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ENVIRONMENTAL PROJECT REEVALUATION WITH RISING CALENDAR TIME BENEFITS

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ABSTRACT

This article examines one aspect of the dynamic analysis of environmental systems, the effects of rising calendar time benefits on project reevaluation and scheduling. The effects of rising calendar time benefits, an aspect of what is known as the optimal scheduling criterion, are assessed here in terms of a water resource project, the Hangang barrage and hydropower unit in Korea. The rising calendar time benefits used in the reevaluation are those resulting from the rise in real fuel prices that occurred following the completion of the plan. When these benefits are used in the reevaluation of the hydropower unit, this previously rejected project increment becomes justified; its optimal scheduling depends on its degree of separability and the existence of calendar time effects other than those studied. The results suggest the importance in environmental systems analysis of not modelling a system on the convenient assumption that key benefit and cost parameter values will remain constant over time.

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The importance of dynamic analysis of environmental systems is hard to overstate, yet such analysis is difficult to handle successfully. This article examines one aspect of the dynamic analysis of environmental systems, the effects of rising calendar time benefits on project reevaluation and scheduling. The effects of rising calendar time benefits, an aspect of what is known as the optimal scheduling criterion, are assessed here in terms of a water resources project, the Hangang barrage and hydropower unit, a project studied by the U. S. Bureau of Reclamation in cooperation with Korean authorities as part of the Han River Basin plan in Korea [1]. The rising calendar time benefits used in the reevaluation are those resulting from the rise in real fuel prices that occurred following the completion of the plan. When these benefits are used in the reevaluation of the hydropower unit, this previously rejected project increment becomes justified; its optimal scheduling depends on its degree of separability and the existence of calendar time effects other than those studied. The results suggest the importance of the scheduling criterion for water resources and other environmental systems planning; it is proposed that a suitable approach in planning is to incorporate an explicit step in which possible calendar time effects on principal benefit and cost estimates are systematically reviewed in order to determine when scheduling analyses should be performed. More generally, the results suggest the importance in environmental systems analysis of not modelling a system on the convenient assumption that key benefit and cost—or, indeed, other—parameter values will remain constant over time. The article has four parts: a brief description of the optimal scheduling criterion and rising calendar time benefits; a discussion of the Han River Plan and the Hangang barrage and hydropower unit; the examination of the effects on the reevaluation and scheduling of the project of rising calendar time benefits; and a summary and conclusion.

THE OPTIMAL SCHEDULING CRITERION

The optimal scheduling criterion can be seen as a correction to a standard, albeit often implicit, assumption of traditional benefit-cost analysis. This is the assumption that in undertaking the analysis the planner is considering the immediate implementation of the project. The analysis examines whether the net discounted benefits of the project are positive for current implementation. This is an appropriate criterion providing that all benefits and costs are functions of "project time," that is, they occur in the same year of the project's life no matter when the project starts. (Benefits and costs are treated in real terms.) In such a case, a project with net benefits for present implementation will have net benefits for all future dates of implementation as well, so that postponement of the project, absent budget or other constraints, simply reduces the net present value of discounted benefits. Thus, the assumption of current implementation is in this case a correct one.

However, when benefits (or costs) are a function of calendar time, that is, when they relate not to a specific year of a project's life but rather to specific calendar years, the assumption that a project should be examined only for immediate implementation can yield incorrect results. The analyst must consider not only the usual factor of project size in the optimization process, but also the optimal date of implementation. This consideration is referred to as optimal scheduling.

The criterion can be considered for the case of rising real benefits over calendar time, with real costs assumed constant as a function of calendar time. In such a case, the discounted net benefits of a potential project for different possible years of implementation might appear as shown in Figure 1. For the example project represented in the figure, the existence of rising calendar time benefits yields negative net benefits, as seen from the present, for current implementation (1987). Benefits become positive in 1992, and peak in 2001. 2001, the date of the highest net discounted benefits as seen from the present, is thus the optimal year for implementation. For project implementation after 2001, net discounted benefits decline because postponement results in the loss of project years with positive net benefits. The scheduling decision turns on the comparison of the value of delaying costs, and thus having the use of capital for other purposes, and foregoing calendar time benefits. The optimal date of implementation occurs at the point when the costs of delay for an additional year exceed the benefits of delay.

A fascinating aspect of the scheduling criterion is that projects such as that represented in Figure 1 would, with normal benefit-cost analysis, be discarded from a potential plan because their net benefits for present implementation are negative. The optimal scheduling criterion applies to multiobjective planning as well as to the traditional single objective economic planning used in the Han Study [2, pp. 42-43]. One can imagine a fairly substantial number of instances in which rising benefits as a function of calendar time might occur; not only with fossil fuels as part of the alternative cost measure of benefit for hydropower, but for other purposes such as recreation, where the unit value of a visitor day might rise over calendar time with rising population and real income. The forecasting aspects of the scheduling criterion are, of course, challenging (as indeed all project forecasting is, whether or not calendar time effects are present), and should be dealt with in practice by the use of sensitivity analysis and switching value techniques.

The scheduling criterion for water resources and other project planning was developed by Marglin [3]; see also [4] and [5] for discussions and [2] for a brief treatment. The scheduling criterion is part of the well-known 1973 Principles and Standards of the U. S. Water Resources Council [6], but it has not been the focus of substantial work by U. S. water agencies except for some applications in hydropower analysis. While the optimal scheduling criterion has not generally been a part of water planning (as opposed to the traditional

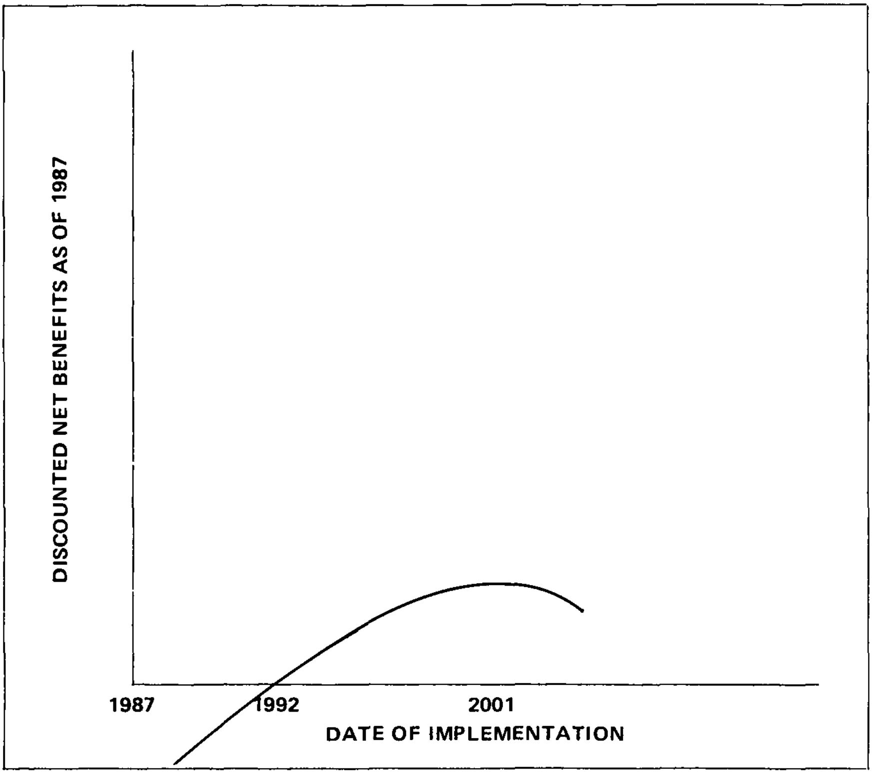

Figure 1. Optimal scheduling.

method of staging to meet phased physical output demands), planners will no doubt remember occasional instances of implicit use of the criterion in reports, relating, for example, to rising real land purchase costs.

THE HAN RIVER BASIN PLAN AND THE HANGANG BARRAGE

The Han River flowing through Seoul is one of the four principal river basins in the Republic of Korea, the others being the Naktong, Yongsam, and Kum [7]. The drainage area is 26,000 km^2, of which 3,114 km^2 are north of the line of demarcation between North and South Korea. The annual average surface runoff is estimated to be 18,060 million cubic meters at the site of the proposed Hangang barrage downstream of Seoul. The Han River Basin Plan is a basin plan formulated by procedures that are for the most part familiar to U. S. water planners. The plan recommends seven projects [1, p. v], including the Hangang barrage, for purposes of water supply, power, and flood control [1, p. vi]. The largest dam is that proposed at Chungju, to be constructed in two stages with a final height of 131.5 meters. The recommended projects are to be constructed over a period of more than forty years [1, p. R-4]; the sequence recommended was based on the relative ranking of benefit-cost ratios and the need to furnish firm water supplies [1, p. R-3]; the latter aspect may be referred to as staging rather than as scheduling.

The Hangang barrage is recommended for implementation as an ungated weir of four meters for the purpose of preventing salt water intrusion downstream of Seoul, thus providing for the alternative use of flows that would otherwise be required for that purpose [1, pp. R-19, R-20]. The barrage was also studied at a height of eight meters, the height appropriate to provide a stable pool for a proposed Inchon-Seoul navigation canal. A non-firm energy project was considered as part of the eight meter project. This energy project was rejected as an increment to the eight meter project on economic grounds [1, pp. B-108, B-109]; and the eight meter project was itself rejected because of the sub-marginal economic returns estimated for the proposed Inchon-Seoul navigation system [1, p. G-58]. The four meter barrage was then suggested for implementation as the last in time of the seven proposed projects on the grounds that the navigation project might be revived and that this would substantially affect the final height chosen for the project [1, p. R-20].

PROJECT REEVALUATION AND SCHEDULING

In this section, the effects on project evaluation and scheduling for the Hangang barrage of rising benefits for energy over calendar time are considered. The Han report was a reconnaissance report, which means that many details were left for further examination (including at the Hangang site, for example, sedimentation, effects on drainage and sewage problems [1, p. B-163], and the possibility of alternative construction methods [1, p. R-29]). Our analysis nevertheless proceeds using the figures developed for the plan, except as we consider the impact of rising calendar time benefits on the evaluation and scheduling of the Hangang barrage. Two decisions are considered: the power installation on the eight meter barrage as an incremental analysis, whether or not the navigation canal was justified; and the eight meter barrage with power, water supply, and navigation. We consider first the case of power as an incremental installation at the eight meter height.

This decision first becomes relevant for the Han planners in 1978, as seen from the time of planning; 1978 was the earliest date considered for the completion of the Inchon-Seoul navigation system. The Han planners used the alternative cost measure of benefits for the Hangang power installation together with a rough estimate of costs from an earlier study [1, pp. H-34, B-108, B-109]. The figure for the alternative cost measure of benefits was $0.00421/kWh based on a fuel cost for Bunker C grade fuel of 3.74 w/liter (W = won, the Korean currency unit), or $0.014/liter in $US 1969 at 270W/$. The formula used to estimate benefits included transportation of fuel, fuel efficiency, and differences between steam and hydro energy facilities [1, p. H-34]. The figure for Bunker C fuel costs was estimated prior to the sharp increases in real fuel prices that occurred in the 1970s (for example, [8, Figure 2-3]). (Recent experience reminds us not only of the undoubted difficulty of forecasting real fuel price levels, but also that real prices can go down as well as up.) The planners assumed a production of 124 GWh on an average annual basis. At a constant energy value over time of $4,120 per GWh (there was no capacity credit for the Hangang barrage energy) [1, p. B-108], this yields an annual power benefit of $522,000. The annual costs of the installation were estimated at $1,200,000. "This clearly shows that a powerplant is not a justifiable increment . . . " [1, p. B-109]. (Benefits and costs for the power increment are summarized in Tables 1 and 2.)

The impacts of rising calendar time benefits on the evaluation and scheduling of the power increment can be considered by taking the actual rise in energy benefits resulting from the increases in real fossil fuel prices that occurred following the plan. One estimate of these is given in [8, Figure 2-3]. This estimate shows an approximately two-fold increase in real terms by 1975 as compared to prices at the time of the Han plan, and a four-fold increase by 1980. The switching value for the project (the value of Bunker C fuel that would just have justified the power increment) is 2.62 times the value assumed by the Han planners or 9.85 W/liter. (This switching value is for the fuel component of the benefit estimate, the principal component of interest. In

Table 1. Benefits and Costs of the Power Increment: Planner's Assumptions

Annual Costs	$1,200,000
Annual Benefits (Based on alternative cost of energy, pre-1970 level)	$ 522,000

Table 2. Benefits and Costs of the Power Increment: Calendar Time Benefit Assumptions

Annual Costs	$1,200,000
Annual Benefits (Based on alternative cost of energy at 1975 level)	$ 937,000
Annual Benefits (Based on alternative cost of energy at 1980 level)	$1,769,000

detailed project studies, estimates of the impacts of fuel price changes on other components might also be appropriate.) While we cannot know that would have been a reasonable range of sensitivity values for fuel in the minds of the Han planners, they might have calculated the switching value as a way of guiding their decisions. The two-fold increase in fossil fuel prices in the mid-1970s would not have justified the project (average annual benefits for a two-fold increase would have been $937,000), but had sensitivity analysis in this range been used, it might have led to further consideration of the conditions under which the power increment would have been justified. By 1980, the real increase was four-fold, meaning that the average annual benefits of the power increment would be $1,769,000 and the power increment would be justified. The scheduling aspects of the increment depend on the impact on net discounted benefits (using the 8% rate employed in the plan) of moving the project in time. If the overall project were justified and if there were no additional calendar time benefits and costs to it; if the costs of the power increment were entirely separable; and if the second rise in fuel price were forecast to take place in 1980, then the project would be constructed as planned and the power increment optimally scheduled for 1980, the first year in which the (assumed constant) annual benefits exceed annual costs. (A curve such as that in Figure 1 would show rising net discounted benefits as of the planning date from 1978 to 1980, and declining net discounted benefits for project implementation after 1980.) Additional calendar time components and lack of separability in the power increment would require additional calculations to obtain the optimal year of implementation. Information on power costs for other projects in the basin on which estimates of separability could be based is given in [1, pp. E-80–E-84]. In the case of the power increment, the lack of separability of costs means that the principal effect of rising calendar time benefits is to justify the increment, rather than to adjust its schedule relative to that of a (presumed) justified barrage.

The evaluation of the eight meter barrage itself can be considered, taking into account the rising alternative cost of fossil fuel. The eight meter barrage is required by the navigation system that was investigated as part of the Han plan, from Inchon to Seoul and further upstream to Paldang and possibly Yongwon. (The navigation project is described in [1, App. G].) Benefits [1, Table 11-G, p. 53] for this project were attributed to navigation (savings over the least cost alternative, rail, including some new rail construction) [1, p. G-44], water conveyance benefits (savings in construction of distribution systems not needed); water supply benefits (assumed by the planners to be equal to those of the recommended four meter barrage) [1, p. G-51]; reduced pumping costs (for diversion of water supplies); construction materials savings (from use of excavated materials); land enhancement benefit (from use of excavated materials as landfill); and bridge construction savings (a proposed road would run along the top of the eight meter barrage). The total annual benefits are given as

$11,553,000 for 1978 implementation and the total annual costs as $15,409,000 [1, p. G-55]; the navigation improvement including the eight meter barrage thus was not justified by the economic criterion as applied in the Han study. Of the benefits, those most likely to be affected by rising calendar time savings in fuel costs for alternatives would be the navigation benefits, which are the largest category ($4,486,000 annual benefits for 1978 implementation) [1, p. G-53]. Insofar as water transportation is more fuel efficient than rail transportation for the range of cargoes considered, the rising calendar time costs of fossil fuels would tend to increase the possibility of the navigation project having positive net economic benefits. However, the alternative costs are not broken down in terms that would permit the isolation of energy costs and thus a recalculation of the benefits (see [1, Table 8-G, p. G-47]). (The application of new criteria often requires the reorganization of input data.) The pump lift benefits [1, p. G-51] can be recalculated. These are given in the report as $695,000, $906,000, and $1,192,000 on an annual basis for implementation in 1978, 1986, and 1996 respectively [1, p. G-52], with the increase in value due to greater water use and thus increased pump savings. (This is one example in the plan of the recognition of benefits related to calendar time.) Assuming the initial energy value given above, and applying increases in energy costs of two-fold for the early 1970s and four-fold for 1980 and thereafter, the pump lift savings become, for 1978, 1986, and 1996 construction, respectively $924,684, $2,486,257, and $3,060,027 on an average annual basis. (The two-fold value is assumed throughout the horizon for 1978.) If these benefits had been taken together with possible increases in navigation benefits, and a full scheduling analysis had been applied, the result might well have been to recommend the navigation project to the Han planners within their planning horizon. (They would also take into account the rising value of the power increment in making their decision.) At the least, such an analysis might have bolstered the planners' own conclusion, noted above, that the navigation project might be revived. A reevaluated (or redesigned) eight meter barrage would, of course, have to be compared in net benefit terms with its physical alternative, the recommended four meter barrage, before a final decision could be made.

SUMMARY AND CONCLUSIONS

The reevaluation of the Hangang barrage and power increment suggest the importance in environmental systems planning of the explicit consideration of calendar time benefits and costs and the scheduling criterion. While it is not of course suggested that the Han planners ought to have used the values employed here, nonetheless explicit sensitivity analysis on the energy benefit value and other parameters of planning, looking toward possible calendar time effects, might have altered their recommendations or, at a minimum, would have increased their concern with design and scheduling flexibility. Like every improvement in planning procedures, the explicit consideration of calendar time effects and scheduling is not a way of getting the "right" answer, but rather is an additional way of enriching our knowledge of a complex multidimensional optimization problem that none of our techniques can fully grasp in its entirety. It is suggested that a suitable approach for environmental systems planners is to incorporate in their planning procedures an explicit step in which the planners systematically review the possibilities of calendar time effects on the principal benefit and cost parameters. This step will suggest first exploratory (as in this note) and then, where warranted, more detailed assessments of the impacts of these effects on project design, evaluation, and scheduling.

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