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ABSTRACT

This document presents an application of cost-benefit analysis to a hypothetical university parking problem. After discussing cost-benefit analysis in general, the document applies this technique to hypothetical data in light of a checklist for general cost-benefit procedure. The checklist includes the following steps: (1) examine and quantify objectives; (2) array all alternatives; (3) develop total costs and analyze alternatives in detail; (4) describe and estimate spillover effects, uncertainties, and unquantifiables; and (5) in light of costs, benefits, and spillover effects, choose the most attractive alternative. Tables and graphs are used to illustrate the analytical process. [Not available in hard copy due to marginal legibility of original document.] (LLR)

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An Illustrative Hypothetical Example of Cost-Benefit Analysis (Problem # 2):

The Parking Problem

Statement of the Problem:

You are a cost-benefit analyst just assigned to the staff of the recently appointed Chancellor of a new University of California campus which is in the planning stages. Since it will be in a rural area, some 50% of the student body will live on campus in University housing, but the balance of the students, the faculty, and the staff are expected to be living in a moderate sized town of Modero nearby. The Chancellor has asked you to recommend the optimum method of getting the personnel living in town to and from the campus. He is able to give you the following facts:

1. Since the campus will be built to relieve greatly overcrowded conditions at the existing campuses, it will reach peak enrollment very quickly through re-directions and transfers; hence ultimate capacities must be programmed and built for initially.

2. Peak enrollment will be 30,000.

3. Peak faculty size will be 4,000.

4. Peak staff size will be 4,000.

5. The town of Modero is 15 miles from campus.

6. Approximately 50% of the students will commute or desire to park on campus.

7. Surveys have shown that 25% of the faculty and staff intend to drive to and from the campus regardless of other potential arrangements.

8. Considering students and clerical staff without cars, the resultant car-pooling, etc., it is estimated that private automobiles when driven from town to the campus average 1.39 passengers each.

9. The University's policy is to provide no reserved parking space for those driving (other than for a very few senior personnel and visitors, all of whom have been provided for separately), but to assure at a 99% confidence level that adequate parking space is available for those who do drive.

10. After all other uses have been met there are 32 unused acres of land on the campus site available for a parking facility.

11. University policy is to have no more than 25% land use/coverage.

12. University policy restricts building heights to 8 stories or less.

13. Land for the campus site was purchased at a cost of $1.5 million per acre.

14. Additional land adjacent to the campus could be purchased at a cost of $1.3 million per acre.

15. Local building codes and University construction standards require high-rise type construction (heavier foundations, multiple elevators, full air conditioning, secondary power sources, reinforced structural skeleton, etc.) for buildings over 4 stories.

16. The University's own funds when invested earn 5% (or alternatively, it costs the University 5% to borrow).

17. In a series of preliminary analyses a consulting firm has considered a large number of alternative schemes. Possibilities such as relocating the campus, building a housing development adjacent to the campus, helicopter service, monorails, rapid transit systems, moving sidewalks, sub-surface parking, etc. were all considered and rejected for specific policy reasons, because of great technical difficulties, or for obviously excessive costs. Consequently, the number of viable distinct alternatives has been reduced to three: (a) surface parking; (b) parking structures; (c) contractual bus service.

Assignment

In working this problem you are not expected to do all of the computations. Rather the emphasis is on structuring the problem, asking the right kinds of questions, and suggesting what calculations need to be made. A "staff analyst" in each working group will be prepared to give the answers to all pertinent questions and to perform or give the answers to all relevant calculations. These requests must be specific and reasonably detailed. In some cases, in the interests of time and practicality, certain possibilities may have to be arbitrarily excluded. This problem is intended as a teaching device in which methodology and approach and a limited number of concepts are the crucial points; hence some simplifications and exclusions have had to be made.

The Parking Problem

This hypothetical problem has been designed in such a way as to maximize its usefulness as a teaching device. Because of time limitations, some real world considerations and possibilities have been arbitrarily (but consciously) eliminated. Though these would be important in a real analysis, they are not necessary in the current problem since the purpose of this exercise is primarily to demonstrate some of the techniques employed in a typical cost-benefit analysis. Accordingly, this in no way detracts from its usefulness as a teaching device.

Cost-benefit analysis can serve a variety of decision-making purposes, dealing with both broadly or narrowly defined problems (i.e., high level or low level optimizations).

In the problem at hand, the role of the analysis appears to be quite straightforward. The problem to be solved has been fully structured beforehand with a single, unambiguous goal: there are a given number of people in the University community who will be living at some distance from the campus and who will require some means of getting from their homes to the campus and back.

This particular analysis lends itself well to quantification, but it should be carefully noted that this is not always the case.

The problem is also, in a sense, a self-contained one. It is unnecessary in this analysis to compare the costs and benefits of allocating resources to this venture, with alternative expenditures on libraries, faculties, etc. Because there are few other programs which could in any way substitute for this one, and these are not practical (e.g., a new town could not easily be built adjacent to the campus), the problem assumes the character of an independent objective.

Most other expenditures of University funds do not fall into this category and in analyzing these other programs, it would be desirable to compare costs and benefits of particular programs with other related ones. Nevertheless, in the example at hand, a very wide range of sub-choices is available within which to meet the overall objective of providing transportation to and from the campus.

Since the particular program to be analyzed is obviously a necessary one if the educational goals of the campus are to be realized, the scope of the analysis is readily and narrowly defined. The problem is simply to choose that method which achieves the specified goal of getting the people to and from the campus with the least expenditure of University resources.

Even at this simple level of analysis, however, two general aspects of the procedure must be carefully noted. Both relate to costs.

First, in speaking of expenditures of resources, or costs, the question of costs to whom must be considered. Does the University wish to minimize only its own costs, or also the costs to the members of the University community and/or the costs to the town? The least cost method to the University may not be the least cost method for the other involved groups.

Second, costs other than direct out-of-pocket ones must be considered. When University land is used for say, a parking lot, the cost is not simply the expenditure for its construction and maintenance. Another important fact is that the land for the parking lot will not be available for alternative uses. If opportunities to purchase additional land are limited, this is a serious opportunity cost to the University.

As the subsequent analysis will indicate, cost-benefit analysis does not merely list in isolation the possible alternative methods of achieving the stated objective, and then choose that distinct method which reaches the objective at the least direct cost. It takes explicitly into account unquantifiables, uncertainties, and spill-over (or side) effects. Furthermore, even in the formal quantitative work, it takes a broader view, analyzing the various alternatives in conjunction with each other, so that the best "mix" of alternatives can be chosen. In order to do this, it is necessary to do more than consider just the average cost of each of the particular alternatives. Though the concept of average cost is an important one, exclusive reliance on it tends to obscure important relations which, if recognized, can lead to a more efficient utilization of resources.

Cost functions can assume a variety of shapes through their relevant ranges. Cost-benefit analysis, by employing the "marginal cost" concept (to be explained shortly) concentrates attention on the different portions of the various cost functions, allowing the analyst to recognize the possibility of various alternatives in different mixes, so that the net result is a true minimum cost, rather than simply the minimum one among a set of distinct "pure" alternatives. In the absence of a systematic cost-benefit analysis, possibilities for effective combinations of alternatives are often overlooked.

Important information is concealed, moreover, by exclusive reliance on average cost. Taking the total cost of producing a specified output level does not tell the analyst anything about the path of costs. By introducing the concept of marginal costs, it is possible to follow the cost path closely and therefore provide additional insight.

Marginal cost may be defined as the addition to total cost which an additional unit of output generates. The relationship between average and marginal costs is a direct and crucial one, and can best be described graphically. Figure 1 is a graphical representation of a "typical" marginal and average cost function.

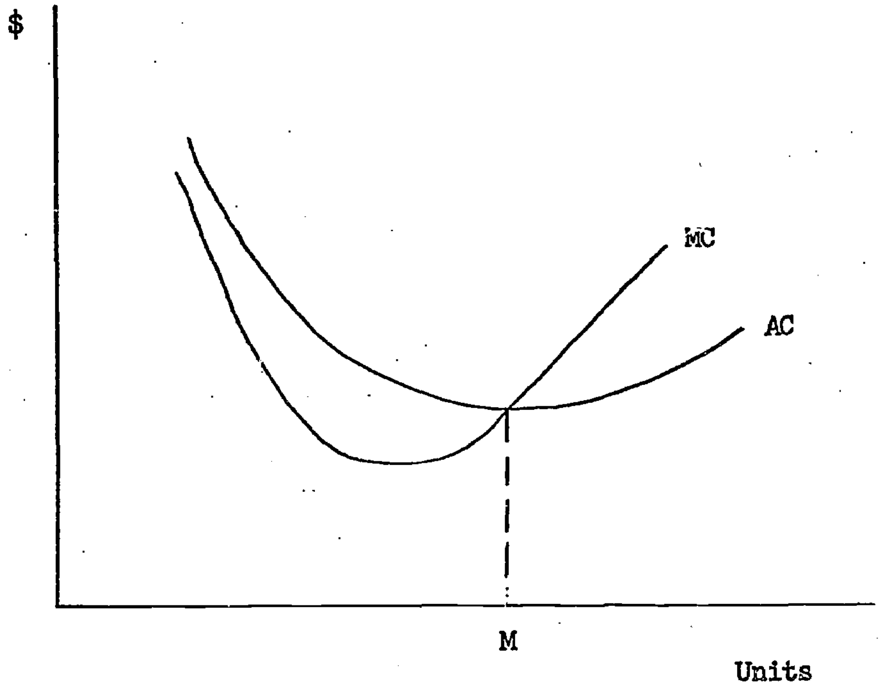


Figure 1

Average cost functions will often display the U shape dipicted above. At low levels of output, the average cost curve is declining, i.e., the average cost of the total output is less and less. Once a certain point is reached, however, it is evident that the average cost of the total output begins to rise.

Now examine the characteristics of the related marginal cost curve. Recall that this curve represents the additional cost of each new unit of output. Thus, in the portion of the curve where marginal cost is declining, the interpretation is that each additional unit of output can be produced at a lower cost than the previous unit. Where marginal cost is increasing, each additional unit costs more than the previous unit.

Now examine the relationship between the average and marginal curves. Where marginal cost is less than average cost, i.e., up to point M, each additional unit is costing less than the average of previous units: so the lower marginal cost curve can be thought of as pulling the average cost curve downward. To the right of point M, each last unit is costing more than the average of previous units: so the higher marginal cost curve is pulling the average curve up.

Note that MC intersects AC at its minimum. This is not an accident, but a mathematical necessity. To the left of M, MC is less than AC and hence pulling AC down. To the right, MC is greater than AC, and hence is pulling AC up. At the minimum point of AC, AC is being neither raised nor lowered by the equivalent MC.

It is important to realize that if MC cuts AC at its minimum, then MC must reach its own minimum before AC does, and must consequently begin to rise before AC does. Thus, there is a portion of the marginal cost schedule which lies below the average cost schedule and is rising, though average costs still continue to fall. The interpretation of this portion of the curve is crucial. In this range of output, each additional unit costs less than the average of previous units, but each additional unit is adding more to total costs than did the previous unit. Thus, it is perfectly possible for average costs to be less than that of another alternative, but marginal costs greater for particular ranges of output.

In the problem to be analyzed, there are several alternative methods of providing a specified number of parking places. If one simply looked at the average cost of providing the given number, the decision would be to use that alternative with the lowest average cost and therefore the lowest total cost. However, if it is recognized that some combination of alternatives is feasible, it is found that a lower total cost method can be achieved by an analysis of marginal costs. Looking at marginal costs indicates that one alternative should be used to provide a portion of the required spaces, but that another alternative should be used to provide the remaining spaces. The net result is less costly than simply choosing the single "pure" alternative with the lowest average cost of providing all the spaces.

In any cost-benefit analysis, there are certain general procedures which should be followed. Some of these will be briefly described here, and a summary check-list is provided on page 9.

The first step in any analysis is to define the objective in a precise, quantified manner. (This often turns out to be the most difficult aspect of the analysis.)

All possible methods of achieving the objective should then be arrayed. The array should not be limited to only those alternatives which appear intuitively to be the best ones. Systematic analysis will often lead to a choice which was not intuitively obvious.

There are two methods of reaching a solution in cost-benefit analyses. One method is to establish a budget constraint, and then choose that alternative or mix of alternatives which provides the most benefits for the specified budget. Alternatively, one could specify the desired level of benefits, and then choose that method which provided the desired benefits at the least cost. In the same range of operations, these techniques will provide equivalent results; i.e., that method which maximized benefits for a given cost, will also minimize costs for a specified benefit level. The choice of which technique to employ is usually made on the basis of convenience; i.e., for each particular problem, it will be found that it is easier to use one method rather than the other. In the present case, it appears that it would be best to minimize the cost of providing the specified transportation service.

Having selected the method, a certain amount of crude analysis should be done to eliminate those alternatives which are infeasible or unattractive for some reason. The remaining alternatives should then be simultaneously examined to see how they complement or substitute for each other. Various interesting-appearing mixes should then be considered in addition to considering the different "pure" alternatives separately.

Next, the cost and benefit consequences of the various alternatives and mixes of alternatives must be carefully analyzed. Marginal, as well as average and total costs need to be considered.

Great care must be taken at this point in the analysis to insure that all costs which the various proposals will generate are included. For the direct costs, this means looking not only at initial capital outlays, but also at the necessary operating and maintenance costs over the relevant time span.

Equally important are the "spill-overs" or indirect effects of the various proposals. Where it is possible to quantify the cost of "spill-overs" these should be explicitly included as part of the total costs for the particular alternatives. Where it is impossible to quantify accurately these costs, it is imperative that qualitative descriptions be explicitly introduced. Explicit recognition of "spill-overs" will often radically effect the choice of preferred alternatives.

Next, the timing of the expenditures of funds under the different alternatives must be carefully and quantitatively introduced into the analysis. The differing alternatives have quite different time patterns of expenditure. The timing of these expenditures is quite significant, and as will be shown, has a major effect in locating the least cost alternative.

The further into the future the expenditure of a given amount of funds can be postponed, the less costly it is to the University. A thousand dollars spent today is "more expensive" than the same thousand dollars expended a year from now. If the University is spending its own funds, if it delays an expenditure for a year, the University's funds may be earning interest during that period. Thus there is an opportunity cost to the University which must be considered for each time pattern of expenditure of funds.

A simple examination of the expenditure streams of the different proposals which will be evaluated does not allow a meaningful comparison to be made. In order to directly compare differing time patterns of expenditure it is advantageous to convert them all to a common basis. This is accomplished by converting all expenditures to what is known as their "present value." As outlined above, the cost of an expenditure of say $1000 a year from now is somewhat less than the expenditure of the same $1000 today. If the funds could be put in a bank that paid 4% annual interest for the year, $40 in interest could be earned. Thus, it can be argued that the present value of an expenditure of $1000 a year hence is $40 less than the present value of expenditure of the same $1000 today.

It is possible to express all income or expenditure streams in terms of its present value, which is a single number. The computation of present values allows an economically meaningful comparison of alternative income and outlay streams. In general, the present value of $1 to be received "n" years from now at any assumed rate of interest "i" can be found with the formula $1/(1+i)^n$. There are, however, tables of present values available so it is not necessary to go through the arithmetic processes involved in computing present values.

The choice of the appropriate interest rate to use in "discounting" future streams of money to arrive at the "present value" figure is flexible, though not arbitrary. In general, the choice depends upon what kinds of alternative investment opportunities are available and what kind of return can be obtained from these alternative opportunities. It is sometimes the case that a slight change in the assumed interest rate will result in a different least cost alternative. It is good practice therefore to perform the calculations with more than one interest rate to see if the results are sensitive to the choice of interest rates.

Because of the complexities which may be involved in costing out the various alternatives, it is extremely important that costs be estimated consistently. One method of insuring that this is done is by developing a costing format by which alternatives may be evaluated.

Finally, the question of uncertainty must be faced. As will be seen, one of the alternatives is of a nature where it is impossible to be 100% sure that the desired objective will always be achieved. If the policy maker is a "risk-averter," he may wish to choose an alternative which achieves the desired goal with 99% certainty, even though at higher cost rather than an alternative which has only, say, 90% certainty. There is no rule which can be applied here as to which of these two solutions is preferable. However, it is often possible again to "mix" the two alternatives, and thereby achieve a given portion of the objective with 99% certainty, and achieve the rest of the goal with 90% certainty. Or put another way, it may be worthwhile to choose a second-best alternative because no matter what happens it never is worse than second-best, rather than the "first best" alternative that falls dramatically in effectiveness in circumstances other than ones assumed in the basic analysis.

The important point here is that these aspects of the problem be explicitly considered and analyzed in a consistent manner. The existence of uncertainty and risk does not preclude rational analysis, nor does it imply that the analysis cannot include explicit recognition of these uncertainties.

Check List for a General Cost-Benefit Procedure

I. Examine and quantify objectives.

II. Array all alternatives

A. Eliminate infeasible and unattractive ones

B. Decide on form or problem:

1. Fixed effectiveness - least cost

2. Fixed budget or cost - maximize benefits

C. Look for interactions between alternatives

D. Look for interesting new combinations of alternatives

III. Develop total costs and analyze alternatives in detail

A. Total costs as sum of marginal costs -- look for changes in marginal costs for the various alternatives.

B. Include all cost elements

1. Capital) direct
2. O & M (for a period of years))

3. Social costs or costs to others affected but outside system (indirect)

C. Show cost stream over time

1. Phasing of capital costs

2. Schedule O & M costs for time period in question

D. Express time preference

1. Discount to present values

IV. Describe and estimate spill-over effects, uncertainties, unquantifiables.

A. Dc sensitivity analysis

V. In light of costs, benefits, and spill-over effects, choose most attractive alternative.

A. Discuss qualifications and interpretations with decision maker.

I. Critical Examination of Objectives

A. What is objective and quantify

1. Provide a transportation system and/or parking facilities for students, staff, and faculty between Modero and campus.

2. How many? Apparent peak demand =

Students	- 50% of peak enrollment	- 15,000
Staff	- 100% of total	- 4,000
Faculty	- 100% of total	- 4,000
	Total	23,000

Questions and Answers Needed to Develop Objective Discussion

1. Peak demand is subject to daily, monthly, and seasonal variation (due to variations in workload, sickness, vacations, etc).

2. Need to consider actual peak loads:

   @ 99% confidence level, study shows that 85% of theoretical peak demand must be provided for.

3. Net demand for service or facilities therefore equals 85% of above categories.

4. Also @ 1.39 persons per car, the total personnel will require only 14,073 parking spaces. (See p. 14 for details of calculation.)

5. Note reservation for 25% x .85 of faculty and staff who will always drive and thus demand some parking. Also affects number of persons to be transported by bus.

II. Array All of the Alternatives

What are the alternative ways or systems for accomplishing the objective? Specify them in enough detail to make a rough comparison; compare them with the appropriate aspect of the quantified objectives; eliminate infeasible and completely unattractive (cost or performance) choices; and re-define in detail the structure of the alternatives chosen for serious analysis and costing.

A. Monorail service -- No, too costly (previous study)

B. Helicopter service -- No, too costly now -- other analyses show possibilities as operating costs decline with next generation of equipment.

C. Bus Service -- Yes, the Blue Dog Bus Lines are interested in a monopoly-charter arrangement.

D. Re-locate everyone onto campus -- No, capital cost is too high. (Previous study.)

E. Encourage use of private autos and build parking facilities.

1. Surface parking - On campus
2. Surface parking - Off campus
3. Parking structure - On campus
4. Parking structure - Off campus
5. Underground parking - On campus
6. Underground parking - Off campus
7. Discriminatory parking pricing policies to encourage car pooling, use of smaller cars, etc. (ruled out by new Chancellor).

Alternative C Bus Service

Calculation of Service Required

Students	= Peak Load x .50 x .85 =	12,750
Faculty	= Peak Load x .75 x .85 =	2,550
Staff	= Peak Load x .75 x .85 =	2,550
	Sub-total	17,850
Less:	(.39) x .25 x .85 x (fac. & staff)	
		- 663
	No. by bus	17,187

Terms of Blue Dog Bus Lines charter offer:

1. To determine the number of passenger spaces needed to meet the peak demand at morning and night rush hours as specified in the objectives (less 25% faculty and staff who will drive, plus those that accompany them), consider the above calculations.

2. Will provide one trip/hour service at off-peak times to coincide with the schedule of classes.

3. Will provide service up to midnight.

4. Wants exclusive franchise - 20 years.

5. Guarantees schedules within ± 5 minutes.

6. Guarantees use of modern air-conditioned equipment.

7. Price quoted is total annual charge payable monthly with guarantee of no change of price during 20 year charter period.

8. Annual charter cost is $2.5 million.

Alternative E: Private auto plus University parking:

No. of parking spaces required:

Students	= Total No. x .50 x .85	= 12,750	
Faculty	= Total No. x .85	= 3,400	
Staff	= Total No. x .85	= 3,400	
	Sub-total	= 19,550	(people)
		1.39	(people per car)
		= 14,073	(spaces required)

III. Analysis and Costing

A. Array alternatives and develop specific detailed outline of such. Structure the choices carefully and quantify.

B. Set up costing format

Initial Investment or Capital Costs	(land) (facilities)
On-going Operation and Maintenance - (Paint, heat, light repair, police, administration)	(annual O & M x 20 years)
	= Total Cost
	@ 5% discount = Present Value

C. Watch out for changes in marginal costs (as compared with average costs), eliminate sunk costs, and price out the total cost implications of the required amount of each alternative course of action or system needed to meet the specified objective.

III. (Continued)

D. Analysis of Alternative E (private auto use and University-provided parking) and its sub-alternatives.

Considering all of the various permutations and combination of high and low-rise parking structures, surface, and sub-surface parking and the choice of on-campus or off-campus locations, there are at least 720 possible alternatives. Some rough preliminary analysis is needed therefore to eliminate infeasible and unattractive choices so that detailed analysis and total costings can be concentrated on likely candidates.

Step I - Eliminate all sub-surface parking: engineer's survey shows that the water table is at 20' below the surface -- too high for underground parking garage.

Step II - Draw some graphs showing marginal cost per parking space provided for each of the principal remaining alternatives; i.e., surface parking lots on- and off- campus and high and low rise parking structures on and off campus.

: -- viz:

On Campus	Off Campus
1. Surface Parking	4. Surface Parking
2. Low-Rise Structure	5. Low-Rise Structure
3. High-Rise Structure	6. High-Rise Structure

Set up costing format which can be used to evaluate marginal costs of each of the above alternatives; thus, Marginal Cost Analysis:

Alt. No. (From Previous Page)	Land ($/Space)	Capital Cost Facilities ($/Space)	Annual O & M x 20 Years ($/Space	Total Cost Per Space ($/Space)	No. of Spaces Per Acre
1	-	242	60	302	360
4	$3611	242	140	3993	360
2&3					
Floor 1	-	3000	400	3400	335
2	-	2600	400	3000	670
3	-	2300	400	2700	1005
4	-	2000	400	2400	1340
5	-	3900	400	4300	1400
6	-	3800	400	4200	1680
7	-	3700	400	4100	1960
8	-	3600	400	4000	2240
5&6					
Floor 1	$3881	3000	800	7681	335
2	-	2600	800	3400	670
3	-	2300	800	3100	1005
4	-	2000	800	2800	1340
5	-	3900	800	4700	1400
6	-	3800	800	4600	1680
7	-	3700	800	4500	1960
8	-	3600	800	4400	2240

(Continued)

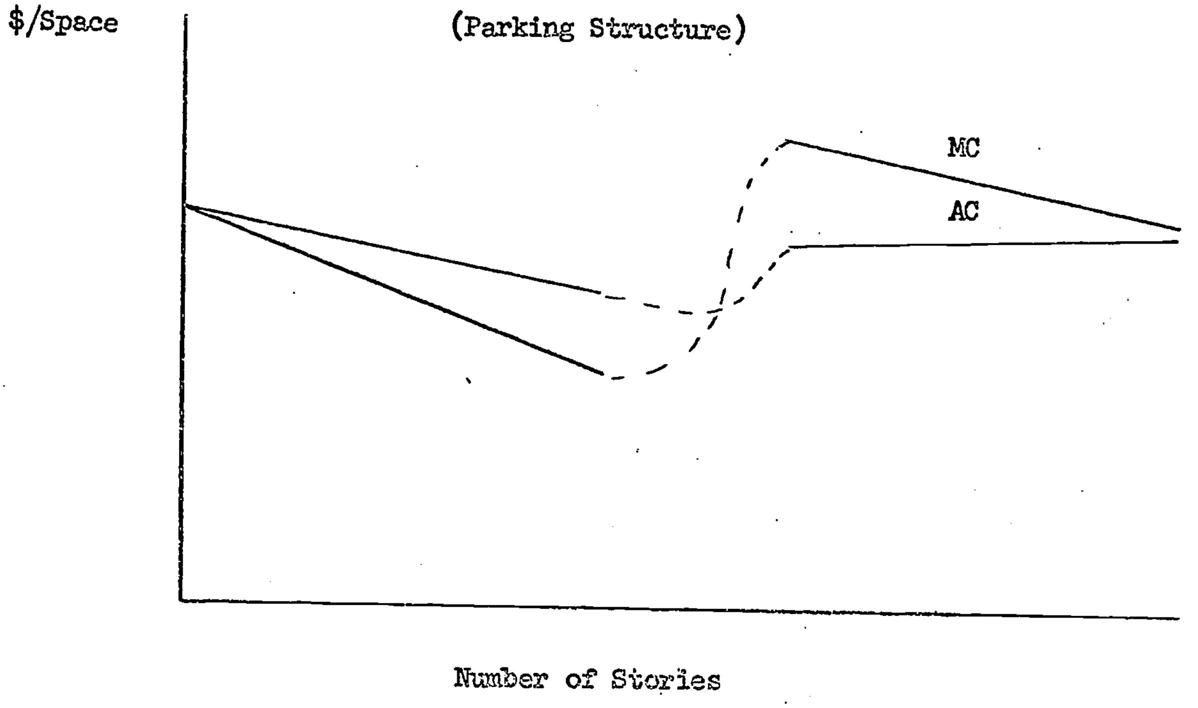
Alternative No. "N"	No. of Spaces Provided	No. of Acres Required or Available	Land Cost Per Acre	Total Land Cost	Facility Cost Per Space	Total Facility Cost	O & M Cost Per Space Per Year	Total 20 Year O & M Cost	Total Cost
On-Campus Surface	2,880	8.0	-	-	$ 242	$ .7M	$ 3	$ .2M	$ .9M
Off-Campus (High-Rise) (8)	11,193	5.0	$1.3M	$ 6.5M	$3,355	$37.6M	$40	$9.0M	$53.1M
TOTAL	14,073			$ 6.5M		$38.3M		$9.2M	$54.0M
Alternative No. "O"									
On-Campus Surface	1,440	4.0	-	-	$ 242	$ .3M	$ 3	$ .1M	$ .4M
On-Campus Structure (Low-Rise) (4)	5,360	4.0	-	-	$2,475	$13.3M	$20	$2.1M	$15.4M
Off-Campus Surface	7,273	20.2	$1.3M	$26.3M	$2,475	$ 1.8M	$ 7	$1.0M	$29.1M
TOTAL	14,073			$26.3M		$15.4M		$3.2M	$44.9M

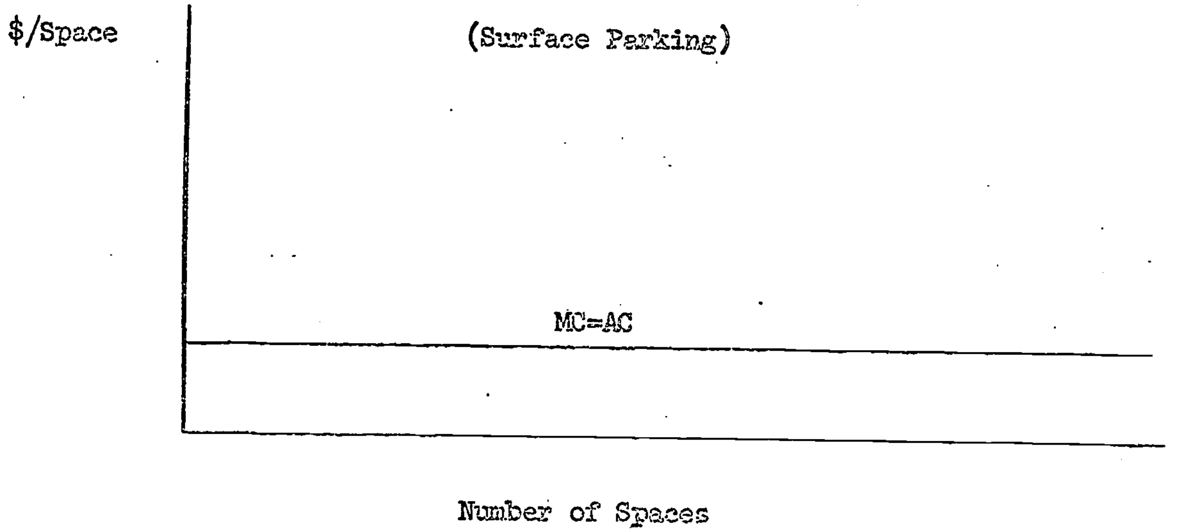
Examination of the above charts shows that sub-alternative "K" is the least cost solution using private autos and University parking. All other variations move away from this minimum cost alternative.

Format for Total Costing of Mixed Alternatives
(All to provide a total of 14,073 spaces)

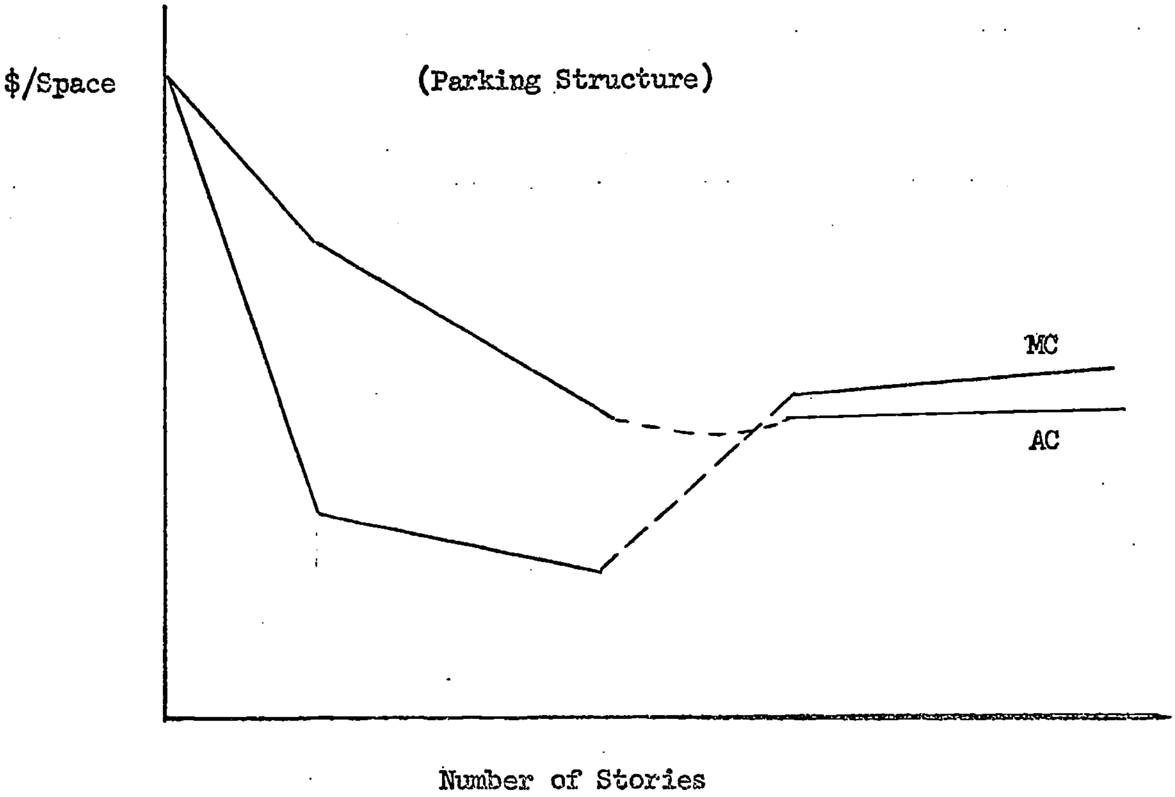
Alternative No. "K"	No. of Spaces Provided	No. of Acres Required or Available	Land Cost Per Acre	Total Land Cost	Facility Cost Per Space	Total Facility Cost	O & M Cost.. Per Space Per Year	Total 20 year O & M Cost	Total Cost
On-Campus Structure (Low-Rise) (4)	10,720	8	-	-	$2,475	$26.5M	$20	$4.3M	$30.8M
Off-Campus Surface	3,353	9.3	$1.3M	$12.1M	$ 242	$ .8M	$ 7	$ .02M	$12.9M
TOTALS	14,073	17.3		$12.1M		$27.3M		$4.3M	$43.7M
Alternative No. "L"									
On-Campus Structure (Low-Rise) (4)	10,720	8	-	-	$2,475	$26.5M	$20	$4.3M	$30.8M
Off-Campus Structure (Low-Rise) (4)	3,353	2.5	$1.3M	$ 3.3M	$2,475	$ 8.3M	$40	$2.7M	$14.3M
TOTAL	14,073			$ 3.3M		$34.8M		$7.0M	$45.1M
Alternative No. "M"									
On-Campus Structure (High-Rise) (8) -	14,073	8	-	-	$3,355	$47.2M	$20	$5.6M	$52.8M
Off-Campus Surface	0								0
TOTAL	14,073					$47.2M		$5.6M	$52.8M

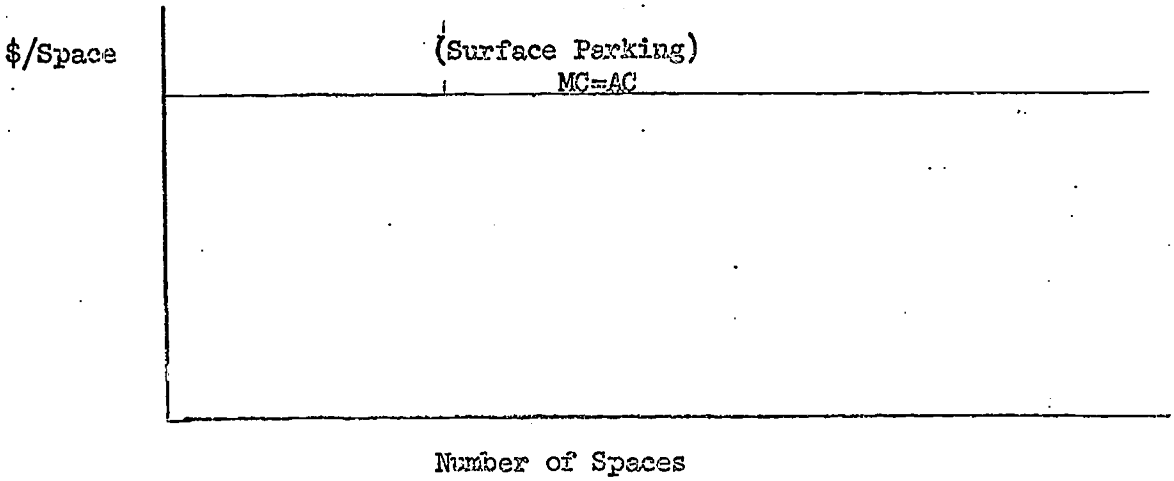
On Campus


$/Space
(Parking Structure)
MC
AC
Number of Stories


$/Space
(Surface Parking)
MC=AC
Number of Spaces

Off Campus


$/Space
(Parking Structure)
MC
AC
Number of Stories


$/Space
(Surface Parking)
MC=AC
Number of Spaces

III. (Continued)

The value of the preceding graphs is not in determining the right mix of alternatives in itself (only total costs can ascertain that) but simply as an aid in reducing further the number of alternatives which must be fully priced out.

Reviewing the above graphs, the following conclusions seem justified:

(a) Surface parking on-campus is by far the least costly approach, but it provides far too few total parking spaces.

(b) High rise buildings, in light of the very high marginal costs per space for the 5th through 8th floors (due to the need for heavier foundations and all of the other special requirements of the building code which are attributable to adding the 5th floor or more to a 4 story structure -- plus the decreased number of available parking spaces per acre due to space loss for elevator shafts, power units, etc.) appear to be always unattractive vis-a-vis other alternatives such as surface parking off-campus or low-rise structures off-campus. It should be noted that if only average cost curves were plotted, 8 story high rise structures would have average costs less than off-campus surface parking thereby disguising the fact that it pays not to go above the 4th floor, but at that point to switch to a wholly new alternative (i.e., off-campus surface parking) whose costs are less than the marginal cost of the 5-8th floors.

(c) Low-rise parking structures on campus appear to be the second best choice, but they don't provide quite enough spaces to meet the total demand either, so some supplementary alternative must also be chosen.

(d) While the marginal costs of off-campus structures look reasonably attractive, there is a good question whether the total costs for the required number of spaces is less than the costs for off-campus surface parking for an equal number of spaces. Only a total costing will answer that question.

(e) A case using some on-campus surface parking and on-campus low rise structures and a case using on-campus high rise structures should also be costed to verify the conclusion that these cases are moving away from optimal mixes.

III. (Continued)

Analysis of Alternative C - Bus Transportation

Blue Dog Bus Lines offers to provide necessary service for all personnel involved (less, of course, the 25% of faculty and staff who will always drive and those who accompany them; i.e., 1.39 persons per car). See Section II for Blue Dog Bus Lines calculation of their peak demand.

Firm offer of $2.5 million per year for 20 years gives total system cost of $50.0 million.

However, for this alternative, campus parking must be provided for the 25% of faculty and staff who will always insist on driving.

No. of Spaces Required = Faculty and Staff (8000) x .25 x .85 = 1700 Spaces

Since surface parking on-campus is cheapest and 1700 spaces @ 360 spaces per acre requires only 4.7 of the 8 acres, the on-campus surface parking alternative suffices. The 20 year total cost of the 1700 spaces = $513,400.

Thus the total 20 year cost of Alternative C is $50.0 million plus $.5 million or $50.5 million.

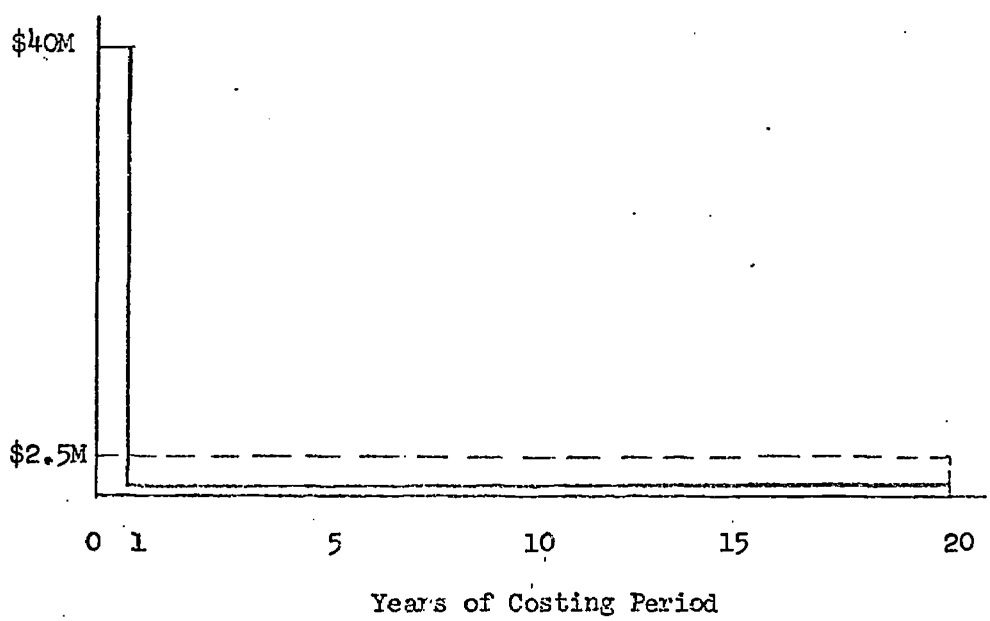
Comparison of Least-Cost Private Auto - Parking Space Alternative ("K") with Chartered Blue Dog Bus Line Service Alternative ("C")

The total 20-year system costs of these two remaining alternatives are as follows:

Private Auto/University Parking ("K")	=	$43.7 million
Blue Dog Bus Lines Charter Service ("C")	=	$50.5 million
Difference	=	$ 6.8 million

III. (Continued)

The choice ostensibly thus falls on Alternative "K". However, there are quite different time patterns of expenditures involved in the two alternatives, with Alternative "K" requiring large amounts of University funds immediately for capital outlay purposes. Either the University must borrow that money in the open market or it must use endowment funds which otherwise might be earning interest or dividends. Hence there is an opportunity cost or a cost of capital charge which needs to be applied to the two cost streams.



One accepted way of recognizing time preferences for money or the cost of capital is to take a cost stream over time and discount it at some appropriate rate (in our case 5% as indicated in the Statement of the Problem). The resulting figures are then on a common time preference basis and are known as the present value of the real cost stream.

If a 5% annual discount rate is applied to each year's costs in the two time streams shown above, the resulting present values are as follows:

Private Auto/University Parking (Alternative K)	=	$42.1 million
Blue Dog Bus Lines Charter Service (Alternative C)	=	31.6 million
Difference	=	$10.5 million

III. (Continued)

Thus, when the cost of capital is considered the alternatives switch places and "C" becomes markedly cheaper than "K". From a strict least-cost standpoint, therefore, the chartered bus service option clearly appears best.

There are, however, some spill-over effects, some uncertainties, and some unquantified aspects of the problem which need exploration before a definit conclusion is reached. These are explored in the following section.

IV. Discussion of Spill-Over Effects

A. When the bus option is chosen, car costs for commuters are avoided. The original selection was made on the basis of the total cost of bus vs. only parking cost to the University. The cost of driving must be included in the total cost analysis either as a social cost or be included as a spill-over effect.

B. On-campus housed students are not considered in the problem -- parking must in all cases be provided for them; also visitors.

C. The bus system leaves land free for alternative uses -- some opportunity cost value if additional buildings are ever required.

D. Bus system also requires no investment by the University -- can later switch to helicopters, etc.; -- the bus system is inconvenient, however, provides less freedom of choice; suffers from possibility of price escalation (despite contract clause) and interruption of service because of strikes. Thus, a disadvantage of the least cost solution is that it doesn't completely guarantee the meeting of the objective. Though the probability of an interruption in service may be extremely low, the cost to the University should this ever occur may be extremely high. Therefore, it might pay to "buy insurance" by providing for some limited number of parking places in addition to providing for the bus service.

E. The use of private autos would require community of Modero to float bond issue to widen road, put in traffic lights, etc; again, a community cost not explicitly recognized in the analysis.

V. Presentation of Results and Recommendation of Solution

A. State objective chosen.

B. Identify alternatives considered.

C. Indicate those ruled out and why.

D. Give costs of principal alternatives.

   1. Undiscounted.

   2. Discounted and rate used.

E. Discuss spill-over effects, unquantified aspects, elements of uncertainty (with results of sensitivity analysis, if any).

F. Indicate cost optimal solution.

G. Discuss costs (above least-cost solution) if another alternative is chosen because of weight given unquantified aspects of problem.