APPENDIX C

CONCEPTUAL APPROACH FOR ANALYZING REHABILITATION

C-1. Background. In thinking about major rehabilitation it is important to remember that the evaluation considers alternative future streams of project services and costs and the reliabilities of those services and costs. Any rehabilitation plan results in a different stream of these variables. The purpose of a risk-based benefit-cost analysis is to determine the economic efficiency of alternative rehabilitation plans. The evaluation must account for the fact that each plan may differ in terms of its effects on project future service levels, O&M costs, and/or project reliability.

C-2. The Base Condition. A useful approach to describing the rehabilitation evaluation problem is to examine the time paths of project services under alternative rehabilitation scenarios. Figure C-1 shows time paths of the **expected value** of project services under 4 different scenarios. The expected value for each year is calculated by weighing the possible service level in each year by its reliability. As shown in Figure C-2, a frequency distribution is associated with each point on each path in Figure C-1.

a. Each time path begins at time **0** when the original project service flow begins. The straight line labeled **b** indicates the "as built" expected value of service flows. The curved solid line beginning at time **0** indicates a decline over time in either the level of service flows, their reliability or both. The straight line labeled **a** represents the current condition and for purposes of this discussion it also represents some "reliability" associated with condition **a** that could be used as a trigger to consider rehabilitation for reliability. Although the paths all begin at time **0** the rehabilitation analysis only considers path segments from **t** to **t+n**.

b. If a project is not rehabilitated it can still be expected to continue functioning albeit with possibly reduced service levels and reduced reliability. Under this condition maintenance is increased as needed (but within limits) and components or sub-features are repaired on an emergency basis. This essentially represents the current O&M practice. The solid curve in Figure C-1 labeled **I** shows the time stream of the expected value of services under this emergency repair scenario. For the evaluation of rehabilitation alternatives this time path is called the Base Condition. There is also some corresponding time stream of O&M costs in the Base Condition. The Base Condition is conceptually equivalent to the "without condition" for new project evaluation in the sense that the benefits and costs of all alternatives are measured by comparison with this condition. Notice that Path **I** indicates that the expected value of the service flow is permitted to fall and remain below the current condition but that the project continues to function. It is possible, however, that emergency repairs may restore the expected value of service flow to level **a** or it might even result in exceeding level **a**.

C-3. Rehabilitation Plans. Path **II** in Figure C-1 shows a rehabilitation alternative that returns the service flows and reliability to the current level, shown by line **a**. Notice that Path **II** does not return the expected service flows to the original project level but it does improve the reliability of the flows.

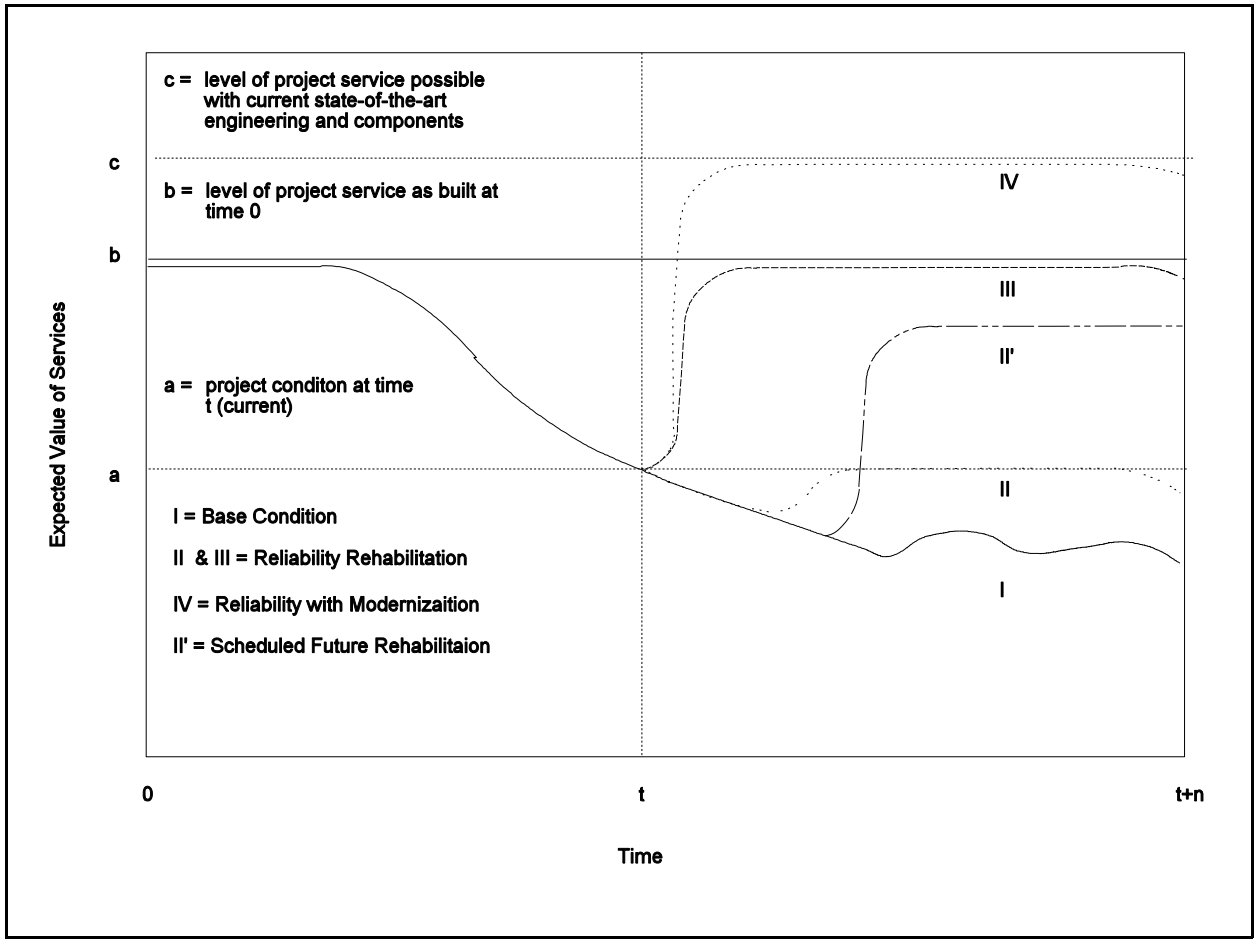

Figure C-1: Expected Value of Service Flows and Rehabilitation

a. Path **III** shows a different rehabilitation alternative that restores the expected service level to the original condition, shown by line **b**, realized when the project was built. This may be described as a full, in-kind replacement of the project feature or features.

b. Path **IV** shows a rehabilitation alternative that clearly "upgrades" the project in relation to the original condition denoted by line **b**. Thus, the service flows and reliability are improved compared to the Base Condition. This rehabilitation would be **Reliability** with **Efficiency Improvements**.

C-4. Reliability. Figure C-2 shows a clearer representation of a reliability rehabilitation. The figure represents the 3-dimensional aspects of service level, time, and probability in 2-dimensions. The vertical axis measures the actual service flow. The figure shows that for Path **I**, the Base Condition, the expected value of service level declines and the variance increases. At time **t** the reliability of service that triggers a rehabilitation study could be displayed in Figure C-2 by comparing the area under the probability distribution with service flow less than **a** with

some risk-based criteria. This comparison might result in an initiation of a rehabilitation study but would not be sufficient to recommend any rehabilitation. The distribution of services shifts from being positively skewed to negatively skewed so that the frequency of lower service levels increases over time. Service level **a** could still be produced under ideal circumstances, e.g. no break-downs, balky equipment functions properly, etc., but the likelihood of level **a** declines. Thus, the Base Condition shows a reduced level of reliability but does keep the project producing some services.

a. The dashed line in Figure C-2, labeled **II**, shows that the rehabilitation shifts the yearly distribution of project services, increasing the mean and reducing the variance (not shown). Notice, however, that the rehabilitation does not increase the "potential" service flow from the Base Condition since under ideal circumstances the Base Condition could still produce level **a**.

b. In fact, any rehabilitation that results in a time path between **II** and **III** in Figure 1 could be described as **Reliability** rehabilitation. Note also that reliability rehabilitation might consider a scheduled future, rather than an immediate, rehabilitation. The time path for this

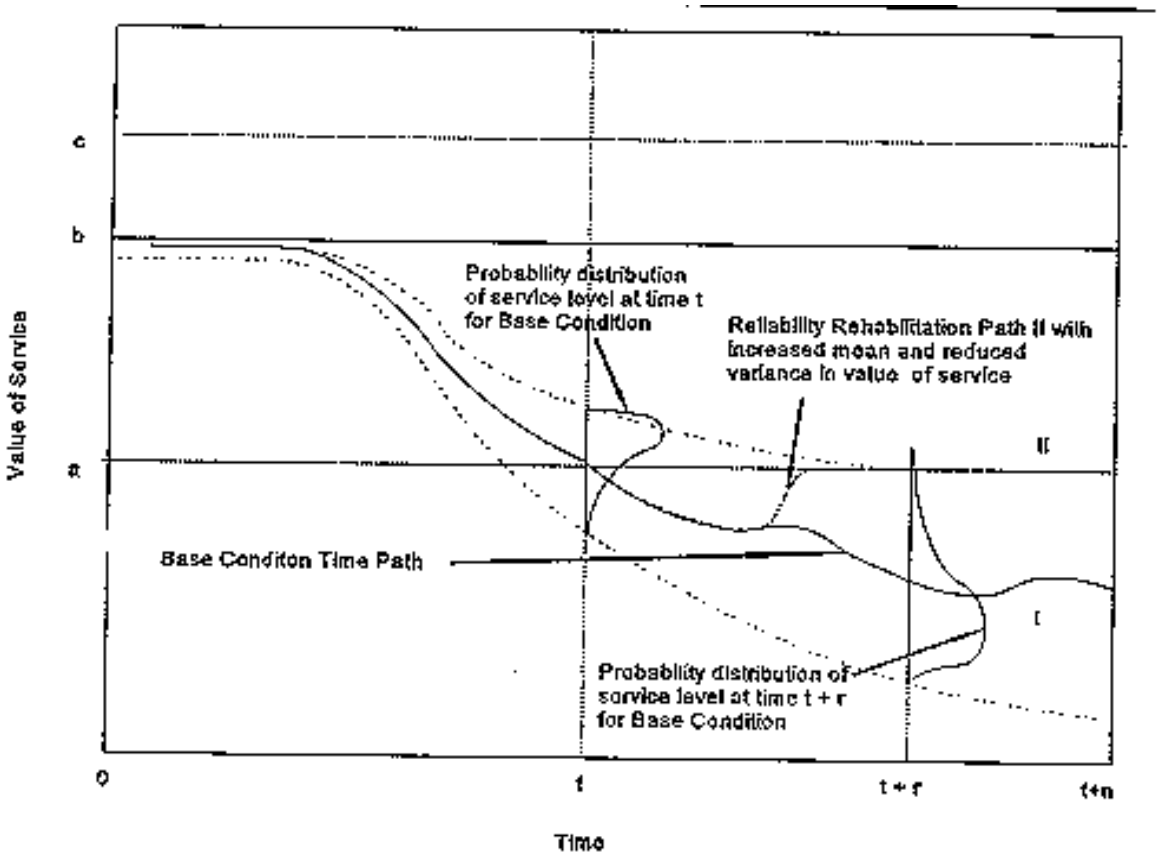

Figure C-2: Distribution of Service Level and Reliability

alternative would follow Path **I** until some point after time **t** then trace a path such as shown by **II** in Figure C-1. Thus, rehabilitation planning should consider the appropriate timing for implementation as well as an expected value of service less than provided by level **b** and more than provided by level **a**.

C-5. Costs. The foregoing description of rehabilitation focused exclusively on service flows in describing the Base Condition and the range of rehabilitation alternatives. O&M and repair costs also have time paths such as those shown in Figures C-1 and C-2. One would expect, however, that the cost path, at least for the Base Condition, would be increasing over time and would display increasing variance. The risk-based benefit-cost analysis must incorporate uncertainties in project costs in each year for the Base Condition and all rehabilitation alternatives.

C-6. Conclusion. All rehabilitation plans result in some time path between Path **II** and Path **IV**. Each plan contains elements that increase expected service levels by both increasing the reliability of a fixed service flow, (with reduced frequency of repairs and costs), and by increasing the level of "potential" service flows from the Base Condition. The analytical procedures for evaluating any rehabilitation plan are the same. The analyst must first be able to quantitatively describe the Base Condition in terms of service levels, costs and reliabilities both now and over the planning period. Correspondingly, any rehabilitation option must also be quantitatively described in these same terms.