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# COST-UTILITY ANALYSIS

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## SUMMARY

Cost-utility analysis is a technique for measuring the value or usefulness obtained from each of several candidate designs that are under consideration for implementation. Each of the designs that are being analyzed by this technique must be an alternative method to accomplish a single objective. For example, different types of bus and/or carpool priority lane designs for a single location can be analyzed by this technique. It may even be used to compare priority lane designs for two different locations. The value, that is developed by the analysis, is a subjective measuring of intangible variables that are affected by design.

The results of a cost-utility analysis are analogous to the use of a cost-benefit analysis. They are both economic tools used in the decision making process. A fundamental characteristic of cost-utility, cost-benefit, and other analytical tools is the systematic examination of courses of action to achieve specified objectives. However, cost-benefit is a quantifiable analysis, measuring mainly tangible elements that are affected by the system's implementation, with the benefit derived being expressed in dollar terms; the cost-utility approach derives utility units which are a measure of intangible items only, such as desires.

Cost-utility lends itself to most decision problems that ultimately must be resolved primarily on the basis of intuition and judgment. However, in no case should it be assumed that the results of the analysis

will be the final answer. The results obtained will help sharpen the decision maker's intuition and judgment on the many intangible (environmental, political, psychological, and sociological) considerations that should be taken into account.

BACKGROUND

The cost-utility analysis approach was initially presented in the Institute of Traffic Engineers, Compendium of Papers from the 1972 Annual Meeting. The report, Cost-Utility Analysis Procedure for Evaluating Alternative Systems by Jack L. Kay, discusses the need for utility measurements. The author stressed the importance in developing decision making tools which facilitate the selection between competing alternatives.

The use for cost-utility analysis came about in 1968 when this procedure was applied to decide on the best signal system for a project. The decision was relatively complex and involved several elements including traffic operations requirements, maintenance complexity, and problems with system implementation. Other modified forms of cost-utility analysis have been used in motorist aid, route location, transit, and many overall transportation studies.[1]

The development of cost-utility analysis as an economic tool further supplements other quantitative tools of measurement. For benefits that could not be explicitly measured in dollars, a proxy value is developed to measure benefit through the use of utility. By using cost-utility in conjunction with a cost-benefit approach, the value of intangible items is placed into perspective with the value of the more measureable elements.

## COST-UTILITY ANALYSIS DEVELOPMENT

### A. Building the Model

It is important to note that the building of a cost-utility model is an experimental process. A major consideration is to include and highlight those factors which are relevant to the problem. It is necessary that the relevant goals and measures are clearly defined.

The first step in the development of a utility analysis is the listing of the overall goals that the system under study is to achieve. Referring to Table 1, the goals developed for a priority lane design are in the areas of traffic operations, attractiveness, the environment, implementation, and public acceptance. The choice of these goals was felt to be appropriate for evaluating a priority lane design. The goals will give insight to a decision as to which competing design is best. Once these goals are established, they are weighted to determine the proper relationships of importance among the goals. The total weighting of the goals should be 100 percent.

The second step of the analysis is listing utility measures under each of the goals. The utility measures are refined descriptions of system requirements and are measures of the effect of a priority lane's implementation. For example, in Table 1, the traffic operations goal was further defined by utility measures such as: ability to reduce the number of vehicles on the road; provide safety for the system's user and non-user; and, the ability of the priority vehicles to cope with the geometric design. The other measures in Table 1 are developed in the same manner. It must be stressed that utility measures should be clearly defined to avoid misinterpreting their meaning. After completing the listing of measures for a goal, they are weighted, delineating the importance of the measures within each goal. The total weighting of measures

| | GOAL WEIGHT | MEASURE WEIGHT | VALUE ASSIGNED (Buses) | VALUE ASSIGNED (Car Pools) | VALUE ASSIGNED (Buses & Car Pools) | RELATIVE WEIGHT (Buses) | RELATIVE WEIGHT (Car Pools) | RELATIVE WEIGHT (Buses & Car Pools) |
|---|---|---|---|---|---|---|---|---|
| **I TRAFFIC OPERATIONS GOAL** | .20 | | | | | | | |
| 1. ABILITY OF SYSTEM TO REDUCE THE NUMBER OF VEHICLES ON THE ROAD. | | 36 | 5 | 3 | 4 | 180 | 108 | 144 |
| 2. ABILITY OF SYSTEM TO PROVIDE SAFETY FOR USER AND NON-USER. | | 45 | 5 | 4 | 3 | 225 | 180 | 135 |
| 3. ABILITY OF PRIORITY VEHICLES TO COPE WITH GEOMETRIC DESIGN. | | 19 | 2 | 4 | 2 | 38 | 76 | 38 |
| | | 100 | | | | 443 (89) | 364 (73) | 317 (63) |
| **II SYSTEM ATTRACTIVENESS GOAL** | .30 | | | | | | | |
| 1. INCREASED PRIDE OFFERED BY THE USE OF THE SYSTEM. | | 10 | 3 | 4 | 4 | 30 | 40 | 40 |
| 2. ADAPTABILITY OF HIGH OCCUPANCY MODES OF TRAVEL FOR SYSTEM USE. | | 28 | 3 | 5 | 4 | 84 | 140 | 112 |
| 3. COMFORT OFFERED BY THE SYSTEM TO USERS. | | 28 | 4 | 3 | 4 | 112 | 84 | 112 |
| 4. ACCESSIBILITY AND CONVENIENCE OF SYSTEM TO THE USER FOR USE. | | 34 | 2 | 4 | 5 | 68 | 136 | 170 |
| | | 100 | | | | 294 (88) | 400 (120) | 434 (130) |
| **III ENVIRONMENTAL GOAL** | .10 | | | | | | | |
| 1. REDUCTION OF AIR POLLUTION RESULTING FROM SYSTEM. | | 60 | 5 | 3 | 4 | 300 | 180 | 240 |
| 2. REDUCTION IN NOISE POLLUTION RESULTING FROM SYSTEM. | | 40 | 3 | 4 | 3 | 120 | 160 | 120 |
| | | 100 | | | | 420 (42) | 340 (34) | 360 (36) |
| **IV IMPLEMENTATION & ENFORCEMENT GOAL** | .15 | | | | | | | |
| 1. SIMPLICTY OF THE EDUCATIONAL AND INFORMATIONAL PLAN REQUIRED FOR USER TO UTILIZE THE SYSTEM. | | 23 | 5 | 3 | 3 | 115 | 69 | 69 |
| 2. EASE OF OBTAINING LEGISLATION REQUIRED FOR THE SYSTEM USE. | | 18 | 4 | 3 | 3 | 72 | 54 | 54 |
| 3. EASE OF DETECTING NON-PRIORITY USERS IN LANE. | | 22 | 5 | 2 | 2 | 110 | 44 | 44 |
| 4. POTENTIAL TO CREATE A SUFFICIENT NUMBER OF HIGH OCCUPANCY VEHICLES TO EFFICIENTLY UTILIZE LANE WHEN OPENED. | | 37 | 2 | 3 | 3 | 74 | 111 | 111 |
| | | 100 | | | | 371 (56) | 278 (42) | 278 (42) |
| **V PUBLIC ACCEPTANCE** | .25 | | | | | | | |
| 1. EASE OF ACCEPTANCE FROM THE LOCAL GOVERNMENT OFFICIALS & THE PUBLIC. | | 77 | 4 | 3 | 4 | 308 | 231 | 308 |
| 2. PSYCHOLOGICAL EFFECT ON THE NON-USER. | | 23 | 4 | 3 | 4 | 92 | 69 | 92 |
| | 1.00 | 100 | | | | 400 (100) | 300 (75) | 400 (100) |
| | | | | | TOTAL UTILITY = | (375) | (344) | (371) |

TABLE I GOAL AND MEASURE APPROACH

$$\frac{U}{C} = \frac{375}{COST} \qquad \frac{344}{COST} \qquad \frac{371}{COST}$$

(within each goal) should be 100 percent. The weighting of the goals and measures can be done by a selected committee who developed the goals and measures or they can be presented to the highest level administrator to weight them.

A review of the overall weight of the "measures" in this analysis may indicate that some measures have more overall weight than other measures that the decision maker feels are more important. For example, in Table 1, measure I.1. has an overall weight of 7.2% (.20 x 36), while measure V.1. has an overall weight of 19.3% (.25 x 77). If the decision maker felt measure I.1. should be at least as important as V.1., the foregoing method of developing the cost-utility analysis would give misleading results. Hence an alternative method to weighting the measures was developed, as shown in Table 2. All the measures were weighted against each other by importance, instead of within each goal. The basic difference between the two methods comes about due to the differences in assigning a weight to the measures.

B. Utility Calculation

Once the goals and measures are established and weighted, the next step is to assign values to the alternatives. Value assignment is accomplished through the use of judgment and could be performed by a selected committee with an interest in the problem. Each measure is valued on a numeric scale based on how well each competing design responds. The values assigned for each measure in both Tables 1 and 2 are on a scale from 1 to 5. A value of five for a utility measure indicates that the candidate design most benefically affects the measure. A value of one

| UTILITY MEASURES | MEASURE WEIGHT | VALUE ASSIGNED (BUSES) | VALUE ASSIGNED (CAR POOLS) | VALUE ASSIGNED (BUSES & CAR POOLS) | RELATIVE WEIGHT (BUSES) | RELATIVE WEIGHT (CAR POOLS) | RELATIVE WEIGHT (BUSES & CAR POOLS) |
|---|---|---|---|---|---|---|---|
| 1. ABILITY OF SYSTEM TO REDUCE THE NUMBER OF VEHICLES ON THE ROAD. | 10 | 5 | 3 | 4 | 50 | 30 | 40 |
| 2. ABILITY OF SYSTEM TO PROVIDE SAFETY FOR USER AND NON-USER. | 10 | 5 | 4 | 3 | 50 | 40 | 30 |
| 3. ABILITY OF PRIORITY VEHICLES TO COPE WITH GEOMETRIC DESIGN. | 6 | 2 | 4 | 2 | 12 | 24 | 12 |
| 4. INCREASED PRIDE OFFERED BY THE USE OF THE SYSTEM. | 3 | 3 | 4 | 4 | 9 | 12 | 12 |
| 5. ADAPTABILITY OF HIGH OCCUPANCY MODES OF TRAVEL FOR SYSTEM USE. | 10 | 3 | 5 | 4 | 30 | 50 | 40 |
| 6. COMFORT OFFERED BY THE SYSTEM TO USERS. | 8 | 4 | 3 | 4 | 32 | 24 | 32 |
| 7. ACCESSIBILITY AND CONVENIENCE OF SYSTEM TO THE USER FOR USE. | 11 | 2 | 4 | 5 | 22 | 44 | 55 |
| 8. REDUCTION OF AIR POLLUTION RESULTING FROM SYSTEM. | 6 | 5 | 3 | 4 | 30 | 18 | 24 |
| 9. REDUCTION IN NOISE POLLUTION RESULTING FROM SYSTEM. | 2 | 3 | 4 | 3 | 6 | 8 | 6 |
| 10. SIMPLICITY OF THE EDUCATIONAL AND INFORMATIONAL PLAN REQUIRED FOR USER TO UTILIZE THE SYSTEM. | 6 | 5 | 3 | 3 | 30 | 18 | 18 |
| 11. EASE OF OBTAINING LEGISLATION REQUIRED FOR THE SYSTEM USE. | 2 | 4 | 3 | 3 | 8 | 6 | 6 |
| 12. EASE OF DETECTING NON-PRIORITY USERS IN LANE. | 6 | 5 | 2 | 2 | 30 | 12 | 12 |
| 13. POTENTIAL TO CREATE A SUFFICIENT NUMBER OF HIGH OCCUPANCY VEHICLES TO EFFICIENTLY UTILIZE LANE WHEN OPENED. | 7 | 2 | 3 | 3 | 14 | 21 | 21 |
| 14. EASE OF ACCEPTANCE FROM THE LOCAL GOVERNMENT OFFICIALS AND THE PUBLIC. | 10 | 4 | 3 | 4 | 40 | 30 | 40 |
| 15. PSYCHOLOGICAL EFFECT ON THE NON-USER. | 3 | 4 | 3 | 4 | 12 | 9 | 12 |
| | 100 | | | | | | |
| | | | | TOTAL UTILITY = | (375) | (346) | (360) |
| | | | | $\frac{U}{C} =$ | $\frac{375}{COST}$ | $\frac{346}{COST}$ | $\frac{360}{COST}$ |

TABLE 2 MEASURE APPROACH

for a measure indicates that the candidate gives very little benefit with respect to the measure. A three value shows the measure is only adequately affected by the candidate design. The value assigned to each measure (in Tables 1 and 2) was accomplished by either averaging the Committee's responses or by deriving a value that the majority felt was accurate.

Once all the measures have been valued, a relative weight is derived by multiplying the measure weight by the value assigned to it. (Refer to both Tables 1 and 2). The summation of the relative weights for each goal (Table 1) are multiplied by each respective goal weight and all goal relative weights are added to derive a final total relative weight (utility) for each candidate design. In the alternative method presented in Table 2, the measure weight is multiplied by the value assigned to derive the relative weight, and the relative weights are added to derive the total utility. Finally, this representation of utility of a candidate design is divided by the cost of the design, forming a utility/cost ratio.

C. Example

The example showing a use for cost-utility analysis was developed for priority lane operation on a freeway. The candidate competing designs under consideration are an exclusive bus lane, exclusive carpool lane, and a priority bus-carpool lane. The values assigned to the candidates were accomplished by a Committee of three research personnel.

The example set forth in Table 1 consists of five goals which are considered to be the areas of importance in analyzing various designs for a priority lane operation. The system goals describe a general framework for system evaluation and take into consideration the implementation and operational aspects as far as setting up and running the surveillance system, the attractiveness of the design to the user, the reaction of public officials, and the effect the design will have on the environment.

The measures that were developed for each goal are a further breakdown of importance of system evaluation. The measures thus highlight and define the requirements which make up the goals. Each measure developed thus fits only the goal it was intended for. For example, the measuring of air and noise pollution would fall under an environmental goal, while the pride, comfort, convenience, and adaptability offered make up a system attractiveness goal.

D. Problems Found Using Cost-Utility

In the investigation for the application of cost-utility, problems arose throughout each phase of the analysis. With the establishing of the goals and their respective measures, there exists the problem of making sure that the goals and measures reflect only intangible variables, that semantics problems are minimized and that the goals and measures aren't biased toward one design over another. For example, the measures, adaptability of high occupancy modes of travel for system use, and accessibility and convenience of system to the user for use (II.2. and II.4. from Table 1) presented semantics problems. The first measure reflects the ease of increased area coverage and service offered to the people, while the other measure reflects the ease and convenience of getting to and from the mode of choice. To overcome problems in the interpretation of measures, each measure should be more thoroughly defined. See the Appendix for a more complete explanation of each of the measures listed in Tables 1 and 2.

The weighting of the goals and measures sometimes resulted in extreme differences in the weights assigned by individual members to a goal or measure. Thus, it was time consuming to get Committee members to resolve their differences and agree on a final weight.

## CONCLUSION

Cost-utility analysis has been found to be a difficult economic tool to facilitate overall value of competing designs. It is a qualitative analysis that can either supplement other purely quantitative analyses or be used by itself to aid in choosing a course of action to be taken. It is up to the decision maker to determine whether he is fully satisfied with the results provided by quantitative measurement, or if it is necessary to also use cost-utility. If cost-utility is used, there must be sufficient insight of the design, so that a value can be assigned when the design is rated. Cost-utility can only be used to measure a design's worth in comparison to other alternatives. A design's utility has no directly measurable value except when compared to another design's utility.

## REFERENCE

1. Kay, Jack L., "Cost-Utility Analysis Procedure for Evaluating Alternative Systems," 1972 Annual ITE Meeting.

# APPENDIX

## EXPLANATION OF GOALS AND MEASURES PRESENTED IN TABLES 1 AND 2

I. TRAFFIC OPERATIONS GOAL - This goal takes into account the traffic improvements that would result from a chosen priority lane design.

1. The number of vehicles on the road is reduced as a result of the shifting of people into higher occupancy modes of travel. For example, if the auto occupancy rate is 1.5, it can be assumed that a 45 passenger bus at capacity can lead to a reduction of 30 vehicles.
2. The possible increase in the mixture of vehicles and types of drivers with different characteristics in priority lane may lead to accidents which will affect all users. For example, an accident in the priority lane, possibly due to the mixture of vehicles with different characteristics in the priority lane, presents a problem in the reserved and unreserved lanes.
3. With the geometrics that are present (grades, curves, lane widths, etc.) vehicle performance may be affected adversely. The increased speeds that would be hopefully attained may not occur as a result of the geometrics. For example, the affect of grades would reduce the speed of buses if they were users of the priority lane. Also, there is the problem of not being able to pass a slow moving vehicle in the priority lane.

II. SYSTEM ATTRACTIVENESS GOAL - This goal takes into account the features of the design that could attract a potential user and keep the existing users.

1. The pride of the user in becoming a user of the system and thereby feeling he is helping to solve problems (reduce congestion, conserve fuel, and reduce pollution). For example, a person may derive personal satisfaction in knowing that by either joining a carpool or becoming a bus user he is doing his part in an attempt to relieve today's problems.
2. Ability of the system to adapt in providing increased area coverage and service offered to the users. For example, is the present bus route suited for existing or potential users and if not, will it alter its route to satisfy the needs of the potential users?
3. Features of the system's comfort such as the seats, air-conditioning, the relaxation of not driving, and the shift of responsibility as a non-driver. For example, how will the user react to the features offered by the bus as opposed to that of the carpool in his choice of mode of travel?
4. The ease of getting to and from the mode of choice from the user's origin and destination. The use of the system depends upon whether the user must walk or ride, and how far, to and from his mode of travel to become a part of the system.

III. ENVIRONMENTAL GOAL - This goal takes into account the features offered by the system to improve conditions in the environment.

1. A net reduction in air pollution is caused by the conversion to higher occupancy vehicles and improvement in traffic operations. With a shift into higher occupancy vehicles, the number

of vehicles are reduced which will result in a smoother traffic flow. Along with the reduction in vehicles, the smoother traffic flow, which is free of congestion, constant stopping and starting, will reduce the air pollution.

2. A net reduction in noise pollution is caused by the conversion to higher occupancy vehicles. With a reduction in the number of vehicles, a reduction in noise is a result, however, the amount of reduction depends on the type of vehicle shifted into.

IV. IMPLEMENTATION AND ENFORCEMENT GOAL - This goal takes into account the factors that must be dealt with in implementing and enforcing the system.

1. The type of information and the number of people who must be educated and informed on how the system works and how they can use it. For example, it would be easier to train the bus drivers on the use of the lane as opposed to training the public on the use of the lane. The training of bus drivers can be accomplished through meetings and group sessions, while the training of carpoolers will have to be done through the mass media which will be much more difficult.

2. The ease of getting the legislation passed that is needed for the use of the system, if the legislation doesn't already exist. One item to be considered is the feelings of the legislators toward each alternative. For example, some legislators stress the need for mass transit and may have tendencies to push for increased bus usage by setting up a priority lane.

3. The ease with which a non-user is detected in the priority lane. For example, it would be easier to detect a violator in a priority lane for buses than a lane for carpools or a mixture of buses and carpools.
4. There must already exist enough priority class vehicles that use the roadway, when the system begins, to prevent excessive delay to non-priority users. For example, consider three lanes of roadway for use, which is operating at near-capacity and, at the time when the priority lane opens, there are five percent of the vehicles qualified to use the lane. With this condition, the results would be five percent of the traffic in one-third of the roadway, while 95 percent of the traffic would be in the other two lanes, thus causing severe delays to non-priority vehicles.

V. PUBLIC ACCEPTANCE GOAL - This goal takes into account the reaction of the local officials and public attitude toward the system.

1. The ease with which the system will be accepted in a particular locale. For example, are the public and local officials willing to accept and support the system that will be implemented?
2. Which system will have the least adverse psychological affect on the non-user, who, for whatever reason, cannot use the system. For example, for those people who require their car for work and cannot take advantage of a carpool, which type of priority lane system will he accept more readily?