of a large number of major transportation infrastructure projects across Europe at an initial cost of 220 billion Euros (Commission of the European Union, 1993, p. 75). As regards costs, we concluded that the knowledge base for the Commission's policy was less than well developed, and we hoped to help remedy this situation through our data collection. Our efforts on this point proved successful. We collected primary data on cost for 37 projects in Denmark, France, Germany, Sweden, and the U.K. and were thus able to greatly increase the number of large European projects with reliable data for both actual and estimated costs, allowing for the first time a comparative study for this type of project in which statistical methods could be applied.

As for any sample, a key question is whether the sample is representative of the population. Here the question is whether the projects included in the sample are representative of the population of transportation infrastructure projects. Since the criterion for sampling was data availability, this question translates into one of whether projects with available data are representative. There are four reasons why this is probably not the case. First, it may be speculated that projects that are managed well with respect to data availability may also be managed well in other respects, resulting in better than average (i.e., nonrepresentative) performance for such projects. Second, it has been argued that the very existence of data that make the evaluation of performance possible may contribute to improved performance when such data are used by project management to monitor projects (World Bank, 1994, p. 17). Again, such projects would not be representative of the project population. Third, we might speculate that managers of projects with a particularly bad track record regarding cost escalation have an interest in not making cost data available, which would then result in underrepresentation of such projects in the sample. Conversely, managers of projects with a good track record for costs might be interested in making this public, resulting in overrepresentation of these projects. Fourth, and finally, even where managers have made cost data available, they may have chosen to give out data that present their projects in as favorable a light as possible. Often there are several estimates of costs to choose from and several calculations of actual costs for a given project at a given time. If researchers collect data by means of survey questionnaires, as is often the case, there might be a temptation for managers to choose the combination of actual and estimated costs that suits them best, possibly a combination that makes their projects look good.

The available data do not allow an exact, empirical assessment of the magnitude of the problem of misrep-

resentation. But the few data that exist that shed light on this problem support the thesis that data are biased. When we compared data from the Swedish Auditor General for a subsample of road projects, for which the problems of misrepresentation did not seem to be an issue, with data for all road projects in our sample, we found that cost escalation in the Swedish subsample is significantly higher than for all projects (Holm, 1999, pp. 11–15). We conclude, for the reasons given above, that most likely the sample is biased and the bias is conservative. In other words, the difference between actual and estimated costs derived from the sample is likely to be lower than the difference in the project population. This should be kept in mind when interpreting the results from statistical analyses of the sample. The sample is not perfect by any means. Still it is the best obtainable sample given the current state of the art in this field of research.

In the statistical analyses, percentage cost development in the sample is considered normally distributed unless otherwise stated. Residual plots, not shown here, indicate that normal distribution might not be completely satisfied, the distributions being somewhat skewed with larger upper tails. However, transformations (e.g., the logarithmic one) do not improve this significantly. For simplicity, therefore, no transformation has been made, unless otherwise stated.

The subdivisions of the sample implemented as part of analyses entail methodological problems of their own. Thus the representation of observations in different combinations of subgroups is quite skewed for the data considered. The analysis would be improved considerably if the representation were more even. Partial and complete confounding occur; that is, if a combination of two or more effects is significant, it is sometimes difficult to decide whether one, the other, or both cause the difference. For interactions, often not all the combinations are represented, or the representations can be quite scarce. We have adapted our interpretations of the data to these limitations, needless to say. If better data could be gathered, sharper conclusions could be made.

The statistical models used are linear normal models (i.e., analysis of variance and regression analysis with the appropriate F-tests and t-tests). The tests of hypotheses concerning mean values are known to be robust to deviations from normality. Also, chi-square tests for independence have been used for count data. For each test, the p-value has been reported. This value is a measure for rareness if identity of groups is assumed. Traditionally, a p-value less than 0.01 is considered highly significant and less than 0.05 significant, whereas a larger p-value means that the deviation could be due to chance.

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PROJECT MANAGEMENT

Understanding and managing risks in large engineering projects

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Abstract

Understanding and managing risks in projects especially large engineering initiatives are challenging tasks. Risks first need to be dissected into categories such as (1) market-related, demand, financial and supply, (2) completion/technical/construction and operational, (3) institutional, regulatory, social acceptability and sovereign. Strategies for coping with foreseeable risks can be developed using management science approaches keeping in mind that costs of controlling risks must fit with expected benefits. Most risks and their control however need to be framed not as technical issues but as managerial problems. Some risks can be mastered by direct allocation and mitigation. Others are best controlled if shifted to cospecialized players with competencies, interest and knowledge. Still others need to be diversified through financial instruments. Finally, a number of thorny risks can only be tackled by influencing drivers and institutions which push risks upward. A process to cope with these varied risks is proposed.
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Keywords: Risks; strategies; institutions; decision theory

Large engineering projects are high-stakes games characterized by substantial irreversible commitments, skewed reward structures in case of success, and high probabilities of failure. Once built, projects have little use beyond the original intended purpose. Potential returns can be good but they are often truncated. The journey to the period of revenue generation takes 10 years on average. Substantial front-end expenditures prior to committing large capital costs have to be carried. During the ramp-up period, market estimates are tested and the true worth of the project appears; sponsors may find that it is much lower than expected. Bankers can discover that covenants will not be respected. Restructuring of ownership and debt may be the only way to save prior investments.

Managing risks is thus a real issue. The purpose of this article is to sketch-out the various components of risks, outline strategies for coping with risks and suggest a dynamic layering model for managing and shaping the risks of projects. The main argument developed in this article is that successful projects are not selected but shaped with risk resolution in mind. Rather than evaluating projects at the outset based on projections of the full sets of benefits, costs and risks over their lifetime, successful sponsors start with project ideas that have the possibility of becoming viable. Successful sponsors then embark on shaping efforts to influence risk drivers. The seeds of success or failure are thus planted and nurtured as conscious choices are made. Successful firms cut their losses quickly when they recognize that a project has little possibility of becoming viable.

Sponsors' difficulties stem largely from the fact that most of what we know about risks has been inherited from either Wall Street or Las Vegas. At the casino, the odds are public knowledge; success is strictly a matter of "beating" them. In financial markets, price fluctuations are not fully probabilistic, but indices make for decision situations that can be modeled with a sophisticated craft. By contrast, risks in real-life projects emerge over time, are indeterminate and often endogenous. External turbulence and surprise shocks can send a project into a degenerating crisis.

1. A risk-based taxonomy of large engineering projects

Risks also differ according to types of projects. Fig. 1 positions various types of projects according to the intensity of the risks they pose to sponsors. For

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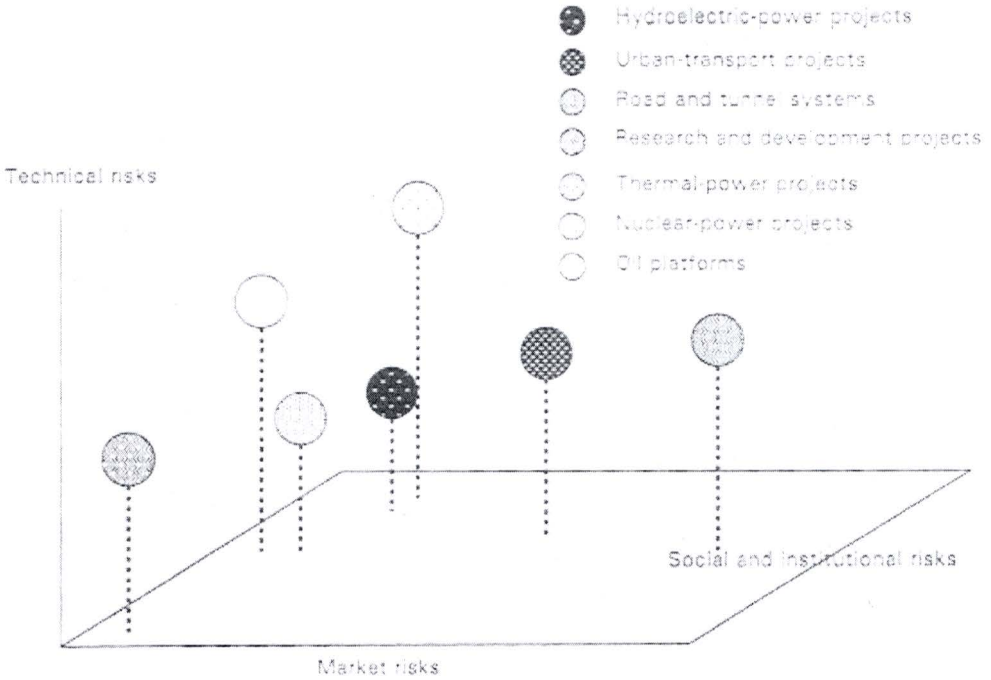

Fig. 1. A risk-based taxonomy of large engineering projects.

instance, *oil platforms* are technically difficult, but they typically face few institutional risks because they are often built far from public attention and are socially desired because of the high revenues they bring to communities and countries. *Hydroelectric-power projects* tend to be moderately difficult insofar as engineering is concerned, but very difficult in terms of social acceptability. *Nuclear-power projects* pose high technical risks but still higher social and institutional risks.

Road and tunnel systems present very high levels of risk. Rock formations usually hide surprises. Social acceptability difficulties abound when user fees are applied. Market risks faced by roads, bridges, and tunnels are very high when they are built by private sponsors under concessionary schemes. *Urban transport projects* that meet real needs pose average market, social, and institutional risks. However, they still pose technical risks, as they regularly involve underground geological work. *Research-and-development projects* present scientific challenges but face fewer social acceptability and market difficulties as they can be broken into smaller testable investments.

2. The nature of risks in projects

Risk is the possibility that events, their resulting impacts and dynamic interactions may turn out differently than anticipated. While risk is often viewed as something that can be described in statistical terms, uncertainty applies to situations in which potential outcomes and causal forces are not fully understood: we refer to both as risks. Risks are multi-dimensional and thus need to be unbundled for clear understanding of causes, outcomes, and drivers. Nevertheless, since their impacts depend on how they combine and interact, reductionism must be avoided.

In the IMEC[1] study in which 60 large engineering projects were investigated across the world, managers were asked to identify and rank the risks they faced in the early front-end period of each project [1].[2] Market-related risks dominated (41.7%), followed by technical risks (37.8%), and institutional sovereign risks (20.5%). Fig. 2 gives the frequency of citations of the risks that managers ranked first, second, and third in the early parts of projects.

Market-related risks

The ability to forecast *demand* varies widely, thus creating high levels of risks. The output of oil projects is a fungible commodity sold in highly integrated world markets: probabilistic forecasts are possible. In contrast, many road projects face a specific set of customers which often have many options. Users of highways, tunnels, bridges, airports, and ports often have alternatives: forecasting is extremely difficult.

[1] The International Program in the Management of Engineering and Construction (IMEC) was sponsored by a dozen large firms as well as by government agencies and institutional investors. Sixty large engineering projects were investigated.

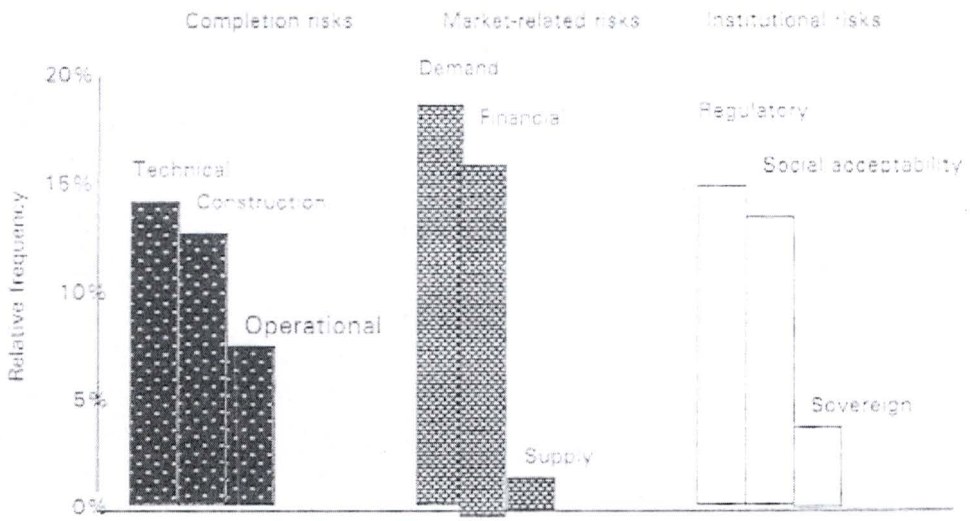

Fig. 2. Major risks in large engineering projects.

The market for *financial inputs* depends on prior risk management. Unless all risks have been addressed by sponsors, financial markets are hard to reach. If a project offers an adequate prospective return, it is often unable to go forward because of the parties' inability to work out acceptable risk-sharing arrangements. *Supply risks* are similar to market risks: both involve price and access uncertainties. Supply can be secured through contracts, open purchases or ownership.

Completion risks

Projects face *technical risks* that reflect their engineering difficulties and novelty; some of these risks are inherent in the designs or technologies employed. *Construction risks* refer to the difficulties that sponsors, prime contractors, and contractors may face in the actual building of the project. *Operational risks* refer to the possibility future income flows will not materialize: such risks can be reduced substantially by the selection of an operator with an economic interest in enhancing revenues and controlling costs.

Institutional risks

The ability of projects to repay debts and investments depends on law and regulations that govern the appropriability of returns, property rights, and contracts. Some countries are governed under constitutional frameworks and the rule of law, while others are led by powerful political parties or clans. Institutional risks are typically seen as greatest in emerging economies — in countries whose laws and regulation are incomplete and in a state of flux.

Regulations concerning pricing, entry, unbundling, and other elements are presently undergoing major changes in many countries, thus opening opportunities. *Social-acceptability risks* refer to the likelihood that sponsors will meet opposition from local groups, economic-development agencies, and influential pressure groups. *Sovereign risks* in turn involve the likelihood that a government will decide to renegotiate contracts, concessions, or property rights.

Many of these risks emerge over time. Projects that appeared sound at a point in time suddenly become ungovernable. Risks combine and interact to create turbulence. Many risks are linked to the life cycle of the project: regulatory risks, for instance, diminish very soon after permits are obtained; technical risks drop as engineering experiments are performed. Some risks, especially market-related ones continue as they are partly independent of project life cycle. Global market risks that are outside the control of virtually all players.

3. Approaches to managing risk in the large engineering project

It is useful to distinguish between two broad categories of approaches to risk management: (1) decision theoretic approaches that by and large assume that risks are exogenous, probabilistic and partly endogenous, and (2) managerial approaches which focus on the front-end issues, turbulence, and the shaping of risk drivers.

Decision theoretic approaches view projects as gambles in which sponsors attempt to identify options and probabilities. Strategists select a move with a high payoff, make a bet, and wait for the probabilities to materialize. Groups of executives brainstorm to identify likely events and decision trees are built to identify the solution with the highest expected utility.

The gamble metaphor is however not always applicable to real-life projects. First, it is simply impossible to predict the future of projects over the 10–15-year period of shaping, building, ramping up, and early operation — not to mention the entire life of the project. Second, the intellectual exercise in which the complete set of relevant futures can be laid out is difficult to achieve under conditions of turbulence. Decisioneering approaches also *view LEP's as ventures that can be planned and specified in advance*. The future of projects is said not to be dictated by circumstances but by management [2,3]. Careful analyses of trade-offs between costs and risks, it is claimed, can yield good approximations for the appropriate timing of investment in projects. Accelerating a project will increase development costs to the point that there is a danger of sinking it. Proceeding with prudence increases the danger of missing the opportunity that the project aims for.

Managerial approaches by contrast view projects as complex adaptive systems facing endogenous risks as well as exogenous surprises that cannot always be anticipated in advance. Diligent sponsors do not sit idle, waiting for the probabilities to yield a "win" or a "loss," but work hard to influence outcomes and turn the selected initial option into a success. They shepherd their choice in light of changing conditions and often succeed against odds. Dynamic complexity, because of its turbulent and unpredictable nature, has to be met by versatile managerial approaches. The front-end decision processes observed by IMEC were messy, often chaotic; the untidiness reflected the various moves made by managers.

4. Managerial strategies to cope with risks

Sponsors strategize to influence outcomes by using four main risk-management techniques: (1) shape and mitigate; (2) shift and allocate; (3) influence and transform institutions; and (4) diversify through portfolios. Fig. 3 illustrates these techniques along two axes: the extent to which risks are controllable and the degree to which risks are specific to a project or systematically affect large numbers of actors. When risks are "endogenous" — that is, specific and controllable — the prescription is to mitigate with traditional risk management approaches. In contrast, when risks are specific but outside the control of any of the potential parties,

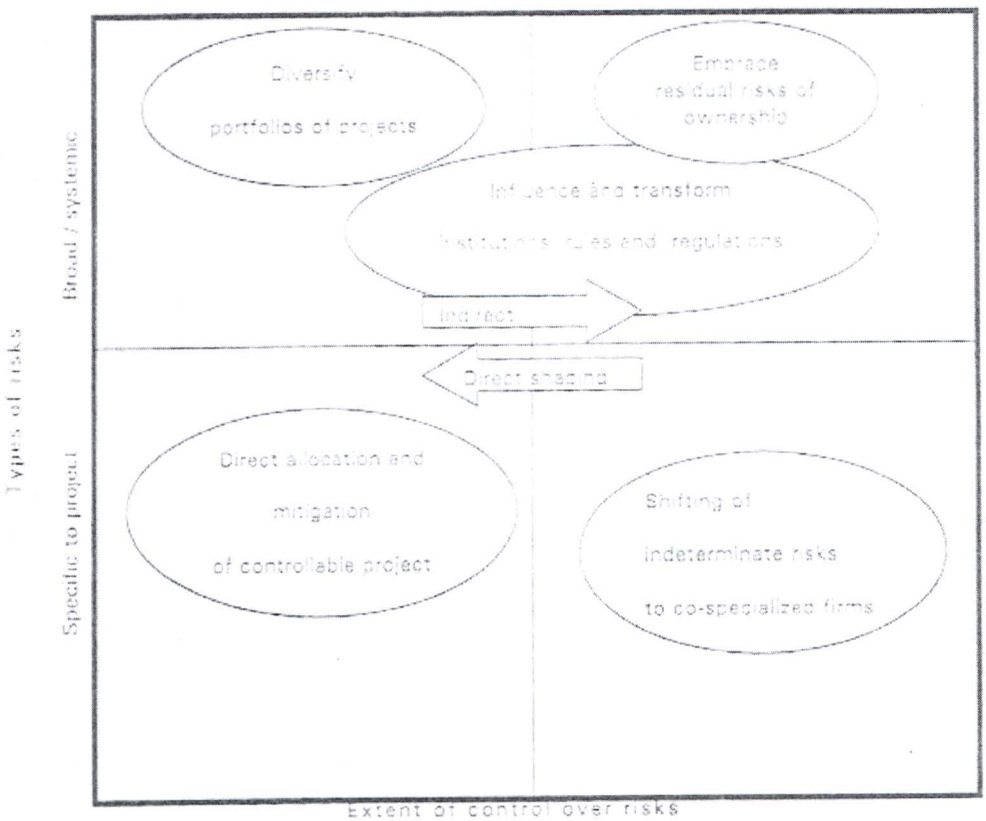

Fig. 3. Strategies to cope with risks.

shifting or allocating them using contracts or financial markets is the appropriate solution. When risks are poorly defined and under the control of affected parties, governments, or regulators, transforming them through influence is the way for sponsors to gain control. When risks are broad, systematic, but controllable, the approach is to diversify exposure through portfolios or projects. Residual, systematic, and uncontrollable risks have to be embraced by sponsors.

The process of strategizing to understand and manage risks prior to embracing residual uncertainties is best described as an interactive layering of choices. The reasoned assignment of knowable risks starts by discovering and assigning them to a coping strategy. Some risks will be dealt with by using financial markets, others by institutional shaping, still others by project coalitions. Many can be assigned to partnership members in accordance with these parties' knowledge, influence, and ability to shape, exploit, and bear them.

Tracing risk management in 60 large engineering projects, we identified six primary layers of mechanisms used by managers for coping with risks (Fig. 4). First, risks are understood by hiring experts or undertaking analysis and simulations. Second, risks that are significant but transferable, especially if they are closely matched by market instruments, can be shifted to parties that can best bear them. Third, project risks are pooled through the constitution of large portfolios. Fourth, options are designed to allow a greater range of responses in line with future outcomes. Fifth, remaining risks are shaped or transformed through influences on drivers as they are the result of behaviors by other social agents. Finally, residual risks are embraced by sponsors. This layering process is repeated in many iterative episodes until final commitments are made.

Potential participants do not have equal comparative advantages in risk bearing. Participants to be selected for membership in a project structure should display complementary comparative advantages in taking the lead with a particular risk. Relative superiority in risk bearing may arise for any one of three reasons: some

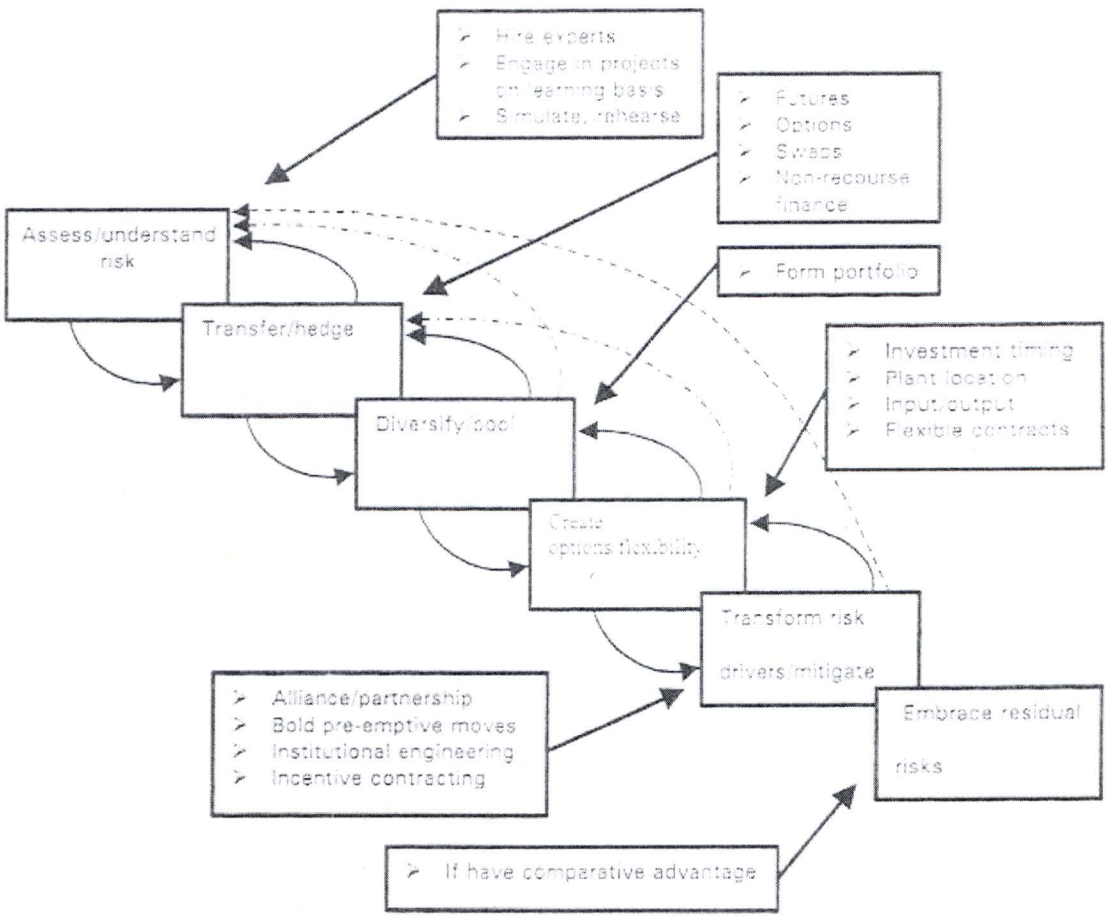

Fig. 4. The layering process.

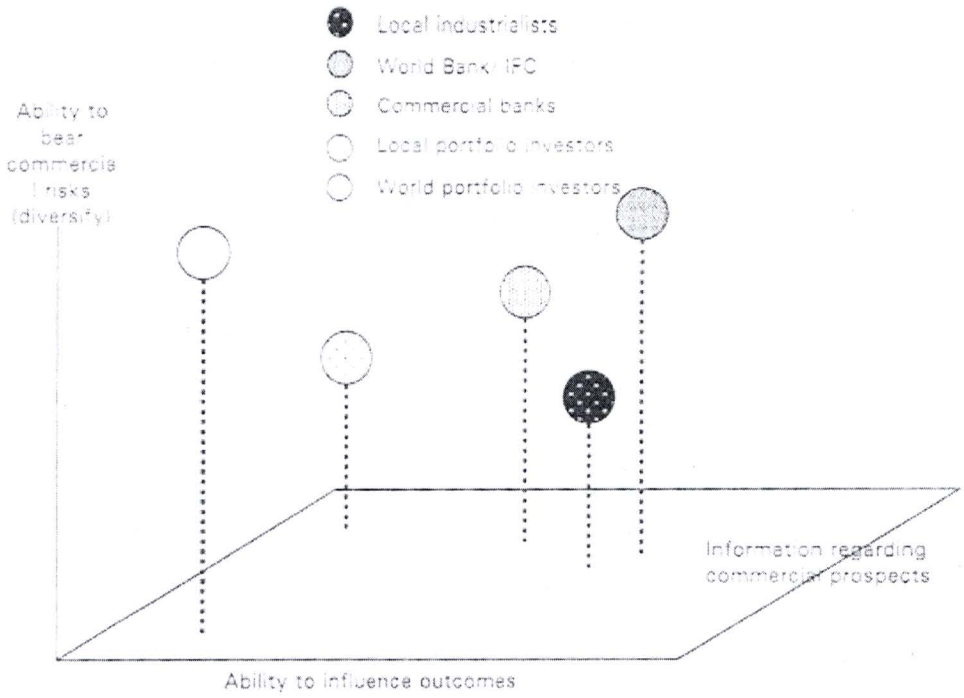

Fig. 5. Comparative advantage in risk taking

parties may have more information about particular risks and their impacts than others: some parties or stakeholders may have different degrees of influence over outcomes; or some investors differ in their ability to diversify risks. Fig. 5 illustrates how potential partners differ in their ability to control risks and enjoy a comparative advantage. For instance, local partners can influence outcomes but have little ability to diversify risks and little knowledge about commercial prospects worldwide. World portfolio investors certainly diversify risks, but their ability to know about local commercial prospects or to influence outcomes is low [4].

Strategizing about risks is almost always beneficial, but at some point diminishing returns set in and the costs of acquiring additional information or gaining control over risks fall short of their value. The design of responses to risks must be judged on a cost-benefit basis. Aligning performance incentives is critical when particular parties to the project have a significant degree of control over the economic value created by the project but do not have an incentive to maximize this overall value.

5. Conclusion: creation and exercise of options

The front-end process to cope with risks is consistent with the real-options framework that is currently revolutionizing academic treatments of project evaluation. The real-options framework is based on the same logic as that of financial options as developed by Black and Scholes [5]. Dixit and Pindyck [6] and Trigeorgis [7] extend it to real options, while Laughton and Jacoby [8] provide operational specification for options valuation. Kulatilaka and Lessard [9] have demonstrated how the real-options approach can be combined with a decision-tree framework.

However, while the emphasis of the real options literature is how to "price" the risks involved, ours is on the managerial process of recognizing, shaping, and realizing these options. In fact, as is often the case with cutting-edge practice, managers have been successful at creating value through the development and exercise of sequential options without explicitly framing the process in options terms. Academics have simply codified this practice in the form of a new conceptual framework.

The real-options approach recognizes that decisions that determine project cash flows are made sequentially over many episodes. The key insight of this approach is that uncertainty or volatility can actually increase the value of a project, as long as flexibility is preserved and resources are not irreversibly committed. As a result, the economic value of a project when it is still relatively unformed is often greater than the discounted present value of the expected future cash flows. Value is increased by creating options for subsequent sequential choices and exercising these options in a timely fashion. Thus, sponsors seek projects that have the potential for large payoffs under particular institutional and technical circumstances.

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From:	Chazell, Russell
To:	Oesterle, Eric
Subject:	FW: FQ Presentation from NINA
Date:	Tuesday, October 09, 2012 1:18:00 PM
Attachments:	10-08-2012 Presentation NRC Workshop on FQ Issues - NINA.pptx NRC Form 665S_NINA FQ Presentation.docx

FYI

From: Chazell, Russell
Sent: Tuesday, October 09, 2012 1:19 PM
To: Hickman, Cindy
Cc: Cubbage, Amy
Subject: FQ Presentation from NINA

Hi Cindy,

Please upload the attached presentation to the ADAMS package (ML12242A218) for immediate release.

Thanks,
Russ

Russell E. Chazell
Project Manager
NRO/DARR/APOB
T-6G01 (Office)
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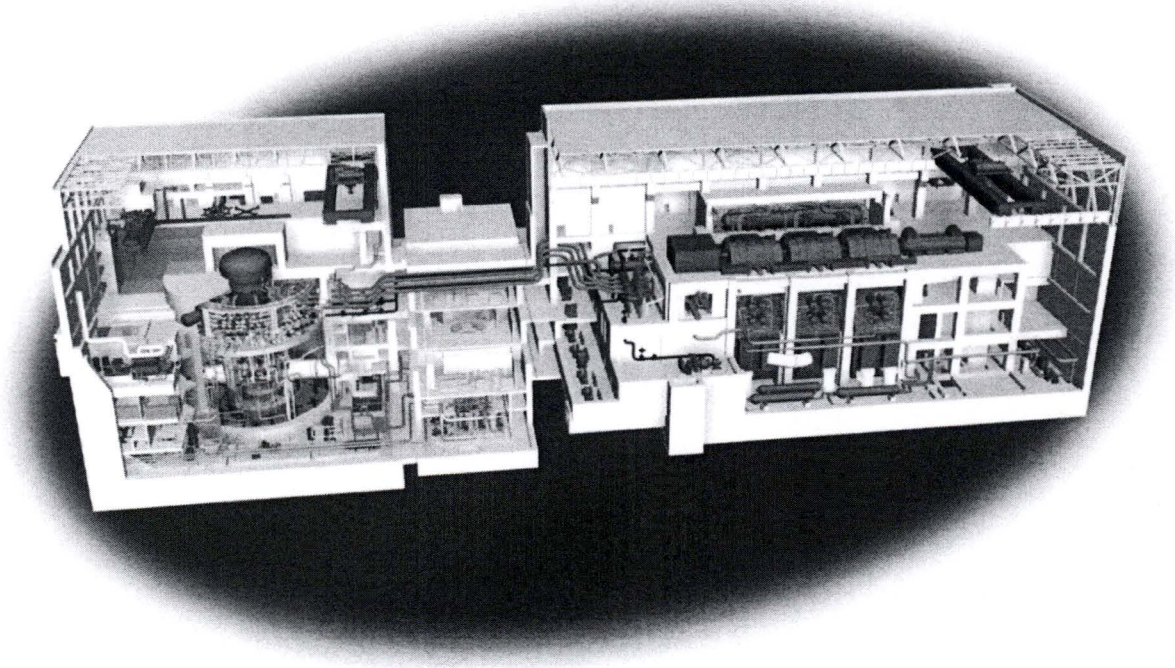
mailto:Russell.Chazell@nrc.gov

South Texas Project Units 3 & 4 Combined License Application

– Financial Qualifications Issues

Mark McBurnett, CEO of NINA
John Matthews, Partner - Morgan Lewis



October 11, 2012

Executive Summary

Financial Qualifications

- NRC legal authority and precedent.
- Generic issue for merchant plants.
- Using a Project Finance model.
  - Assures funding for entire project is available prior to closing
  - Some licensees (*e.g.*, NINA) will commit to requiring that at least 50% of loan funding comes from a U.S. Government loan or involves a DOE Loan Guarantee .
- A License Condition can be used to satisfy the required financial qualifications finding.
  - Established precedent under NRC regulations and practice.
  - Provides "reasonable assurance" for construction and operating funds – in addition to the information submitted to comply with 10 CFR 50.33(f).
  - Provides for documentation of information specified in 10 CFR Part 50, Appendix C prior to commencing construction.
  - Protects safety – if condition is not satisfied, plant will not be built.

NRC Has Broad Legal Authority Regarding FQ

- NRC has wide discretion:
  - The Atomic Energy Act "does not impose any financial qualifications requirement; it merely authorizes the Commission to impose such financial requirements as it may deem appropriate."
    - *Public Service Co. of New Hampshire* (Seabrook Station Units 1 & 2), CLI-78-1, 7 NRC 1, 9 (1978).
  - This has been upheld by federal courts. "***The Act gives the NRC complete discretion to decide what financial qualifications are appropriate.*** The regulations require only a 'reasonable assurance.' We will not second guess the NRC as to its interpretation of the level of proof that standard requires."
    - *New England Coalition v. NRC*, 582 F.2d 87, 93 (1st Cir. 1978).
- The purpose of the FQ requirement is safety.
  - The FQ regulations are not intended to impose a requirement that measures the economic desirability of the project, which is a business decision that can be left to investors.
  - The implementing regulations state that the rules "reflect that the fundamental purpose of the financial qualifications provisions … is the protection of the public health and safety and the common defense and security." 33 Fed. Reg. 9704 (July 4, 1968).
  - Rather, the ASLB has explained, that ***"[t]he purpose of the financial qualification*** requirements of 10 C.F.R. § 50.33(f) is to ensure 'the protection of the public health and safety and the common defense and security' and ***not to evaluate the financial wisdom of the proposed project.***"
    - *Progress Energy Florida, Inc.* (Levy County Nuclear Power Plant, Units 1 & 2), LBP-09-10, 70 NRC 51, 83 (2009).

NRC's FQ Regulations Provide Flexibility

- NRC requires the applicant to demonstrate that it "possesses or has reasonable assurance of obtaining the funds necessary to cover estimated construction costs and related fuel cycle costs" – 10 CFR 50.33(f)(1).
  - 10 CFR Part 50, Appendix C sets forth information "requirements," but it also states: ***"The kind and depth of information described in this guide is not intended to be a rigid and absolute requirement."***
- NRC has used a License Condition to satisfy FQ requirements for non-reactor facilities.
  - The Commission upheld the use of a License Condition for FQ:
    - Part 70 License. *Louisiana Energy Services* (Claiborne Enrichment Center), CLI-97-15, 46 NRC 294, 299-300 (1997)
    - Part 72 License. *Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), CLI-00-13, 52 NRC 23, 29-30 (2000).
  - Compare 10 CFR 72.22(e): "The information must show that the applicant either possesses the necessary funds, or has reasonable assurance of obtaining the necessary funds . . . to cover . . . [e]stimated construction costs."

A License Condition May Be a Critical Tool for Merchant Plants to Address the FQ Issue.

- An Applicant may have a "plan" that could meet NRC requirements, but any new merchant plant project is unlikely to have the committed funding required for construction unless it can complete the Financial Closing of a Project Finance.
  - Lenders , *e.g.*, U.S. Federal Finance Bank (FFB) and DOE, will insist upon issuance of the COL before the closing of a large infrastructure Project Finance can be completed.
- The conditions required by Lenders (FFB) for a Project Finance assure that construction will be completed so the project is able to repay debt.
  - This provides reasonable assurance of funding to cover estimated construction costs.
- DOE's Regulations for Loan Guarantees illustrate the Lender requirements that would apply to any Project Finance:
  - 10 CFR 609.10(d)(8) (requiring that "[t]he amount of the loan guaranteed, when combined with other funds committed to the project, will be sufficient to carry out the project, ***including adequate contingency funds***").
  - 10 CFR 609.10(d)(9) (requiring that as a condition to issuance of a loan guarantee there must be "***reasonable prospect of repayment*** by Borrower of the principal and interest" for all project debt, *i.e.*, the project revenue must be sufficient to not only pay O&M costs required to generate revenue, but also to make debt payments).
- These Project Finance Principles present an opportunity to fashion an appropriate License Condition.

Project Finance Model

- Many merchant plants are to be built using a Project Finance Model.
- Under this Model, the Lenders require assurance that funding is adequate for completion of the entire project so that the loans will be repaid from project revenues:
  - Led by DOE Loan Guarantee of funds provided by U.S. Federal Finance Bank.
  - Includes requirements for equity contributions, contingencies, cost overruns, working capital, decommissioning funding assurance, debt reserves to pay for debt service, *etc.*
- Detailed Preconditions for Financial Close:
  - Prior to loans being committed, all sources of funds (debt and equity) must either be provided at closing (paid in) or committed (with credit requirements).
    - This standard is much higher than "reasonable assurance."
  - License Condition requiring Financial Close = demonstration of reasonable assurance of obtaining the funds necessary to cover estimated construction costs and related fuel cycle costs.
- Documentation required by lenders and License Condition would provide all of the information contemplated 10 CFR Part 50, Appendix C.
- Developer must also demonstrate to Lenders at Financial Close that it has all regulatory approvals to begin construction.
  - Requires NRC sign-off that Facility has satisfied the FQ License Condition.

FQ Condition for Construction Finance Funding

- Financial Closing of "Project Finance" Must Occur Prior to Construction:
  - Post-COL, major funding for construction will have to come from a future Project Finance, *e.g.*, loan from U.S. Federal Finance Bank with a DOE Loan Guarantee.
  - To be required by a License Condition.
  - Will include mix of Equity and Debt.
- Equity:
  - Substantial equity typically has been contributed prior to issuance of COL.
  - Additional equity from new investors may be required.
    - Per 10 CFR 50.80, NRC would need to review and approve any new investor that provides material equity.
- DOE Loan Guarantee Program likely will require payment of pre-existing debt:
  - Debt from development effort typically will have to be paid off.
    - This is necessary so that new debt can have a first lien, which is required by DOE regulations.
    - This means that development loans need to be paid off prior to closing or converted to equity.
  - New debt will often come from the United States Government.
    - U.S. Federal Finance Bank.
    - U.S. Government prefers to see some loans from foreign export credit agencies (ECAs).
    - In any case, all creditor rights must be consistent with the interests of the United States.
      - Required by DOE regulations.

NINA's Proposed FQ License Condition

The Licensee is financially qualified based upon the following License Condition being met prior to commencing construction authorized by an operating license for each facility:

Excepting only construction otherwise authorized by an exemption granted by the NRC, construction pursuant to this license shall not commence before funding is fully committed at a Financial Closing with Lenders in connection with a Project Finance for the Facility.

At least 30 days prior to the Financial Closing, the Licensee shall make available for NRC inspection, draft copies of documents to be executed at the Financial Closing of the Project Finance that demonstrate the following:

1. *The United States Department of Energy, or other agency of the United States Government, will either loan the funding for or guarantee loans for at least 50% of the construction funding to be provided through loans.*
2. *The Lenders' Independent Engineer has provided an updated estimate of the Total Project Costs.*
3. *Funding totaling not less than the amount of Total Project Costs estimated by the Lenders' Independent Engineer shall have been funded or will be made available through: (1) equity either funded or committed by a Qualified Investor; and/or (2) loans committed by a government institution of the United States and/or one or more Qualified Financial Institution(s).*
4. *In order to provide financial support during operations, provisions are made in the Financial Closing for the following to be maintained upon initial plant operation: (1) a debt service Reserve in amount not less than one year's worth debt service payments; and (2) a revolving credit facility of at least $100 million for operating and maintenance expenses, with a Lenders' requirement that a zero balance be maintained at least once per year.*

For purposes of the foregoing:

a. *A "Qualified Investor "must have a senior, unsecured and unenhanced credit rating of Baa3 or better by Moody's, or BBB- or higher by Standard & Poor's or Fitch, or a rating meeting other comparable international standards.*
b. *A "Qualified Financial Institution" must have a senior, unsecured and unenhanced credit rating of A2 or higher by Moody's, or A or better by Standard & Poor's or Fitch, or a rating meeting other comparable international standards.*

Proposed License Condition Protects Safety

- Purpose of the financial qualifications requirement in 10 CFR 50.33(f) is to protect public health and safety.
- NINA's proposed License Condition accomplishes that purpose.
  - Provides reasonable assurance that that there will be adequate funding in place prior to construction.
  - Provides all of the information contemplated by 10 CFR Part 50, Appendix C and more.
- If the condition is not satisfied, the plant will not be built.
  - Ensures no adverse impact on safety.

Questions and Comments