REVIEW DRAFT

Prioritization and Programming

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Contents

Introduction

Transportation planning is the development of strategies for the design, construction, maintenance, and operation of facilities for moving people and goods. The transportation planning process is coordinated, continuing and comprehensive.

Transportation planning can include such activities as
- classification of traffic
- safety studies
- analyzing transportation needs
- financial planning,
- coordination with state, federal, tribal,and other levels of government.

A typical transportation plan will identify projects that need to be completed in order to satisfy the plan. What the plan does not usually contain is any kind of prioritization of the identified projects. This task should be the job of the tribal leadership, because they control the expenditures.

This manual discusses prioritization and programming of projects, important steps of the planning process that are often not given proper attention. Several techniques for developing the project selection and prioritization list will be presented. They range from simple to complex. Users will likely use the method that is most appropriate for their situation.

Programming also needs to be considered by tribal leaders. Programming means staging the prioritized projects over time, based on available funds. Programming may be short-term or long-term. What is considered in this manual relates to the short term (1-5 years).

Priorities are based on the goals and objectives of the tribe. Therefore, before we can begin to prioritize, we must identify the tribe's goals and objectives.

Goals

A goal is an ideal, and as such is expressed in abstract terms. It is in every sense intended to be a community consensus, a base on which alternatives can be considered.

Applicable goals need to be identified for each transportation problem. Some goals may be available from an overall tribal, regional, or state development plan. Other broad goals can be identified from general tribal policy statements and through the political leadership. In many cases, goals are arrived at in reaction to a crisis that was unforeseen or unusual.

In the process of goal determination, there must be ample opportunity for participation by the public at-large and particularly by interested groups within the tribe. Setting the transportation goals in context with the goals of the tribe will exhibit the awareness of the relationship between transportation and the other things the tribal membership wants and needs. The goals of the tribe must be the guide in prioritizing the transportation programs.

Goals cannot be attained once-and-for-all. They must be continually sought anew. Goals may become unattractive with the passage of time. Thus, what is acceptable today may be unacceptable tomorrow. Goals must be in continuous development to reflect the developing needs and wishes of the tribal community.

What are acceptable goals and what areas do they cover? Based on the above discussion there is no one-size-fits-all solution to this question. To illustrate some possibilities of goals within a series of broad subject areas, the following are provided as typical goals, which may or may not relate directly or indirectly to transportation.

Example Goals

Social
More equitable distribution of income
Compatible neighborhoods within the tribal community
Involve tribal members in the decision-making process
Provide a sense of community
Provide stability and security for tribal members
Improve living conditions for tribe

Environmental
Promote clean air and a trash-free landscape
Lower levels of noise pollution
Reduce water pollution

Financial
Preserve the tax base
Lower transportation cost
Promote economic growth

Transportation
Improve access to employment
Provide for access to tribal facilities
Promote multiple modes of transportation
Increase safety of transportation
Improve Mobility

Obviously this list is not comprehensive and each tribe should be able to define other goals that meet their particular needs.

Objectives

Objectives are the added refinements needed to analyze the goal. An objective is a result one intends to achieve. The objective provides the specific measurable statement that can be used to assess the goal in relation to the given projects.

Specific objectives need to be identified for each transportation goal. In order to assess the contribution toward the attainment of a goal, the objectives should be stated in a way that can be used as a measure of the project's contribution to achieving the goal.

The objective statement should be structured to match the attitude of the community. Care should be taken to ensure the stated objective is not used just because it is easy to measure. Some important objectives may in fact not have a easily measurable results.

Note that each of the objectives listed in the chart is a statement that has a measurable answer. For example, the objective to decrease travel time to work can be analyzed using standard delay-study methods known to traffic engineers. This data may require some effort to obtain but that does not prevent the tribal planner from obtaining the information.

In delineating goals and objectives, the decision-makers and their staffs must strive to attain a balance between goals that are so broad as to be meaningless, and objectives so specific that they hinder the prioritization process.

Once the goals and objectives of the tribal government have been stated and a transportation plan has developed a set of projects, it is necessary to evaluate the projects in some way in order to select the best possible project in terms of the goals and objectives.

Examples

Social Goal—Improve Living Conditions for Tribe

Objectives

- Increasing number of housing units available to tribal members
- Reducing average cost of housing
- Increase transportation in underserved areas

Environmental Goal—Reduce Water Pollution

Objectives

- Reduce Biological Oxygen Demand in streams
- Prevent salt intrusion from winter road maintenance
- Implement well-testing program

Financial Goal - Promote Economic Growth

Objectives

- Increase access to jobs
- Reduce cost of transportation
- Reduce cost for land development

Transportation Goal - Improve Mobility

Objectives

- Decrease travel time to work
- Increase transit opportunities
- Increase number of paved miles on reservation
- Improve park and ride facilities
- Install traffic control devices at critical intersections
- Reduce number of vehicles/day

Prioritizing Methods

Prioritization is a process for assisting in the determination or selection of the preferred project from among a number of feasible alternatives. The process may be used by professional planners in selecting the best projects, or it may be used by the leadership to determine the best plans for the tribal community.

The actual techniques used to make the decision vary in detail and difficulty. Some techniques are complicated and require some mathematical abilities to understand and use the processes. Other techniques are simple to use and require very little mathematical analysis. In the discussion that follows several methods of prioritization will be presented, proceeding from the simple to the more complex. The list of techniques is not all-inclusive, and other methods are available in the list of related publications, but this discussion should provide at least one technique that will be appropriate to all decision-makers.

Evaluate Projects Using Goals

Evaluating a project using this method means determining a set of numbers that relate the relative significance of the project to satisfying the goals. The best way to incorporate this into a simple process is to prepare an evaluation table that lists each project and each goal. The table can be as elaborate as desired but should be easy to make and use. Notes related to the scoring system used, goal definitions, and project definition can also be added.

To score a project it is not necessary to do any detailed or complicated evaluation. It is only necessary to answer the question: Does the project satisfy the goal and to what degree? For example, if a project satisfies the given goal it is given a score of "3." A project that has no influence on the goal is given a "2." And a project that has a negative effect on the goal is given a "1."

3=Project satisfies goal
2=Project does not affect goal
1=Project has a negative effect on goal

Some goals are more significant than others and are provided a multiplication factor (weight). For example, tribal unity may be more important to the tribe than safety for the traveling public. In this case, it would be appropriate to make the scores associated with the goal **promote tribal unity** higher than the scores for the goal **improve safety for traveling public**. This is done in the example by multiplying scores for **promote tribal unity** (Goal 5) by a weighting factor of 6, and **improve safety for traveling public** (Goal 4) by one. This suggests that tribal unity is six times as important to the tribe as safety. Suggested weighting factors might be as follows:

Significance of Goal	Weighting Factor
Very High	10
High	8
Medium	6
Low	4
Very Low	2
None	0

The evaluation of a project can proceed in a straightforward manner once the goals are known and a scoring system is selected. Each project is scored in terms of each goal using the selected scoring system. The project score for each goal is multiplied by the appropriate weighting factor and the sum of the scores for each project is determined, followed by a rank based on the summed score. The highest project score is ranked number 1 and lowest sum has the lowest rank. A completed evaluation table is shown in Table 1.

PROJECT SCORE								PROJECT EVALUATION					
GOAL	A	B	C	D	E	F	**WEIGHT**	A	B	C	D	E	F
1	3	3	2	3	3	3	10	30	30	20	30	30	30
2	2	3	3	3	3	2	6	12	18	18	18	18	12
3	3	2	3	3	3	2	2	6	4	6	6	6	4
4	1	3	3	2	2	1	1	1	3	3	2	2	1
5	1	2	1	3	3	1	6	6	12	6	18	18	6
							SUM	55	67	53	74	74	53
							RANK	4	2	3	1	1	3

Table 1 Evaluation Table

Example Projects
A. Design and implement intersection improvements at Aquoni Rd. and U.S. 441
B. Design and construct streetscape and parking improvements (Downtown)
C. Implement shuttle bus service
D. Study, design, and construct U.S. 119 improvements
E. Study, design, and construct U.S. 441 improvements
F. Install signal at Aquoni Rd. and Big Cove Rd.

Example Goals
1. Improve transportation system performance
2. Increase mobility for tribal members
3. Enhance land use
4. Improve safety for traveling public
5. Promote tribal unity

Project Score
3=Project satisfies goal
2=Project does not affect goal
1=Project has a negative effect on goal

The evaluation process just completed should produce a list of projects that are ranked from best (highest score) to least important (lowest score).

Evaluate Projects Using Objectives

In this method each project is scored in accordance with its ability to meet the specific objective. In general this may be achieved by one of two methods: judgment or numerical analysis.

Judgment - a subjective scoring of the performance characteristics. Since the assessment of projects is subjective, the process depends on the involvement of highly informed and experienced persons if intelligent decisions are to be made.

Numerical Analysis - if the score is based on some analytical method it might appear to be more impartial. For many objectives that are in transportation-related areas, there are well-defined methods of analysis. For example, an objective **reduce number of vehicles/day** as part of the goal **improve mobility** might be evaluated by considering how the proposed projects will reduce the number of vehicles-per-day that use the project. This could be determined by obtaining the traffic counts for existing vehicles-per-day before the project (most states have this information in their traffic divisions) and comparing it with how many vehicles-per-day will use the facility after the project is completed (information in the planning report or from other sources). This ratio of before and after conditions should be obtained for each project and a scale be established that reflects the relative significance of each project in terms of satisfying the objective **reduce number of vehicles/day**. The overall score for each project is obtained by adding the individual scores for each objective.

Scoring techniques have the purpose of assigning a meaningful number to the projects in a manner that reflects the degree in which they differ from each other.

Judgment Technique

In the following example, using the judgment technique for scoring, the planner or leader assigns a number from one to six as an indicator of how well the project addresses the objective, where one is good and six is poor. In its simplest form it might look something like Table 2.

	Score					
Objective	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**	**Project 6**
1	5	4	1	6	2	3
2	6	3	2	5	1	4
3	3	1	4	2	6	5
4	5	4	3	1	2	6
5	6	3	1	2	4	5
Total	25	15	11	16	15	23
Rank	5	2	1	3	2	4

Table 2

For variety and to illustrate other approaches, the best project in this example is given the lowest score. The projects and objectives are generic. Individual users would use their own projects, objectives, and scores.

Numerical Analysis Techniques

At this time a more detailed look at the numerical analysis technique is in order. The idea is to put the score on a more analytical basis and to include some mathematics in the process.The score for any objective involves the following steps.

1. obtain the data that measures the objective (different objectives may be measured using different scales).
2. Relate the data to the objectives
3. Place the quantified data on a common scale of measurement

In Table 3 the following data is used to put the objectives on a common scale of measurement.

Project Data

	Project Number		
	1	**2**	**3**
Project Cost ($x1000)*	15	30	20
Accidents-/VM **	10	5	20
Aesthetics (%)***	70	50	80

Table 3
notes:
*Project cost is an estimate of total cost. Lower is more desirable.
**Accidents per vehicle mile is an estimate. A lower number is better.
***Aesthetics is a subjective determination of how the project looks. The higher the percentage of improvement, the better.

For each objective, score each project from best to worst, and obtain the combined score by adding the result for each project. Note, as in the judgment technique, the lowest final score is associated with the most desired result, because the number one ranking is the best choice and the number three is the least desirable.

	Project Number		
Objective	**1**	**2**	**3**
Minimize Project Cost	1	3	2
Reduce Accidents	2	1	3
Improve Aesthetics	2	3	1
Score	5	7	6
Rank	1	3	2

Table 4 Project Rating

In mathematical terms the result is

$$S_j = \sum R_{ij}$$

where i is the row (objective) and j is the column (project). The statement says sum the elements in column j one row at a time. Expanded, the sum for column j=1 (project number 1) equals the score on row 1 plus row 2 score plus row 3 score = 5.

Weighting

Obviously there are no weights associated with the above example (or all objectives have a weight of 1).

The objectives may be assigned weights in relation to the significance of the objective relative to achieving the goal. This is included in the expression as follows:

$$S_j = \sum_i w_i \; R_{ij}$$

where w_i is the weight assigned to the objective i. Continuing the example given above the results would be as in Table 5, assuming that the weights for the respective objectives are 1, 3, and 6 for the **Minimize Project Cost, Reduce Accidents**, **and Improve Aesthetics**. Note in this case since the low score is best, the least significant objective is given the highest weight.

Objective	**Project Number**			**Weight**	**Project Number**		
	1	2	3		1	2	3
Minimize project cost	1	3	2	1	1	3	2
Reduce Accidents	2	1	3	3	6	3	9
Improve Aesthetics	2	3	1	6	12	18	6
Score	5	7	6	**Weighted Score**	19	24	17
				Rank	2	3	1

Table 5

Since low is good, we see that project three is the best alternative, and has switched position with project one due to the weighting.

Ranking Techniques

The example above leaves us with an ordinal 1-2-3 ranking. Another way to express the ranking is by using a percentage based on a scale of 100. In this case it would be necessary to convert the scores to the percentage by letting the best weighted score be equal to 100 and inversely proportioning the others to that value.

Using the formula:

$$\%S_n = (\tfrac{W_O}{W_A})100$$

where %S is the percentage score, W_O is optimum weighted score (best score). W_A is the actual weighted score, and n is the project number.

Following that formula, we have the following calculation for project number 1:

$$\%S_1 = \frac{17}{19} x \ 100 = 89$$

Project Number	**1**	**2**	**3**
Score	5	7	6
Weight Score	19	24	17
% S	89	71	100

Table 6

In the examples given above the scores were based on a numerical order (sometimes called the *ordinal method*). This is a convenient method and easy to do. Additional methods are available and might be better in certain situations.

1. *Index method* if project values are accurate and up-to-date
2. *Percentage method* if the values are subjective.

Index Method - expresses the proportion of distance that a given project value lies between the best and worst values. The value between the best and worst projects is called the range. In symbols the relationship is

I = (X/R)*M

where

I = Index value for the project

X = difference between the given project value minus the lowest project value

R = Range of the project values

M = Maximum scale value (typically 10 or 100)

For example, using the project scores given above and repeated below, for project one, two, and three, and for objective one (**Minimize Project Cost**) the index values are:

$$I_1 = \left(\frac{1-3}{1-3} \right) x \ 10 = 10$$

$$I_{2=} \left(\frac{3-3}{3-3} \right) x \ 10 = 0$$

$$I_3 = \left(\frac{2-3}{1-3} \right) x \ 10 = 5$$

	Project Number		
Objective	**1**	**2**	**3**
Minimize Project Cost	1	3	2
Reduce Accidents	2	1	3
Improve Aesthetics	2	3	1
Total	5	7	6
Rank	1	3	2

Table 7 Project Scores

Using this technique the value for the projects given above results in the following index values:

	Project Number		
Objective	**1**	**2**	**3**
Minimize Project Cost	10	0	5
Reduce Accidents	5	10	0
Improve Aesthetics	5	0	10
Total	20	10	15
Rank	1	3	2

Table 8 Index Values

Note that now high numbers and totals are best using this approach but the rank remains the same.

Percentage method - Expresses the score as being better than a certain percentage of scores for all projects. It is derived by the formula:

P = (W/(B+W))*M

where

P = Percentage rank of the project
B = Number of projects with equal or better values
W = Number of projects with lesser values
M = Maximum value of the scale (100 for percentage)
n = Project Number

A less desirable value is one that would place an project in a lower priority. Those projects with the same value are excluded from the count for best and worse.

For the objective **“Minimize Project Cost**,” the calculation would be:

$$P_1 = \frac{2}{(0+2)}\ x\ 100 = 100$$

$$P_2 = \frac{0}{(2+0)}\ x\ 100 = 0$$

$$P_3 = \frac{1}{(1+1)}\ x\ 100 = 50$$

The complete table is:

	Project Number		
Objective	**1**	**2**	**3**
Minimize Project Cost	1	3	2
Reduce Accidents	2	1	3
Improve Aesthetics	2	3	1
Total	5	7	6
Rank	1	3	2

Table 9 Project Score

	Project Number		
Objective	**1**	**2**	**3**
Minimize Project Cost	100	0	50
Reduce Accidents	50	100	0
Improve Aesthetics	50	0	100
Total	200	100	150
Rank	1	3	2

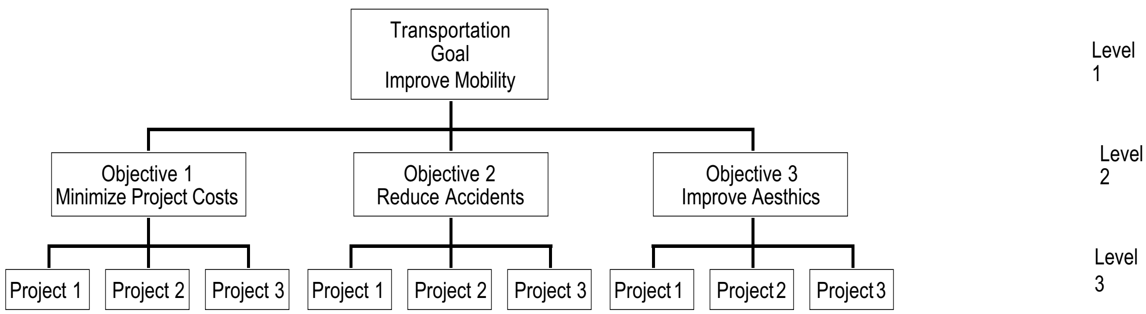
Table 10 Percentage Score

In the examples above all techniques produced the same rank for the various projects. There are other techniques that might be as appropriate and as valid. The usefulness of any technique lies in its ability to help organize the decision-making process. As to the choice of technique, it is largely the decision of the user and it depends on the quantity and quality of the available information.

Analytic Hierarchy Process (AHP)

A fundamental problem in decision theory is how to derive weights for objectives/goals. This is a process of decision making which may be studied though a hierarchical structure.

For example, a typical hierarchy for transportation planning might include the following:



A hierarchical structure usually consists of a series of subsystems in combinations and arrangement. They are decomposable with connections between levels being simpler then connections between elements in a level. Only the aggregate properties of the level determine the interaction between levels, and not the properties of the individual elements.

AHP is a general theory that can be used to develop ratio scales and weights from paired comparisons, both discrete and continuous. The comparisons are designed to reflect the relative strength of preferences and can be derived either from actual measurements or from a qualitative scale. There has been a reasonable amount of application of AHP in various fields.

AHP uses three phases: modeling, comparative judgment, and analysis. Under the modeling phase a problem is structured with its elements in a hierarchy of levels, each being independent from those in succeeding lower levels. The object is to develop weights (which might be called priorities) to allocate a resource at each level.

For example, consider the structure shown above with the problem of determining the relative weights for objectives 1, 2, and 3. By use of AHP, a series of pairwise comparisons of each of the objectives is made. In our case, is **Minimize Project Cost** more significant in promoting the goal of **Improve Mobility** or is **Reduce Accidents** and to what degree?   Likewise is **Minimize Project Costs** more significant than **Improve Aesthetics** and to what degree? Assume that **Minimize Project Costs** is four times more significant than **Reduce Accidents**, and eight times more significant than improve aesthetics. Finally, **Reduce Accidents** is twice as significant as **Improve Aesthetics**. These results could be put in a comparative judgment matrix as shown in Table 11.

Objective	Minimize Project Cost	Reduce Accidents	Improve Aesthetics
Minimize Project Cost	1	4	8
Reduce Accidents	1/4	1	2
Improve Aesthetics	1/8	1/2	1

Table 11 Comparative Judgment Matrix

Note the elements on the main diagonal are all one (comparing an objective to itself), and in general the matrix is inverse symmetric. That is, the elements in the off diagonal locations are inversely related.

For a matrix of n rows and columns, we approximate the solution as follows:

1. For each row i of the matrix, find the product of the elements in that row and denote it as I_i.
2. Calculate the geometric mean $I_i^{1/n}$
3. Normalize the geometric mean value by forming $p_i = I_i^{1/n} / \sum I_i^{1/n}$

This is best illustrated by completing the calculation using the matrix given above as shown in Table 12.

Objective	Minimize Project Cost	Reduce Accidents	Improve Aesthetics	I_i	$I_i^{1/n}$	p_i
Minimize Project Cost	1	4	8	32	3.17	.73
Reduce Accidents	1/4	1	2	1/2	.79	.18
Improve Aesthetics	1/8	1/2	1	1/16	.40	.09

Table 12 SUM=4.36

The result is that Objective 1 should have a weight of 0.73, compared to weights of 0.18 for Objective 2 and 0.09 for Objective 3. Thus **Minimize Project Costs** will contribute more to satisfying the goal of **Improve Mobility** than either **Reduce Accidents** or **Improve Aesthetics**. The procedure given above is a reasonably good approximation as long as the matrix is consistent.

To continue, it is possible to determine the relative significance of the projects in relation to each of the objectives and to combine those results with the previous to form a composite weight for each of the projects. This is done by constructing a judgment matrix for each objective. For example, for the objective **Minimize Project Costs** we need to form the matrix for each of the projects as shown in Table 13.

Reduce Costs	Project 1	Project 2	Project 3	I_i	$I_i^{1/n}$	p_i
Project 1	1	2	4/3	8/3	1.38	.44
Project 2	1/2	1	2/3	2/6	.69	.22
Project 3	3/4	3/2	1	9/8	1.04	.34

Table 13 Sum=3.11

Likewise for the objective **Reduce Accidents** and **Improve Aesthetics** as shown in Tables 14 and 15 respectively.

Reduce Accidents	Project 1	Project 2	Project 3	I_i	$I_i^{1/n}$	p_i
Project 1	1	1/2	2	1.0	1.0	.29
Project 2	2	1	4	8	2.00	.57
Project 3	1/2	1/4	1	1/8	.50	.14

Table 14 Sum=3.13

Improve Aesthetics	Project 1	Project 2	Project 3	I_i	$I_i^{1/n}$	p_i
Project 1	1	7/5	7/8	49/40	1.06	.35
Project 2	5/7	1	5/8	25/56	.76	.25
Project 3	8/7	8/5	1	64/35	1.22	.40

Table 15 Sum=3.04

To obtain the composite hierarchical priority for the projects, it is necessary to multiply a square matrix formed from columns of project priorities from each objective by a column matrix formed from the priorities for the objectives as shown in Table 16.

	Reduce Costs	Reduce Accidents	Improve Aesthetics		
Project 1	.44	.29	.35	.73	Reduce Costs
Project 2	.22	.57	.25	.18	Reduce Accidents
Project 3	.34	.14	.40	.09	Improve Aesthetics

Table 16

The composite result for the projects are determined by matrix multiplication:

Project 1= 0.44*0.73+0.29*0.18+0.35*0.09 = 0.40
Project 2= 0.22*0.73+0.57*0.18+0.25*0.09 = 0.29
Project 3= 0.34*0.73+0.14*0.18+0.40*0.09 = 0.31

As can be seen, the project values are combined as the columns of a matrix. The combined matrix of a level is then multiplied on the right by the weight matrix of the next higher level. If one decision is required, the option with the highest weight is selected; otherwise the resources are distributed to the options in proportion to their weights in the final vector. In the case above, (0.40, 0.29, and 0.31 for projects 1, 2, and 3, respectfully)

At this point it might be appropriate to define the pairwise comparison scale that is the basis for the comparison matrix. In making the comparison you need to determine which of the projects will contribute the most to accomplishing the objective that is being considered. In this case the values are determined from judgment. However, in some instances it may be possible to make comparisons based on some quantifiable measured data such as accidents per vehicle mile traveled. Following is a suggested scale for making judgement-based comparisons:

Intensity of Importance	Definition
1	Equal importance of both elements
3	Moderate importance of one element over another
5	Strong importance of one element over another
7	Very strong importance of one element over another
9	Extreme importance of one element over another

Other Methods

Optimization - Optimization methods provide tools that are capable of allocating funds over time in an efficient manner. They generally give better solutions than the ranking/weighting or AHP procedures. Optimization methods can include future budget limitations and other condition limitations necessary to provide the optimal answer. However, optimization models are more complex and difficult to understand. They also may be expensive in terms of computer usage and time required for analysis.

In order to give the user some idea of application of optimization a simple example is given below. It includes the following elements:

1. There are four projects that have to be completed within two years

2. The costs and benefits associated with each project have been determined and a benefit/cost (B/C) ratio for each year of completion and each project has been determined.

3. Any combination of projects and completion year can be accepted as long as it produces the maximum B/C for the combination. The data follows:

	Year 1	**Year 2**
Project 1	1.75	1.5
Project 2	1.88	1.44
Project 3	1.67	2.0
Project 4	1.60	1.50

Table 17 B/C Ratio

In linear integer programming notation:

Maximize B/C $= \sum\sum Bi / Ci * X\mathrm{ij}$ (1)

Subject to $\sum$Xij < 1 for i =1,2,3,4 (2)

Where

i=Varies from 1 to number of projects

and

j= Varies from 1 to number of years

Xij= Factor for project i in year j of the program period

Equation (1) is the objective function for maximization of benefit /cost ratio.

Equation (2) states that Xij is unique and can't be done twice. Either it is or isn't built.

These equations result in 16 possible combinations that could produce the maximum B/C ratio. They are :

Year of Completion for Project Combinations		
Year 1	**Year 2**	**∑B/C**
1	2,3,4	6.69
2	1,3,4	6.88
3	3,3,4	6.11
4	1,2,3	6.54
1,2	3,4	7.13
1,3	2,4	6.36
1,4	2,3	6.79
2,3	1,4	6.55
2,4	1,3	6.98
3,4	1,2	6.21
1,2,3	4	6.80
1,2,4	3	7.23
1,3,4	2	6.46
2,3,4	1	6.65
1,2,3,4	*	6.90
*	1,2,3,4	6.44

Table 18

The sequence that produces the maximum B/C summation (7.23) is to do projects 1, 2, 4 in year one and project 3 in the second year. This is the essence of linear programming and optimization. Details and formal presentation methods are required to improve on this simple overview.

Selection of Method

The evaluation procedure that best fits any given situation is the one appropriate to the type of decision being made and the quality of the input data available. In general, it is true that all of the ranking procedures lack the ability to determine the absolute desirability of undertaking any action. Accordingly these procedures are easier to apply to projects with quantifiable objectives but are hard to apply to subjective objective evaluation.

Prioritization Summary

Project selection methodology consists of three main tasks: Definition of a priority-setting framework, the selection of evaluation criteria and the development of criterion measures, weights, and point distribution.

The priority-setting framework is defined by statements regarding what is wanted (goals) and evaluation criteria (objectives) that are guidelines for measuring progress toward the goals. The goals need to be comprehensive, including all transportation and community considerations. Technical and policy groups as well as the public should actively assess these policy inputs as the evaluation proceeds.

Critical issues and conflicts should be identified early in the evaluation process. Quantified technical data may be required to clarify the problem.

There are other considerations that might go into the prioritization process, including more elaborate numerical evaluation techniques, but these methods will be refinements of the process described, not a change in the process itself.

Programming

Programming has been defined as the matching of desired projects with available funds to accomplish the goals of the organization. Several levels of programming can occur including programming of all projects for the tribe or programming of projects related only to transportation. In both cases the process must take into account resource availability, political jurisdictions, and specific project types. The process must also be concerned with the staging of projects over time.

In particular, developing a transportation program requires an awareness of the impacts of the projects on the community and an understanding of the many local political agendas. It is rare that a decision regarding a major transportation project is based on technical data alone. Non-technical factors can override the technical analysis of a project.

Several characteristics of an effective programming process can be identified. They are:

1. The programming process must be linked to the planning steps that precede it. The program should be considered as a step toward the realization of the adopted transportation plan and as one of the components of managing the tribe's investment plan.

2. The program should have a multi-year framework that integrates projects over time and location. The multi-year framework should provide a general direction for transportation investment and identify the interdependence between the short-term and long-term outcomes.

3. Individual projects should have a priority established. Establishing priorities based on tribal goals and objectives is a critical component of the programming process.

4. Understand the amount and source of funding available to the tribe. For the programming process to be credible, the level of funds identified in the program must be realistic in terms of what can be expected.

5. The program should also have a means of monitoring the progress of previously programmed projects and the degree to which the projects were implemented in conformance to tribal policies.

6. The program should help assure consistency between the transportation program and the community goals and objectives outlined in the transportation plan.

The two major quantitative tasks in the programming process are setting priorities and determining the availability of funds. Setting priorities has been discussed in detail above and any of those techniques can be used depending on the type of data available and the level of sophistication required. Determining availability of funding is more dynamic and requires a comprehensive knowledge of national, state, and local sources of funds. As an example, typical sources of transportation funding are shown in the table below. Additional information about funding sources and programs are included in *A Guide to Federal-Aid Programs, Projects, and Other Uses of Highway Funds*, published by the FHWA.

Table 19 Typical Funding Sources
*Each State has different funding programs and eligibility requirements. Contact State DOT

Funding Sources - Federal	
Program	**Source**
Indian Reservation Road Program (IRR)	BIA
Surface Transportation Program (STP)	FHWA
Congestion Mitigation Air Quality	FHWA
Publics Lands Highway	FHWA
Safety Enhancement (402)	FHWA
Bridge Replacement Program	FHWA
Enhancement Program	FHWA
Funding Sources - State	
Program	
Economic Development Programs	
Economic Development Fund	
All Season Roads	
Forest Roads	
Bridge Replacement (HBRRP)	
Funding Source - County	
Program	
Cooperative Road and Bridge	
Funding Sources - Tribal	
Program	
Direct Assessment	
Mileages	
Permit Fees	
Downtown Development Authorities	
Department of Commerce	
Bonds	

Once the funding sources have been identified, the programming process can continue with project selection as follows.

1. Associate each project developed from the transportation plan with a possible funding source and program. In the example below the projects listed were taken from a report, *Cherokee Indian Reservation Transportation Plan* by Kimbley - Horn and Associates, Inc. The project codes are arbitrary letters assigned by the author.

Project		Project Code	Funding Source	Program
Safety Improvement				
	Intersection Improvement	A	FHWA	402
	Signing & Striping	B	FHWA	402
Parking/ Downtown		C	EDC/TRIBE	
Shuttle Bus Service		D	FTA	Rural Bus
U.S. 19				
	Plan/Design	F	FHWA	STP
	Construct	G	FHWA	STP
U.S. 441				
	Plan/Design	H	FHWA	STP
	Construct	I	FHWA	STP
Traffic Signal		J	STATE DOT	Safety
Local Street Signs		K	TRIBE	Trans Fund
Tribal Housing Service Road		L	BIA	IRR
Snow Removal/Maintenance		M	BIA	Maintenance
Bridge Replacement				
	U.S. 441	N	STATE DOT	HBRRP

Table 20 Funding Source for Projects

2. Separate each project by funding source and program. Include estimated cost of the project. The sum of all project costs is the total need developed under the transportation plan.

		Project		Program
Source	Program	**Code**	Cost ($1000)	**Total ($1000)**
FHWA	STP	F	500	
	STP	G	2000	
	STP	H	400	
	STP	I	1500	
				4400
	402	A	600	
	402	B	50	
				650
FTA	Rural Bus	D	200	200
BIA	IRR	L	400	400
BIA	Maintena-nce	M	100	100
State DOT	HBRRP	N	3000	3000
State DOT	Safety	J	30	30
EDC/Tribe	Parking	C	100	100
Tribe	Signs	K	50	50
		Total Need	8930	8930

Table 21 - Project: Source and Program Determination

3. Forecast the funds likely to be available from each funding source and for each program as in the table below. Past experience may be a good place to start. Contacts with the appropriate funding source are important. For multi-year programming this forecast may require some estimation. Many programs have restrictions or require match funds. These should be included in the list. The need for funds from each program may be indicated to help in planning for future years. This value is carried forward from Step 2. It is apparent that the need for funds will likely exceed the annual amount available and the program, to complete all projects, will have to be multi-year.

Source	Program	Program Need ($1000)	Program-Available $/yr ($1000)	Match	Restrictions
FHWA					
	STP	4400	1000	20% State/Local	
	402	650	*	20% State/Local	
FTA					
	Rural Bus	200	200		
BIA					
	IRR	400	200		
	Maint	100	100		
State DOT					
	HBRRP	3000	*	20% State/Local	
	Safety	30	*		
EDC/Tribe	Parking	100	50		
Tribe	Signs	50	*		
Total		8930	1550		

Table 22 Fund Availability and Need

* Funded by project

4. Determine funds required to meet critical needs - projects not included in the planning process that address critical safety problems or impending structural failures. These projects may not be delayed and should be included in the program for the current year.

Project Description	Priority	Funding Source	Cost ($10
Emergency	1	Tribal Maintanance	100

Table 23

5. List all projects to be included in the programming determination by priority. Include continuing and emergency work. Separate by source and program. Put in order of priority for each program.

Note: It is possible to prioritize all projects into a single list or to separate the projects by funding source and program and then prioritize within the funding program. The latter technique is used in Table 24.

Source	Program	Project Code	Overall Priority	Program Priority
FHWA	STP	F	5	1
		H	6	2
		G	7	3
		I	8	4
	402	B	2	1
		A	3	2
FTA	Rural Bus	D	5	1
BIA	Maint	M	1	1
	IRR	L	2	2
State DOT	Safety	J	9	1
	HBRRP	N	11	2
EDC/Tribe	Parking	C	4	1
Tribe	Signs	K	10	1

Table 24 - Prioritization by Funding Source and Program

6. Allocate funds for prioritized projects by funding source and program. The object is to determine the best use of all available funds throughout the programming period (1 - 5 years). The process proceeds as shown in Table 26:

A. Enter the estimated annual budget for each source and program (step 3) for year 1.

B. Enter the amount of funds available for each source and program. This may be the annual budget (A) or the annual budget plus some amount of money carried over from a previous year.

C. For each program, enter the project cost for the project with the highest remaining priority (step 3) for the particular source and program.

D. Enter the project expenditures for the project selected in step C. If this project is not to be funded in the current year, enter a zero.

E. Enter the budget year for project expenditure in step D

F. Subtract the funds expended from the funds available and enter the amount on the next line for the funds available for the next project. Add any budget additions.

G. Repeat C - F for the project with the next highest priority for the given source and program.

H. Continue until all projects are considered or available funds are exhausted.

If projects are added to the initial list, they should be added in location that reflects their priority. Others may have to be deferred due to lack of funds. As projects are completed, deletion should be from the top down always attempting to maintain the monetary distribution of the budget allocation plan.

Once the projects have been programmed, target dates must be established for each improvement project. The target dates are the points in time for each project when either necessary construction commences, right-of-way can be purchased, or equipment can be purchased. They are the target dates for beginning expenditure of the allocated capital funds.

No completely prescribed procedure can define the many programming decisions. Full knowledge of local and area conditions is necessary as well as the timing of other developments.

A possible major source of concern is the question of whether one large high-priority project should be deferred (because of lack of funds for the entire project) in favor of several smaller lesser priority projects. In general, if the smaller projects cause only slight delay to the larger project, the smaller ones should precede the larger.

					(C)	(A)	(B)	(D)	(E)	
Source	**Program**	**Project Code**	**Priority Overall**	**Priority Program**	**Project Cost**	**Annual Budget**	**Funds Available**	**Project Expen- diture**	**Budget Year**	**Comments**
FHWA										
	STP	F	5	1	500	1000	1000	500	1	
		H	6	2	400		500	400	1	Carry over 100 to next budget year
		G	7	3	2000	1000	1100	0	2	
				3	2000	1000	2100	2000	3	Carry over 100
		I	8	4	1500	1000	1100	0	4	Carry over to
				4	1500	1000	2100	1500	5	Carry over 600 6
							600		6	
					Total	5000	600	4400		
	50	50	50	50	1		402	B	2	1
	402	B	2	1	50	50	50	50	1	
	A	3	2	600	600	600	600	1		
			Total	650	0	650				
FTA	Rural Bus	D	5	1	200	200	200	200	1	Annual exp
BIA	Maint	M	1	1	100	100	100	100	1	
	Maint	M	1	1	100	100	100	100	2	
	IRR	L	2	2	400	200	200	0	1	Carry over 200
			2	2	400	200	400	400	2	
					Total	600	0	600		
St. DOT	Safety	J	9	1	30	30	30	30	1	
	HBRRP	N	11	2	3000	3000	3000	3000	1	
					Total	3030	0	3030		
EDC/In	Parking	C	4	1	100	50	50	0	1	Carry to Year 2
				1	100	50	100	100	2	
					Total	100	0	100		
Tribe	Signs	K	10	1	50	50	50	50	1	
				Total	50	0	50			

Table 26 Allocation Plan

Programming Summary

Programming is an essential part of the planning process. It requires a detailed understanding of the specifics of project prioritization as well as general knowledge related to funding sources and programs. Once the funding source and program is known, a well-defined procedure is available to identify the projects that will be funded during the program cycle. Flexibility and the ability to modify programs is imperative to the successful programming process.

The key points to keep in mind concerning programming are these:

1. The program is rarely all new. It usually contains commitment from previous years and to other agencies and groups.

2. Many projects are in various stages of development from basic planning to final design. At any point and for any number of reasons a project may be stopped and removed from the program.

3. The funds available are usually restricted to certain programs of use, although there may be some flexibility with regards to transferring funds between programs or reassigning projects to different categories.

4. Priorities may be constantly changing because of changing philosophies, needs, economic conditions, political conditions, and other factors affecting individual or collective priorities.

Other Programming Considerations

The program is a living document out of date the minute it is finished. When there is a change in factors that were used to establish a program, the program changes. Most likely to cause modification in the program are:

Philosophical changes - changes in leadership, social changes, economics changes etc. demand for citizen participation

Finance changes - availability of money, inflation etc.

Design changes - new standard become required,

One of the areas of concern in allocating resources to programs is the frequent occurrence of emergency projects. Another is the problem of unforeseen delays in the projects approval process (particularly environmental and archeological concerns). Other material changes to the project in terms of scope or in execution may require a reappraisal of the program and the schedule attached to it.

Summary

The purpose of this manual is to present some techniques to assist tribal leadership and planners in their understanding of the prioritization and programming processes.

Prioritization is a necessary part of transportation planning and several techniques are presented. They include methods that involve ranking and scoring, analytical hierarchy process, and optimization. The main emphasis is on the ranking and scoring procedures using goals and objectives.

Programming is concerned with funding projects in a timely manner. A simple process is presented that allows the user to locate a source and program for each project and then distribute the funds to the project based on the project priority.

In all the activities presented, the need for continuing, coordinated, and cooperative efforts is emphasized.

References

Goals, Objectives, Scoring, and Ranking

Byer, Phillip H., David Saunders. “Choosing Objectives in Transportation Planning.” *Transportation Engineering Journal of ASCE*, Jan. 1979.

Campbell, Bruce, Thomas Humphrey. *Methods of Cost-Effective Analysis for Highway Projects. NCHRP Synthesis of Highway Practice 142*. Transportation Research Board. National Research Council, Washington D.C., 1988.

Choninard, L. E., G. R. Andersen, V. H. Torrey III. “Ranking Models Used for Condition Assessment of Civil Infrastructure Systems.” *Journal of Infrastructure Systems*, Vol. 2, No. 1, March 1996, pp. 23-29.

Fricker, Jon D. “Priority-Setting Procedures and Scarce Data: The Synthetic Solution.” *Transportation Research Record 1134*. Transportation Research Board. National Research Council, Washington D.C., 1987, pp. 10-17.

Fwa, T. F., W. T. Chan. “Priority Rating of Highway Maintenance Needs by Neutral Networks.” *Journal of Transportation Engineering*, Vol. 119, No. 3, May/June 1993, pp. 419-32.

Harness, M. D., K. C. Sinha. “Setting Priorities of Highway Projects by Successive Subsetting Techniques.” *Transportation Research Record 955.* Transportation Research Board. National Research Council, Washington D.C., 1984, pp. 35-40.

Humphrey, Thomas F. “Consideration of the 15 Factors in the Metropolitan Planning Process.” *NCHRP Synthesis 217.* Transportation Research Board. National Research Council, Washington D.C., 1995.

Jenkins, Steven V., Don Degraftenreid. *Transportation Planning Manual for Small Loal and Tribal Governments*. Montana Local Technical Assistance Program, Montana State University, 1996.

Mak, King K., Paul S. Jones. “Priority Analysis Procedures for Ranking Highway Improvement Projects.” *Transportation Research Record 585*. Transportation Research Board. National Research Council, Washington D.C., 1976, pp. 35-48.

“Management System for Setting Highway Priorities and Scheduling Improvements.” *Transportation Research Record 1124*. Transportation research Board. national Research Council, Washington, D.C., 1987, pp. 17-25

Shaffer, J. L., J. D. Fricker. “Simplified Procedure for Determining County Road Project Priorities.” *Transportation Research Record 1124*. Transportation Research Board. National Research Council, Washington D.C., 1987, pp. 8-16.

Sharaf, Essam A. “Ranking Versus Simple Optimization in Setting Pavement Maintenance Priorities.” *Transportation Research Record 1397.* Transportation Research Board. National Research Council, Washington D.C., 1993, pp. 34-38.

Taylor, David R. Godschalk, Michael A. Berman. “On Native Ground: Collaborative Transportation Planning on Indian Reservations.” *Transportation Research Record 1499.* Transportation Research Board. National Research Council, Washington D.C., 1995, pp. 11-18.

Tyndall, Gene R., John Cameron, Chip Taggart. “Strategic Planning and Management Guidelines for Transportation Agencies.” *NCHRP Report 331*. Transportation Research Board, National Research Council, Washington D.C., 1990.

Young, Kristina E., David G. Murray. “Developing a Method of Multimodal Priority Setting for Transportation Projects in San Francisco Bay Area in Response to Opportunities in ISTEA.” *Transportation Research Record 1429.* Transportation Research Board. National Research Council, Washington D.C., 1994, pp. 1-6.

Analytical Hierarchy Process

Hagquist, Ronald F. "High-Precision Prioritization Using Analytical Hierarchy Process: Determining State HPMS Component Weighting Factors." *Transportation Research Record 1429.* Transportation Research Board. National Research Council, Washington D.C., 1994, pp. 7-14.

Khasnabis, Bharat B. Chaudhry. "Prioritizing Transit Markets Using Analytical Hierarchy Process." *Journal of Transportation Engineering*, Vol. 120, No. 1, January/February 1994, pp. 74-93.

Saaty, T. L. *The Analytic Hierarchy Process*. McGraw-Hill, New York, N.Y., 1980.

Saito, Mitsuru. "Application of the Analytic Hierarchy Method to Setting Priorities on Bridge Replacement Projects." *Transportation Research Record 1124.* Transportation Research Board. National Research Council, Washington D.C., 1987, pp. 26-35.

Optimization

Davis, Christian F., C. Peter Van Dine. *Linear Programming Model for Pavement Management. Transportation Research Record 1200*. Transportation Research Board. National Research Council, Washington D.C., 1988, pp. 71-75.

Hajek, J. J., W. A. Phang. "Prioritization and Optimization of Pavement Preservation Treatments." *Transportation Research Record 1216.* Transportation Research Board. National Research Council, Washington D.C., 1989, pp. 58-68.

Monma, Clyde L. *Algorithms and Software for Optimization.* Basel, Switzerland: J.C. Baltzer, 1986.

Niemeier, Debbie A., Tracy Reed, G. Scott Rutherford, Pat Morin. "Statewide Programming: Implementing Transportation Policy Objectives." *Journal of Infrastructure Systems*, Vol. 2, No. 1, March 1996, pp. 30-39.

Schonfeld, Paul M., "A Transportation System Optimization Model" *Computing in Civil Engineering*, 1980, pp. 530-47.

Programming

Neumann, Lance A. "Improving Highway Investment Programming Methods." *Transportation Engineering Journal*, Vol. 106, No. 5, September/October 1980, pp. 599-610.

Niemeier, Debbie A., Zelda B. Zabinsky, Ahaohui Zeng, G. Scott Rutherford. "Optimization Models for Transportation Project Planning Process." *Journal of Transportation Engineering*, Vol. 121, No. 1, January/February 1995, pp. 14-26.

Transportation Research Board. Conference on Transportation Programming Methods." *Transportation Research Record 465.* National Research Council, Washington D.C., 1996.

Transportation Research Board. "Evaluating Options in Statewide Transportation Planning/Programming: Issues, Techniques, and their Relationships." *NCHRP Synthesis of Highway Practice 179*. National Research Council, Washington D.C., 1977.

Transportation Research Board. "Transportation Planning, Programming, and Finance: Proceedings of a Conference." *Transportation Research Circular 406*. National Research Council, Washington D.C., 1993.