Simulation Procedure for Automatic Highway Needs Updating

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This paper describes a computerized system for maintaining a continuously updated evaluation of highway needs, through simulation of future long-range improvement programs.

The system is designed to provide for the determination of highway needs as a regular part of a threefold planning process involving (a) the establishment and maintenance of a long-range highway plan, (b) the determination of needs and priority factors in achieving goals, and (c) the objective development of current, short-range (4-5 year) programs contributing to eventual accomplishment of the long-range plan.

Computer programs provide for detailed evaluations of highway and city street characteristics and conditions as related to traffic service requirements. The computer determines deficiencies and selects and schedules future improvements. Through a recycling process, traffic is increased annually in keeping with traffic assignment projections, conditions are depreciated by statistical factors, and road or street sections are reevaluated each year in the needs study period. Maintenance costs are assigned to road sections each year, changing when the improvement program schedule calls for a new surface type. The entire future highway program is simulated in accordance with ground rules which may be changed easily to "test" needs on different premises.

•ALTHOUGH the American Association of State Highway Officials, since 1947, has encouraged state highway departments to maintain an up-to-date evaluation of highway needs as a logical basis for obtaining highway program support from Congress and the state legislatures, only a few states are in a position to produce an objective, up-to-date evaluation. In most states, overall needs determinations are performed sporadically, in answer to requests from AASHO or federal authorities, and by methods that are considerably lacking in objectivity. Results of the needs studies reported every few years since 1947 show a lack of consistency. A search of the current needs reports for back-up data to support the figures given therein indicates the true value of these reports.

Where the expected costs of future highway development and maintenance are supported by specific references to the nature and extent of deficiencies on the present highway systems, this most often is the result of a comprehensive needs study recently performed, under contract, by a consultant. These studies, of course, are valid—until the traffic patterns and construction and maintenance cost bases begin to change. Unfortunately, we do not now have the foundation for solid predictions of the rate and nature of these changes.

A foundation like this can only be constructed through a procedure allowing for the tracing and evaluation of specific changes as they occur. The conduct of a major needs study every 5 or 10 years does not provide for tracing these patterns of change. Most likely these studies will be conducted in accordance with methods and philosophies that

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are somewhat different. As a result, it is difficult, if not impossible, to determine values associated with changes. The ability to provide measures of change in a dynamic situation, as a basis for predicting future changes, is dependent on the ability to trace the continuity of changes through the regular use of consistent procedures. If the planning job is to be performed adequately it is necessary for state highway departments to face up to the task of maintaining a continuously up-to-date highway needs inventory. Such an inventory provides the basis for appearing before state legislatures or the Congress with a consistent report on funding requirements to develop adequate highways, and it also provides the only logical basis for objectively established highway improvement and maintenance programs.

Without this type of inventory, highway programs tend to be established on a political basis. The executive authorities lack any other basis for making decisions between a number of competing highway improvement projects. The result is a program that has not been structured for the accomplishment of previously defined highway development goals. The exception, of course, is the Interstate systems for which goals have been defined and needs are up to date. This is not to suggest that politics can be removed altogether from program decisions. But the experience in states that have established some rational basis for project selections based on priority needs is that the Commissions and other executive authorities do tend to appreciate, accept, and follow rational methods, to a large extent.

THE PLANNING PROCESS

Through long experience in the highway planning field, our organization has concluded that good highway planning dictates (a) the establishment and up-to-date maintenance of an overall highway plan for the future, (b) a continuously up-to-date determination of highways needs and priorities, and (c) the development of a relatively short-range program geared to eventual accomplishment of the plan, in accordance with the current needs and priorities.

The plan represents the specifically defined objectives for future highway development: the completion of the Interstate System; the transportation system envisioned as a result of comprehensive urban or rural transportation planning studies; or the less sophisticated plans for traffic service in areas of relatively low population density. Resources to develop the plan include comprehensive transportation planning studies and route and area studies that involve the projection of land uses, economic effects, and traffic requirements. As a result of studies of this kind, a plan can be developed for providing future traffice service to the state or community, establishing the basic design concept and relationship of each highway or street facility. This plan should be continuously revised as time goes on. At any one time, it represents the established goal for future highway development.

The next logical step in highway planning is the determination of needs and priorities. Part of the total needs already will have been developed as a result of cost and benefit studies performed to establish elements of the plan, particularly where new locations or types of facilities are involved. However, the plan will incorporate many existing highways and streets without basic changes in location or design character. Most of these will require improvement between that time and the projected date for plan accomplishment. Some will require more than one improvement in the intervening period. The total future needs bill is the accumulation of costs for all the interim and ultimately planned improvements, plus maintenance and administration costs. Requirements for the successful reckoning of these costs include

1. An up-to-day inventory of geometric features, roadway condition, and traffic on all segments of the system;
2. Projection of traffic growths on all segments;
3. Evaluation of geometric features and road conditions as related to traffic;
4. Standardized improvement solutions for traffic, geometric, and condition relationships; and
5. Evaluation and application of statistical improvement and maintenance cost relationships.

Improvement solutions need to be standardized because it is impossible to specify improvements exactly without careful design analyses. For the same reason, costs need to be applied on a statistical basis—costs per mile experienced for defined improvement types and maintenance (condition) situations.

The analysis is designed to provide valid total needs figures through a summation of average improvement types, maintenance characteristics—and costs. Some refinements of statistical cost data by areas with respect to terrain, construction and maintenance materials, and rural and urban environment, may lead to better total needs values. Others only give the appearance of greater accuracy and should be avoided.

There are two broad classes of needs requiring determination: needs currently existing on the highway systems, often called backlog needs, and needs that may be expected to accrue in the future through traffic growth and condition obsolescence.

Actually, provided the needs analyses are made on a regularly scheduled basis with current data, it is only necessary to analyze existing needs in detail to make a valid determination of total future needs. In making this determination, changes in existing needs are related to the construction performed in periods between needs evaluations. Some of the current construction is lost to obsolescence. From the relationships, an obsolescence rate can be determined and future accruing needs established. The method has been basically outlined by Jorgensen (1).

However, the more usual method of determining future accruing needs has involved a section-by-section prognostication based on present indications of traffic growth and surface life expectancy. In the past, the method has not been any more reliable than the statistical method of determining accruing needs in total—perhaps less so. By hand rules, it is difficult to define an improvement on a section of highway that is expected to become deficient in the future. The method has usually required some arbitrary program-juggling and guesswork with respect to so-called "stopgap improvements" and "second generation replacements." Recent developments in electronic data processing technology and equipment, however, have eliminated many of the problems and shortcomings of the section-by-section method of determining accruing needs. Through a computer program, it is now possible to make a consistent application of firm ground rules both to predict future section-by-section accruing deficiencies and to establish appropriate improvements. Since the rules provide for stopgaps and replacements, the resulting program is realistic.

It still is highly unlikely that the actual order of deficiencies occurring 10 years from now can be accurately predicted, or the actual improvement program, in that year, accurately detailed. However, because the ground rules are applied consistently, because the resulting program is realistic in terms of the total traffic situation, and because the projected traffic, in total, is considered valid, the variances are largely a matter of event-order and should average out so as not to greatly influence total needs.

This computerized method of determining needs, which will be described presently, is considered capable of sound needs determination. One of the advantages is the ability to make future predictions of deficiency occurrences by applying ground rules and then comparing actual occurrences. This permits evaluating and amending the ground rules to improve predictions. Over a period of time, it allows measurement of changes that are taking place in the dynamic traffic situation.

Nevertheless, whatever method of needs determination is utilized, practically attainable objectives are limited to the following: (a) a good estimate of the cost of overcoming existing highway system deficiencies, (b) good estimates of the cost of meeting future deficiencies over varying program periods; and (c) objective listings of needs priorities.

No matter how well done, a needs study does not provide adequate project estimates for the development of a 4- or 5-year construction program. As noted previously, the section-by-section costs used in a needs study are statistical averages for the situations encountered. For any specific situation, the project cost could be considerably different. For this reason, selection of projects in the short-range program should be based on project planning reports, documenting the results of planning studies that establish location control points and basic design features and that provide preliminary estimates of project work quantities and costs.

The needs output provides a sound priority basis for making these planning studies and, ultimately, for project selection. However, other priority factors also need to be considered. Some of these are earmarked funds such as federal aid, district workloads, continuity of construction, and immediate highway safety needs. The needs study, therefore, does not stand by itself either as a total highway planning objective or as a basis for program selection. Instead, it forms a necessary link between the total plan objective and the immediate program in the complete highway planning process.

This process, composed of three integral parts—plan development, needs study, and programming—is not dissimilar from the process that has proved successful in the development of the Interstate System. It is as follows:

1. The master plan for the Interstate was developed. This was subject to restudy and revision during the development period.
2. The needs to complete the System were determined at regular intervals. These were regularly reported to Congress in seeking funds to complete the System.
3. The short-range programs were developed in accordance with the states' priority procedures.

The end result will be the successful completion of the System.

CONTINUOUS NEEDS UPDATE SYSTEM

This system has been designed, as part of the regular planning process, to fulfill the function of needs studies, which have been outlined. It has the following characteristics:

1. It allows incorporation of the master plan in the determination of long-range needs to the extent the plan has been developed. In Iowa, for example, where this system is being placed in operation, the Commission has approved the plan for the supplemental freeway system, which was established on the basis of statewide traffic assignments. The needs study procedures will simulate the annual construction of this system, part by part, in the priority order of needs occurring in its corridors. Other defined plans for the future likewise will be incorporated with improvements scheduled.
2. Needs on segments of the system being replaced (for example, the freeways) are determined on the basis of the reduced traffic at the expected time of replacement. The traffic reduction is carried over from the traffic assignment program.
3. Stopgap improvements are automatically simulated on a logical basis, depending on the time period chosen to catch up with the backlog of needs. Second-generation replacements (some early improvements may become deficient a second or third time during a lengthy future period) are automatically simulated at the appropriate time.
4. More than one alternative future program decision, such as catch-up in 10 or 15 years, can be quickly tested by running a new needs bill. The effect on needs of the overall level of systems improvement can be determined just as easily. In Nebraska, in one instance, it was found that raising the adequacy critieria for road improvements produced only a nominal increase in needs. This increase was easily justified by the improved overall travel conditions anticipated. In a typical case, the lower criterion might result in a new base and surface and a second-generation resurfacing within 15 years—no basic improvement in geometrics. The higher criterion would require early reconstruction to design (20-year traffic) standards, higher surface type, and no resurfacing. The 15-year difference in cost between the sum of the improvements, on one hand, and the single improvement, on the other, did not justify retention of the borderline facility. Thus, the analysis can help make important economic decisions.
5. Maintenance costs are simulated in accordance with improvement program decisions. (This and all of the foregoing features have actually been applied in the Nebraska needs study.) Appropriate maintenance costs are applied to a section annually until the year the ground rules indicate an improvement changing the surface type. Beginning in that year, annual maintenance costs appropriate to the new surface type are applied automatically. The potential to test the effects of improvement program decisions on maintenance is obvious.

6. Although it has not been done as yet, the currently adopted 4- or 5-year program can be incorporated in the simulated long-range program. This requires some minor adaptation of the present procedures and computer programs.

7. Needs are produced from the programs in priority order. A summary current adequacy or suficiency rating is given for each road section. Procedures for determining this rating incorporate a capacity analysis based on the new capacity manual—all performed automatically in the computer.

8. A new adequacy rating is projected for each section of road for each future year in the needs study period. The computerized system automatically projects traffic in annual increments, route segment by route segment, to tie in with projected systems-wide traffic assignments, and accordingly, it reevaluates the current geometrics and makes a new capacity analysis year by year. The conditions of roadway elements are depreciated annually by using statistical depreciation factors based on an analysis of previous sufficiency rating experience. Based on these programmed obsolescence determinations, the computer recycles to make the projected annual adequacy ratings.

9. The future construction program is simulated, through ground rules, on the basis of the total adequacy ratings and the component ratings of individual roadway elements. When a section deficiency is found to exist—it may be in a future year—the computer "decides" on an improvement. It may select a stopgap measure, "reach" for a solution from the master plan, or use a statistically derived solution. It then "schedules" the improvement in accordance with the selected catch-up period and other program decisions, enters the cost in the appropriate year, reevaluates the maintenance cost, etc.

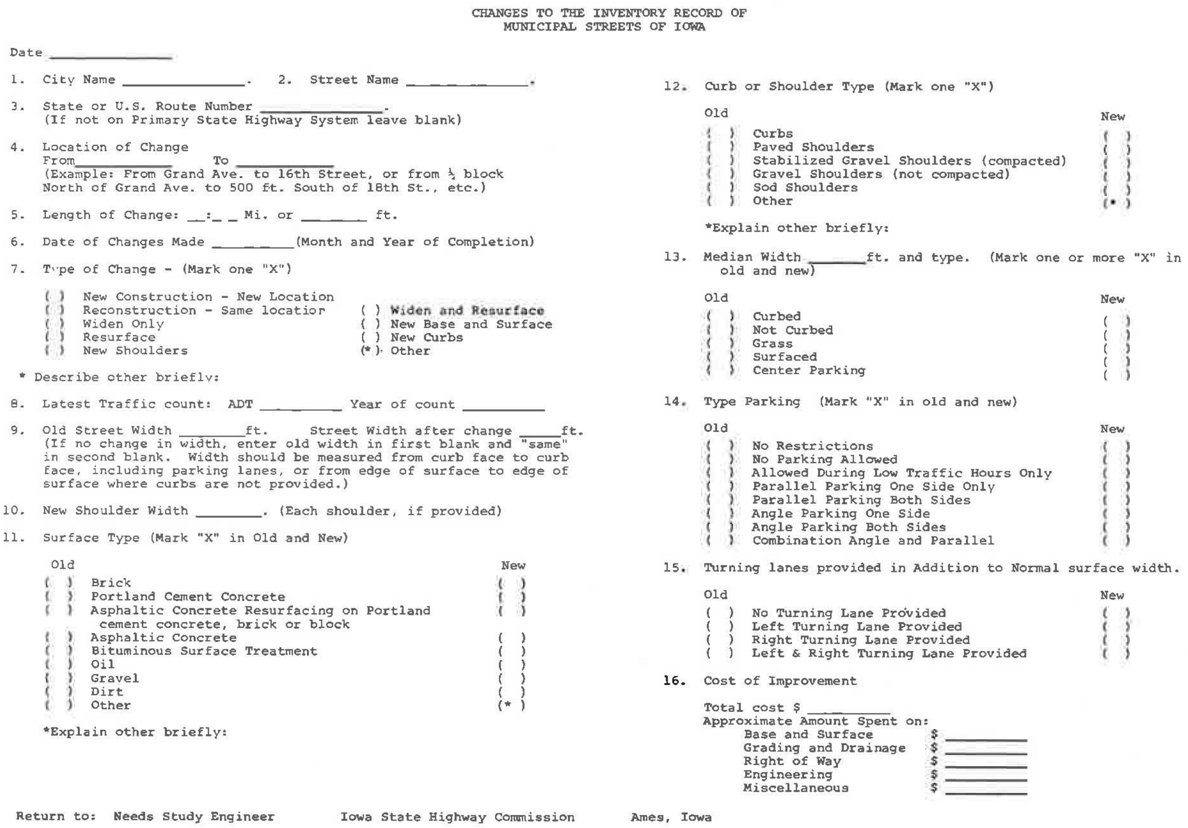
The result is a complete simulation of the future long-range construction and maintenance program based on predetermined logic-oriented ground rules and the best present prediction of future obsolescence. Since the predictions, in every case, are based on measurements of current trends, the method is basically statistical. In this respect, it is sound.

There are problems with respect to the data on current trends that have been available in the two states where it is now being applied. Office updating of all or part of the annual sufficiency rating, or failure to record component rating data have made condition obsolescence trends difficult to evaluate. It is anticipated that these problems will disappear with time and experience on the new system. Indeed, the ability to compare actual adequacy ratings, in total and for individual roadway elements, with previously predicted adequacy ratings ought to lead to ever-improving predictive capability.

The problem—if it is one—of using a "pat" procedure for ordering the future construction program is minimized because of the ability to vary the ground rules in many ways and to recalculate needs for each variance. Because the current ground rules are logic-oriented and produce a sound program—although it is certain not to be duplicated in actual experience—it is believed that logic-oriented variances in the ground rules will not produce significantly different total needs values. All alternatives are directed toward providing for the same total traffic using essentially the same traffic-based design standards for whatever future year that is selected.

In the program simulation method used in Nebraska and Iowa needs determinations for local roads and streets are made on the basis of an inventory sample. The methods are similar to those already described—analysis of current deficiencies, determination of obsolescence, simulation of the future program; all performed through the computer program—but the analytical steps are simpler in keeping with the characteristics of local roads and streets. Once the sample program is determined, the results are expanded automatically to represent the universe.

The recommended scheme calls for full coverage of the local systems over a period of years by scheduling inventories of a different sample each year, with some replication. In this way, changing conditions on the local roads and streets eventually can be noted and analyzed. Also, as time goes on and the sample size is increased, the universe can be more truly represented. The procedures will involve statistical updating of data from samples a few years old before these data are combined with data from the latest sample. This, largely, is the reason for replication. The sampling process



CHANGES TO THE INVENTORY RECORD OF
MUNICIPAL STREETS OF IOWA

Date ____________

1. City Name ____________. 2. Street Name ____________.

3. State or U.S. Route Number ____________.
(If not on Primary State Highway System leave blank)

4. Location of Change
From__________ To __________
(Example: From Grand Ave. to 16th Street, or from ½ block North of Grand Ave. to 500 ft. South of 18th St., etc.)

5. Length of Change: __:_ _ Mi. or ______ ft.

6. Date of Changes Made ______(Month and Year of Completion)

7. Type of Change - (Mark one "X")

( ) New Construction - New Location
( ) Reconstruction - Same location
( ) Widen Only
( ) Resurface
( ) New Shoulders
( ) Widen and Resurface
( ) New Base and Surface
( ) New Curbs
(*) Other

* Describe other briefly:

8. Latest Traffic count: ADT ________ Year of count ________

9. Old Street Width ________ft. Street Width after change _____ft.
(If no change in width, enter old width in first blank and "same" in second blank. Width should be measured from curb face to curb face, including parking lanes, or from edge of surface to edge of surface where curbs are not provided.)

10. New Shoulder Width ________. (Each shoulder, if provided)

11. Surface Type (Mark "X" in Old and New)

Old		New
( )	Brick	( )
( )	Portland Cement Concrete	( )
( )	Asphaltic Concrete Resurfacing on Portland cement concrete, brick or block	( )
( )	Asphaltic Concrete	( )
( )	Bituminous Surface Treatment	( )
( )	Oil	( )
( )	Gravel	( )
( )	Dirt	( )
( )	Other	(*)

*Explain other briefly:

12. Curb or Shoulder Type (Mark one "X")

Old		New
( )	Curbs	( )
( )	Paved Shoulders	( )
( )	Stabilized Gravel Shoulders (compacted)	( )
( )	Gravel Shoulders (not compacted)	( )
( )	Sod Shoulders	( )
( )	Other	(*)

*Explain other briefly:

13. Median Width ______ft. and type. (Mark one or more "X" in old and new)

Old		New
( )	Curbed	( )
( )	Not Curbed	( )
( )	Grass	( )
( )	Surfaced	( )
( )	Center Parking	( )

14. Type Parking (Mark "X" in old and new)

Old		New
( )	No Restrictions	( )
( )	No Parking Allowed	( )
( )	Allowed During Low Traffic Hours Only	( )
( )	Parallel Parking One Side Only	( )
( )	Parallel Parking Both Sides	( )
( )	Angle Parking One Side	( )
( )	Angle Parking Both Sides	( )
( )	Combination Angle and Parallel	( )

15. Turning lanes provided in Addition to Normal surface width.

Old		New
( )	No Turning Lane Provided	( )
( )	Left Turning Lane Provided	( )
( )	Right Turning Lane Provided	( )
( )	Left & Right Turning Lane Provided	( )

16. Cost of Improvement

Total cost $ ________
Approximate Amount Spent on:

Base and Surface	$ ________
Grading and Drainage	$ ________
Right of Way	$ ________
Engineering	$ ________
Miscellaneous	$ ________

Return to: Needs Study Engineer Iowa State Highway Commission Ames, Iowa

Figure 1. Sample form for distribution to municipalities in Iowa.

eventually may be extended to the condition inventory of all systems. Once it has been noted that condition changes on parts of the systems are in accord with previous predictions, these parts will not need to be field checked as often.

After the first complete field inventory of any system, subsequent field coverages will only be for the purpose of updating condition information. Geometric and traffic data will be kept up to date through a system of regular reports to the needs analysis unit as changes occur through construction improvements and as new traffic counts are made. The recommended scheme calls for local units of government to report changes on geometrics and surface types immediately as contracts are let or work orders issued. Figure 1 shows a sample form prepared for distribution to municipalities in Iowa. As these forms are completed and returned, the basic record data can be continually updated throughout the year. This day-to-day procedure will avoid the necessity for time consuming year-end searches of construction and maintenance records by the local subdivisions. In particular, very small units of government often do not have knowledgeable highway personnel who can properly interpret records on highway work. These units may be asked to have their contractors report current work to the State as a regular contract obligation. Practical working relationships to obtain regular reports of road and street changes still need to be worked out in Nebraska and Iowa. Nebraska has only had one statewide determination of needs through use of the system. Development of the system in Iowa has not yet progressed to the extent of establishing the regular reporting procedures. However, in Iowa, the Association of County Engineers and the League of Municipalities are kept abreast of the developing system and are ready to assist in the establishment of the necessary cooperative relationships. In fact, the counties and cities already have supplied data for initial statistical analyses.

There is every indication that the regular determination of needs on county and city facilities will be performed by the Iowa State Highway Commission as a service to the local subdivisions. The state authorities need to have the information from all systems for regular reports to the legislature, as a basis for legislative actions on highway funding and distribution of funds. However, successful operation of the system also will make detailed data on their systems continually available to local agencies for their own programming purposes. It is because of this mutual interest that little difficulty is anticipated in developing workable reporting relationships and procedures.

All initial field inventories in Iowa are being performed by state or state-trained crews. To maintain proper control, the consultant has recommended that all subsequent condition inventories be performed by the Commission's district crews as part of the regular off-season work program. By scheduling regular highway and street systems coverage, the additional district workloads will not be excessive, and the experience provides good training for district personnel.

A unique feature of the system application in Iowa is the development of a single set of road inventory records compatible with all planning requirements, including the requirements of the needs update system. All current data on the roadway are being placed on tape consecutively by road section. The data recorded for each individual section of roadway are shown in Figure 2. Included are administrative classifications, sequencing, log mileages, physical dimensions and features, conditions, traffic and traffic factors, percentages of commercial vehicles, maintenance cost factors, and construction controls and cost factors. Municipal sections follow rural sections in proper route sequence order. All inventory data on structures and railroad crossings similarly are being placed on a single tape record with identity codes that locate the structures in relation to the roadway or street sections.

This format of roadway and structures records lends itself to the coincident evaluation. By this method, a structural deficiency may influence the scheduling of a complete road section improvement (this is characteristic of practical programming).

INVENTORY AND EVALUATION PROCEDURES

The needs characteristics of city streets are markedly different from those of rural roads, there are different relationships between traffic and deficiencies, especially

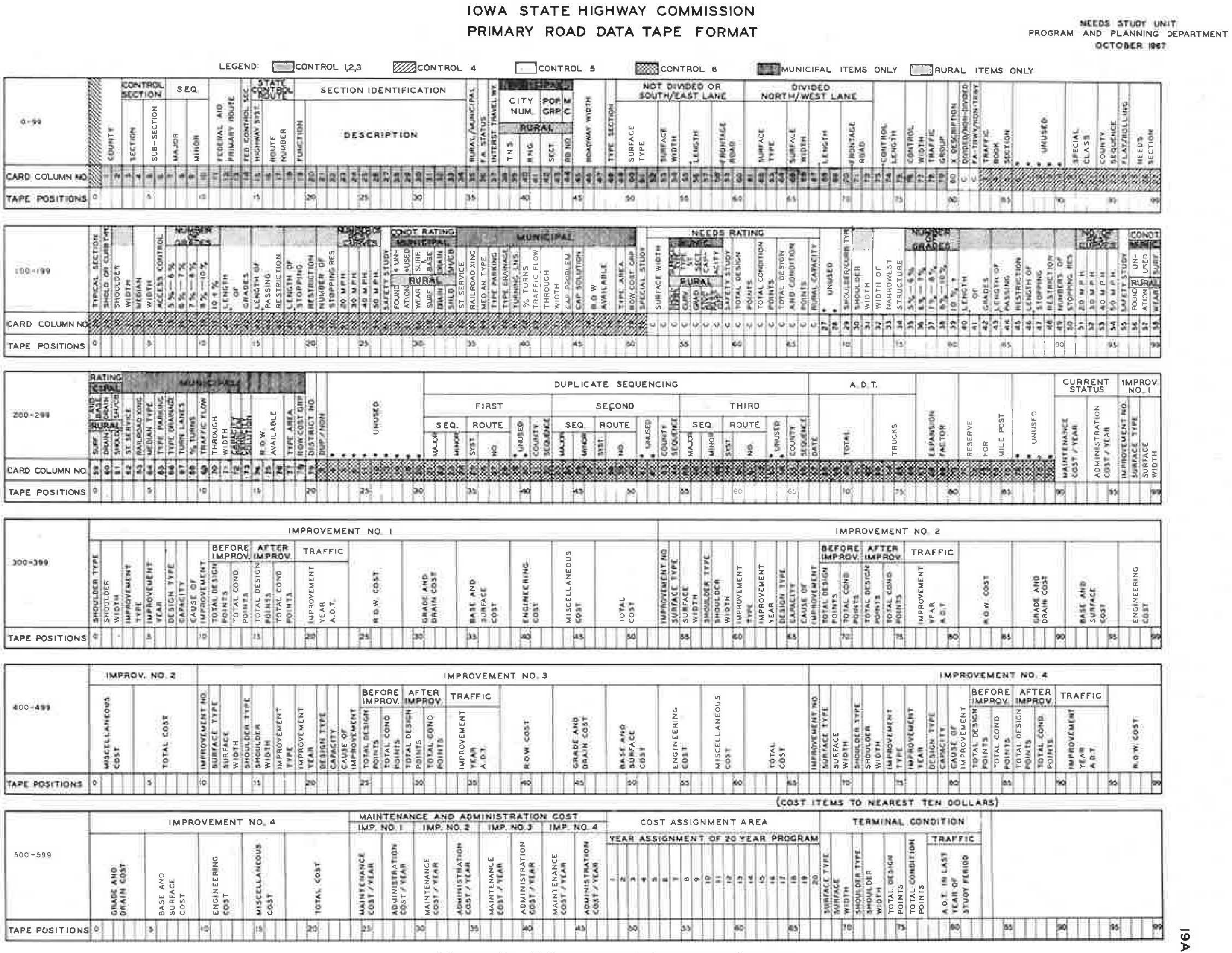


Figure 2. Primary road data tape format.

capacity relationships, and different improvement solutions. For this reason, inventory and evaluation procedures are distinctively different. However, the computer evaluation programs are structured in the same way for the development of compatible outputs, and a single system of identification codes is used to embrace both classes. This allows the computer programs to be fitted together, as one program, to make runs by administrative system—a procedure followed in Iowa.

Because the differences in inventory and evaluation are differences in analytical detail, and because it is beyond the scope of this paper to describe the detailed analytical methods, one outline will be used to describe the basic concepts of the computer evaluation program applicable both to rural roads and city streets. As the basic steps are given, distinctive differences in evaluation methods will be noted.

First, a note about the differences in inventory methods. Aside from the collection of detail relative to capacity on city streets, city inventories differ from rural inventories in that the city crews are given criteria for indicating solutions to apparent capacity problems. This is necessary because of the several possible alternatives to a city street capacity problem—widening in place; one-way couplets; an alternative street; or a facility on new location, possibly a bypass. So that the city inventory crews will obtain the necessary inventory data on other streets that may figure in the alternatives, they are provided with formulas to roughly project traffic, formulas for approximately determining capacities, and a step-by-step procedure for investigating alternative solutions if the indications are that capacities will be exceeded by projected traffic.

The only purpose in following these procedures is to obtain inventory data on streets possibly figuring in alternative solutions. Later, the computer program makes a detailed capacity analysis, based on the Highway Capacity Manual, and objectively determines a solution based on the inventory data. Thus, more data are obtained than may be needed, but this avoids calling for unrealistic widening of streets that cannot be widened because of adjacent property development.

In rural inventories, the crews obtain only the data on the existing facilities and their environmental situation. The computer performs all evaluations. In both cases the computer begins by reading the identification codes and selecting the appropriate analytical routine. The flow diagram in Figure 3 shows the basic steps in these analyses.

The paths to the left and right distinguish between arterial highways or streets and local roads or streets in the rural and urban programs. The arterial routine begins with an evaluation of existing road or street elements against design standards for the existing traffic. This evaluation is accomplished by assigning rating values to the elements, including surface and shoulder or curb characteristics, sight distances, grades, alignments, and other pertinent features. The rating depends on the relationship of existing measurements to traffic standards. Typical point ratings for these characteristics as well as the point ratings for physical condition are shown in Figure 4. Traffic versus capacity also is evaluated both for rural highways and arterial streets, in accordance with the new HRB Highway Capacity Manual, but this analysis is more detailed for streets, and the results are more significant in determining improvements requirements.

Local roads and streets are evaluated against a table of acceptable or "tolerable" geometric features and conditions in a less sophisticated analysis appropriate for this class of facility. In the case of the arterials, however, the physical conditions of each appropriate element of the road or street sections are also rated in accordance with variances from "perfect" or newly constructed conditions.

On the arterial side (Fig. 3, left side) the total assigned rating (the sum of geometric and condition values) is compared with a preselected figure representing adequacy based on judgment. Sections that are inadequate by this test then go through a subroutine that selects an appropriate improvement based on the geometric and condition ratings of individual roadway elements and combinations of elements. The improvement year is then set, based on the rating priority, the expected distribution of ratings, and the selected catch-up period. (The distribution of ratings may be known

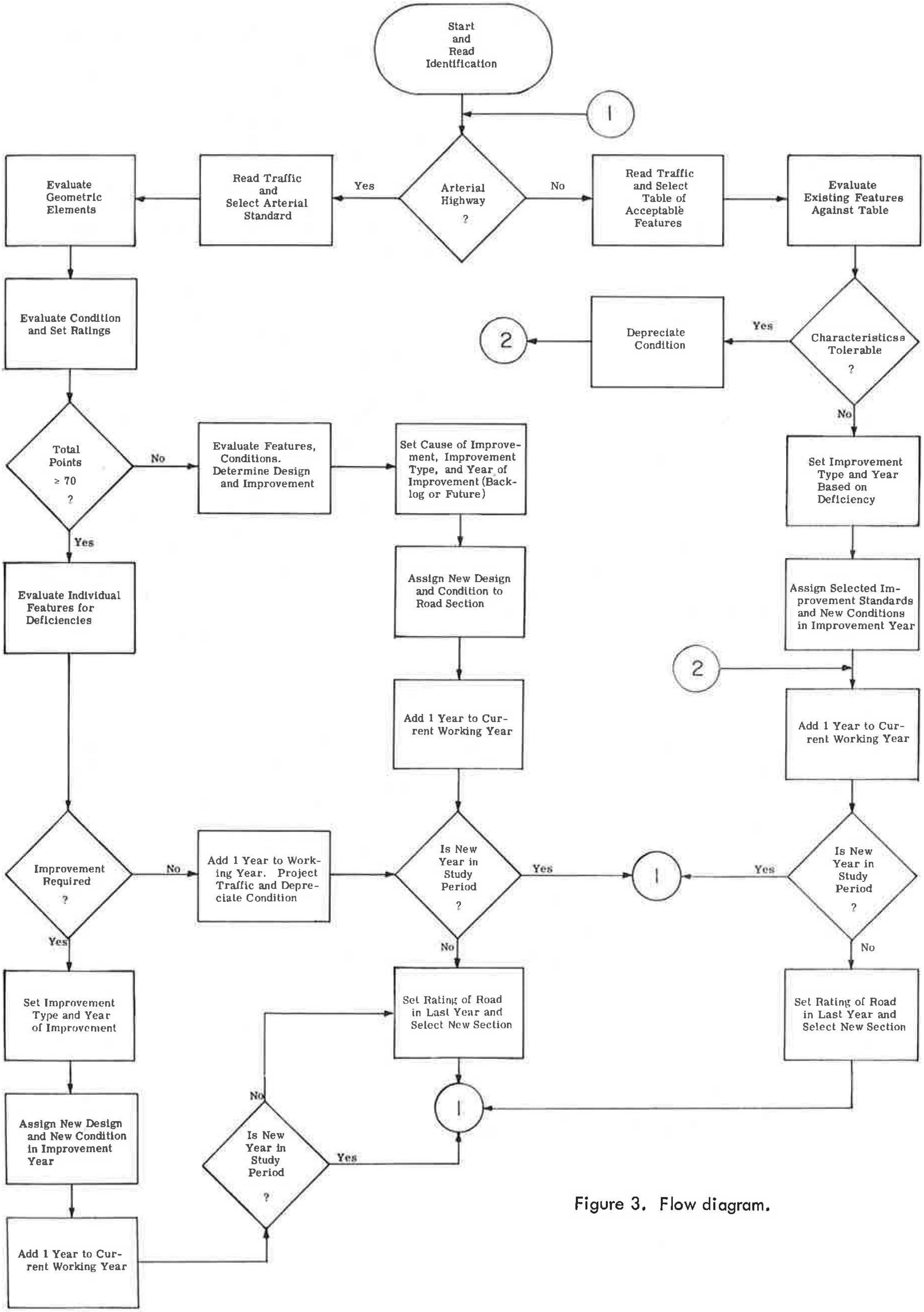


Figure 3. Flow diagram.

Rural Roadway	
Geometrics:	
Surface width	20
Shoulder width and type	9
Stopping sight	8
Alignment	8
Grades	6
Safety study	6
Passing or median	8
Condition:	
Foundation	15
Surface	10
Drainage	5
Shoulder	5
Total	100

Municipal Streets	
Geometrics:	
Surface type	5
Type street section	10
Capacity	35
Surface width	15
Condition:	
Surface and base	25
Drainage	5
Curb or shoulder	5
Total	100

Structures	
Geometrics:	
Structure width	30
Vertical clearance	5
H-Loading	20
Safety study	5
Condition:	
Superstructure	15
Substructure	15
Deck	5
Waterway opening	5
Total	100

Figure 4. Point ratings.

from prior rating experience, or part of the program can be run initially to obtain ratings and summaries.) If the improvement year is several years from the current year and the surface is poor, a stopgap surfacing will be ordered.

Both of the next steps are designed to upgrade the improved facilities to the improvement year. The computer projects the traffic on the arterials for 20 years after the improvement year to select and record the new design standards. When the improvement year is passed, as the computer recycles the program, the new design and condition will be depreciated for further evaluations.

As the computer evaluates sections of arterials that pass the test on total rating points, there still may be outstanding deficiencies in one or more features of these sections, for example, the surface width may be dangerously narrow. The computer evaluates these features against limiting criteria and selects improvements accordingly. An improvement year is scheduled and the new design standards are determined and assigned as described previously.

The other parts on the flow diagram show some of the steps involved in the recycling process (a) when there is no deficiency in the current (working) year, and (b) when an improvement is scheduled. The program is recycled to analyze sections with traffic projected for an additional year and the condition of the roads and streets statistically depreciated.

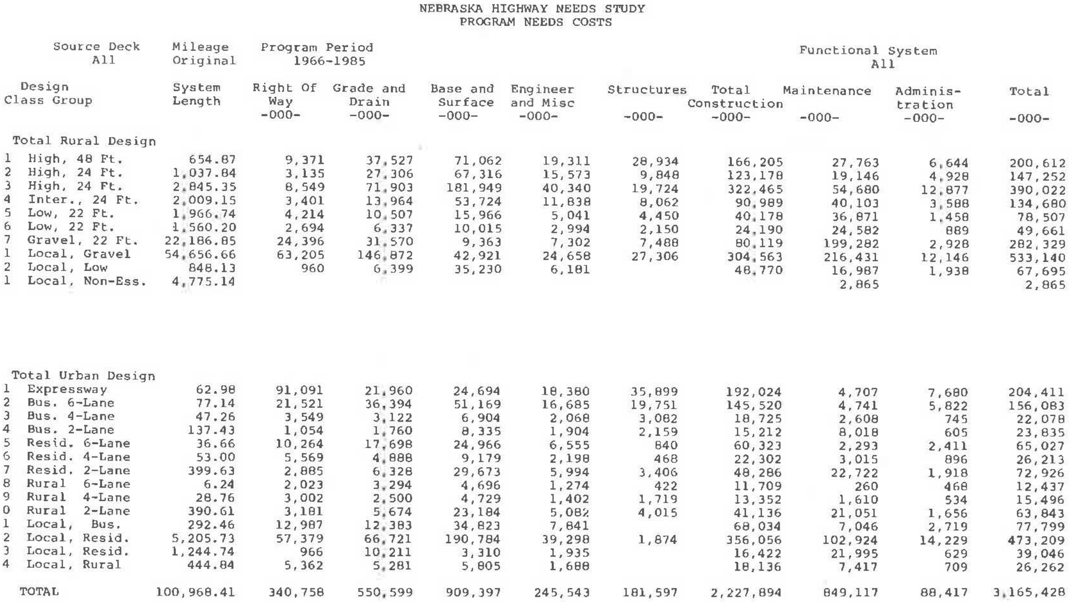
The foregoing provides an idea of how the system functions. It covers only major steps in the evaluation procedure, and some of these are left out. The structural evaluation, for example, is a completely separate routine that is performed while the corresponding road evaluation is "held in hand." This routine provides for examining the relationship of the structure to the roadway or street, and vice versa. For example, if the road is selected for improvement and the structure does not measure up to the new design standards, the structure is selected for reconstruction in the same year. In the selection of improvements for city streets, the computer may select or reject the improvement solutions suggested by the inventory crews, depending on its own detailed analysis.

The assignment of construction and maintenance costs has not been described. The procedures are relatively simple and easily inferred from the program outline. Improvement costs are statistically related to the improvement types, and of course, are assigned in the same year. Maintenance costs are assigned in accordance with surface types and lives (if data are available) in the current working year.

The flexibility of the system deserves further emphasis. The ground rules with respect to such factors as adequacy levels, catch-up program periods, and even order of improvements can be changed easily to test needs on different premises. In addition, there are potential applications that have not yet been explored. One apparently feasible potential is to evaluate future highway accident occurrences againt long-range program alternatives. With established or assumed relationships between road design and condition features and accident occurrences, future accidents could be simulated for different basic levels of adequacy on the systems, master plan changes, and levels of program expenditure. Simulated accidents could be tested against actual occurrences.

SUMMARY

The system provides a powerful planning tool (a) to keep needs continuously up to date, (b) to analyze long-range program alternatives and the relationship of current



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                                                        NEBRASKA HIGHWAY NEEDS STUDY
                                                            PROGRAM NEEDS COSTS

      Source Deck       Mileage     Program Period                                                    Functional System
          All           Original       1966-1985                                                              All

  Design                  System    Right Of   Grade and    Base and    Engineer  Structures       Total Maintenance    Adminis-       Total
Class Group               Length         Way       Drain     Surface    and Misc              Construction                 tration
                                       -000-       -000-       -000-       -000-       -000-       -000-       -000-       -000-       -000-

 Total Rural Design
1  High, 48 Ft.           654.87       9,371      37,527      71,062      19,311      28,934     166,205      27,763       6,644     200,612
2  High, 24 Ft.         1,037.84       3,135      27,306      67,316      15,573       9,848     123,178      19,146       4,928     147,252
3  High, 24 Ft.         2,845.35       8,549      71,903     181,949      40,340      19,724     322,465      54,680      12,877     390,022
4  Inter., 24 Ft.       2,009.15       3,401      13,964      53,724      11,838       8,062      90,989      40,103       3,588     134,680
5  Low, 22 Ft.          1,966.74       4,214      10,507      15,966       5,041       4,450      40,178      36,871       1,458      78,507
6  Low, 22 Ft.          1,560.20       2,694       6,337      10,015       2,994       2,150      24,190      24,582         889      49,661
7  Gravel, 22 Ft.      22,186.85      24,396      31,570       9,363       7,302       7,488      80,119     199,282       2,928     282,329
1  Local, Gravel       54,656.66      63,205     146,872      42,921      24,658      27,306     304,563     216,431      12,146     533,140
2  Local, Low             848.13         960       6,399      35,230       6,181                  48,770      16,987       1,938      67,695
1  Local, Non-Ess.      4,775.14                                                                               2,865                   2,865



 Total Urban Design
1  Expressway              62.98      91,091      21,960      24,694      18,380      35,899     192,024       4,707       7,680     204,411
2  Bus. 6-Lane             77.14      21,521      36,394      51,169      16,685      19,751     145,520       4,741       5,822     156,083
3  Bus. 4-Lane             47.26       3,549       3,122       6,904       2,068       3,082      18,725       2,608         745      22,078
4  Bus. 2-Lane            137.43       1,054       1,760       8,335       1,904       2,159      15,212       8,018         605      23,835
5  Resid. 6-Lane           36.66      10,264      17,698      24,966       6,555         840      60,323       2,293       2,411      65,027
6  Resid. 4-Lane           53.00       5,569       4,888       9,179       2,198         468      22,302       3,015         896      26,213
7  Resid. 2-Lane          399.63       2,885       6,328      29,673       5,994       3,406      48,286      22,722       1,918      72,926
8  Rural  6-Lane            6.24       2,023       3,294       4,696       1,274         422      11,709         260         468      12,437
9  Rural  4-Lane           28.76       3,002       2,500       4,729       1,402       1,719      13,352       1,610         534      15,496
0  Rural  2-Lane          390.61       3,181       5,674      23,184       5,082       4,015      41,136      21,051       1,656      63,843
1  Local,  Bus.           292.46      12,987      12,383      34,823       7,841                  68,034       7,046       2,719      77,799
2  Local, Resid.        5,205.73      57,379      66,721     190,784      39,298       1,874     356,056     102,924      14,229     473,209
3  Local, Resid.        1,244.74         966      10,211       3,310       1,935                  16,422      21,995         629      39,046
4  Local, Rural           444.84       5,362       5,281       5,805       1,688                  18,136       7,417         709      26,262

   TOTAL              100,968.41     340,758     550,599     909,397     245,543     181,597   2,227,894     849,117      88,417   3,165,428
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Figure 5. A typical summary output from the Nebraska Highway Needs Study.

programs, (c) to develop priority values for programming purposes, and (d) possibly to relate highway accidents to long-range highway programs.

In order to fulfill these purposes, once the initial field inventories are made, there must be a regular system of reports on changes due to construction or maintenance; updating of traffic counts; traffic assignments; analyses of construction and maintenance costs; incorporation of changes in the highway plan; and regularly scheduled road condition surveys. There also should be a regular updating of financial projections to compare with the needs. Other than this, once the computer programs are written, little more is required than "pressing a button." A typical summary output from the computer (the result of one run made during the Nebraska Needs Study) is shown in Figure 5.

REFERENCE

1. Jorgensen, Roy E. Planning and Measuring Highway Progress. HRB Proc., Vol. 40, p. 35-44, 1961.