A SYSTEM FOR PLANNING ROADWAY IMPROVEMENTS

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Abridgment

Some of the most perplexing problems facing highway engineers are in the area of roadway improvements. When will roadway improvements be required? What type of improvement is required to maintain a satisfactory level of performance? How much of a correction, including cost, will be required to maintain the roadway for its intended life? What budget limitations are there on improvements? What priority system can be used to determine the order for improvements? These questions are answered by using a systems approach to look at the various elements affecting performance. Ignoring one element could result in early failure of the facility. This early failure could be the result of factors such as poor construction, inadequate design, inferior materials, and severe climatic conditions. Preventing failures before they occur can result in significant savings. The system for planning improvements includes 4 elements: sufficiency, structural adequacy, serviceability, and slipperiness.

Sufficiency is the element that is concerned with the safe, uncongested movement of the traffic over the roadway at design speeds and is the relative compliance with approved design standards (11, 12). Sufficiency of a roadway is related to capacity, hazards, alignment consistency, stopping and passing sight distances, grade, roadway section, roadway width; operating lane width, access or traffic control, curbs or shoulders, and drainage. Sufficiency ratings are the primary consideration in determining when major improvements or reconstruction should be undertaken. There is no need to overlay a pavement surface if the roadway is going to be reconstructed in the near future.

Sufficiency determinations are based on data gathered through a physical inventory of existing features. Data on present and future traffic are used to determine the future needs of a roadway section. The budget may become the controlling item when several sections fit into the same time period for improvement, so it must also be considered. The time when a roadway will be insufficient is determined by careful examination of the factors that affect it. Once the required life is determined, then the improvement can be designed by using the results from the other 3 elements: structural adequacy, serviceability, and slipperiness.

Structural adequacy is the ability of the roadway to support repeated traffic loads without failure and is related to the strength of the various layers making up the composite pavement design. It is determined by field deflection measurments. Pavements fail structurally as they are subjected to repeated traffic loads; failure generally appears in the pavement surface as rutting, cracking, and increased roughness. Research has demonstrated that deflections can be used to predict failure (1, 3, 4, 8, 9, 13). In Utah, research (8) is undertaken for the purpose of determining the applicability of the AASHO Road Test findings. This study utilizes a factorial design of 3 factors at 3 levels each and 1 factor at 2 levels. The factors are traffic, soil support, age, and

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terminal serviceability index; in-service projects fill the cells. Deflection measurements are also used to determine the amount of correction required for the roadway. Thus, deflections can be used to determine the structural condition and needs of a pavement.

Figure 1. Dynaflect.

Deflection measurements are made in Utah with the Dynaflect (5) as shown in Figure 1. Studies in Utah established a relationship between Dynaflect deflections and the Benkelman beam by using 18-kip axle load and "creep speed normal" (1). The Dynaflect maximum deflection multiplied by 22.5 equals the Benkelman beam deflection.

Equations developed at the AASHO Road Test for predicting performance are shown in Figure 2 in nomograph form for use with the Dynaflect. Benkelman beam data can be used by making the proper adjustment and substitution in the nomograph. The nomograph can be used to determine the number of loads to failure from a given deflection or the required deflection from a given predicted traffic load.

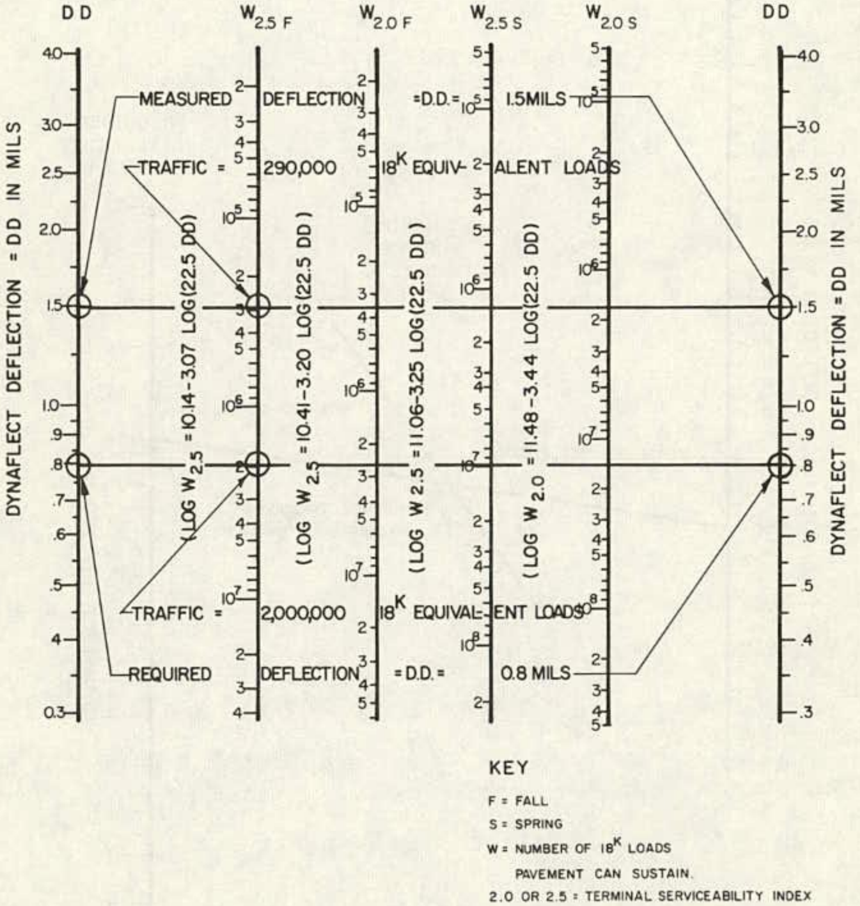

Figure 2. Relationship between terminal 18-kip axle loadings and deflections.

Figure 3 shows a nomograph for determining the required overlay thickness of bituminous surface from measured and required deflections. The measured deflections are from the field, and the required deflections are obtained from predicted traffic loads (Fig. 2).

Different materials exhibit different structural coefficients, so the overlay thickness required may be affected by the material used. The nomograph shown in Figure 4 is similar to that shown in Figure 3 except that structural number is determined instead of bituminous surface thickness. The structural number of a layer is equal to its structural coefficient times its thickness. The number shown in Figure 3 is based on a structural coefficient of 0.40. The required structural number divided by the structural coefficient of the material determines thickness requirements.

Seviceability is the element that travelers are most aware of and is described as an estimate of the public's opinion of the relative quality of pavement surfaces. Pavements, subjected to repeated traffic loads, show distress making the roadway less

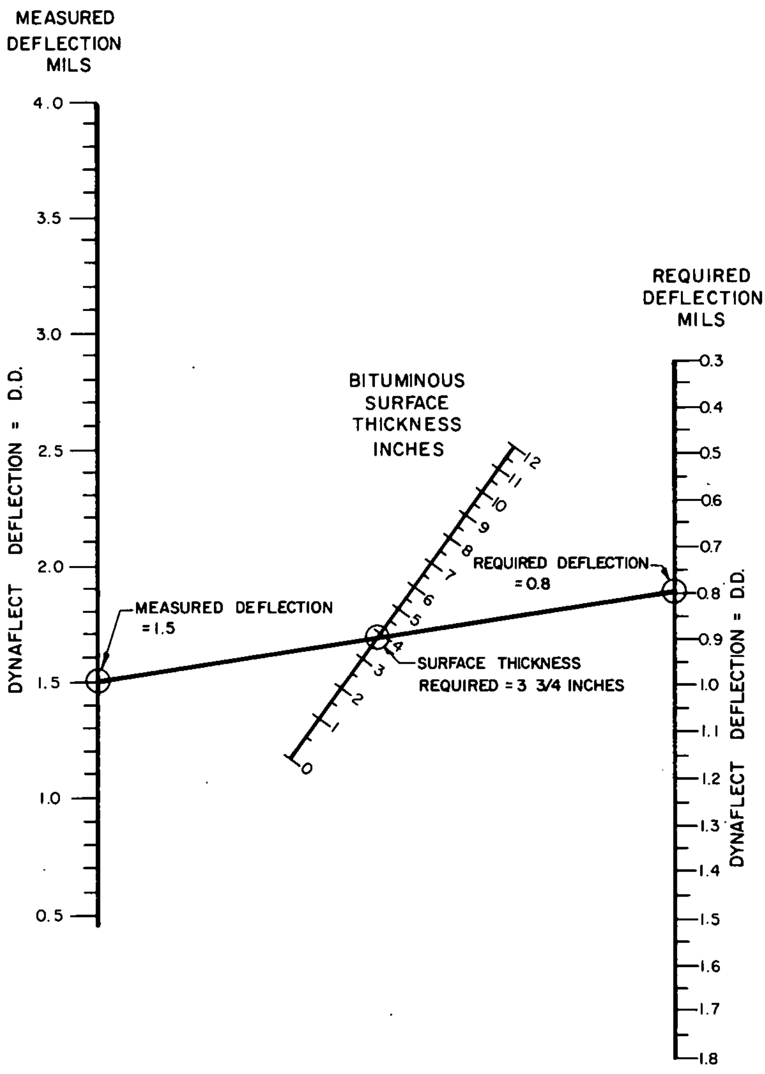

Figure 3. Bituminous surface thickness determinations from deflections.

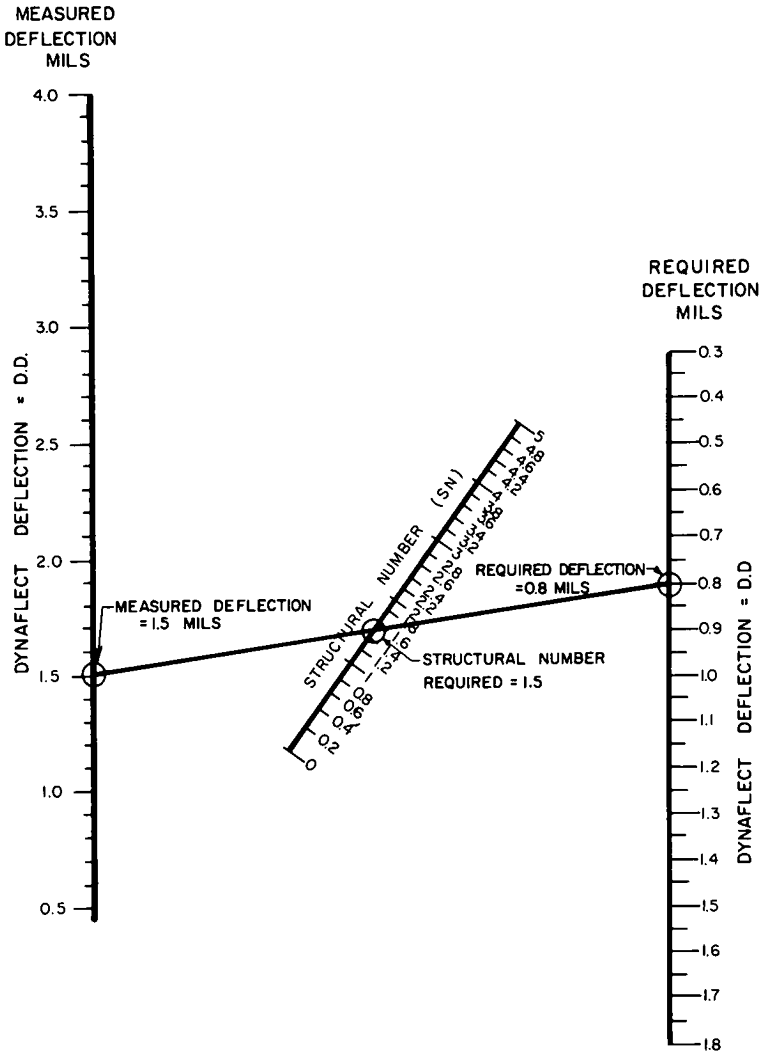

Figure 4. Structural number determinations from deflections.

serviceable. The existing condition is the present serviceability, and the change with time is the serviceability trend. Research at the AASHO Road Test (1) first developed the serviceability concept and equations, and subsequent research was conducted by other agencies (2, 6). The present serviceability index (PSI) evaluates pavements on a scale from 0 to 5, with higher values indicating better pavements.

The equations used in Utah to determine PSI on pavements with the PCA type of road meter shown in Figure 5 are as follows:

$$PSI = 4.24 - 0.000277(\Sigma RC)^{1.15416} - 0.01\sqrt{C_f + P + S} - 1.34\overline{RD}^2$$

for flexible pavements, and

$$PSI = 7.221 - 0.9929 \log \Sigma RC - 0.08\sqrt{C_r + P + S}$$

for rigid pavements, where

ΣRC = summation of roughness count from road meter per mile;
C_f = sq ft of cracked area per 1,000 sq ft of surface;
C_r = linear ft of crack projection per 1,000 sq ft of surface;
P = sq ft of patched area per 1,000 sq ft of surface;
S = sq ft of spalled area per 1,000 sq ft of surface; and
RD = average rut depth in in. measured at deepest part of rut.

Research being conducted in Utah (6) is a satellite study to the AASHO Road Test and utilizes a factorial design identical to the one for the deflection study (8). In-service projects fill the cells of the design, and prediction equations have been developed for the serviceability trends so that expected life can be determined for a project fitting into a cell. Figure 6 shows a typical performance curve with PSI from various time periods plotted against the corresponding cumulative 18-kip equivalent loads. Pavement failure can be predetermined from the prediction equation applicable to the proper cell for the pavement section being evaluated.

Slipperiness is the element related to the safe movement or stopping on wet pavements and is the skid resistance of pavement surfaces. Accidents result from pavement surface with low coefficients of friction. The coefficient of friction becomes lower through repeated traffic loads (7).

Slipperiness is measured in Utah with a Mu-meter (10) that determines the skid index (100 times coefficient of friction). The Mu-meter measures the side force friction that is generated between the artificially wetted pavement surface and the 2 pneumatic tires. The Mu-meter is shown in Figures 7 and 8.

The rate of change of the skid index is important in predicting future condition. A factorial design is used for skid resistance with 5 surface types, 3 levels of traffic, and 3 levels of age. Prediction equations were developed for the various cells based on test data from in-service projects. The rate of change of the skid index is determined with the appropriate prediction equation for the cell. Then the remaining expected safe life can be determined from the present skid index and the expected traffic loads. A skid index of 35 has been selected as the unsafe level. Figure 9 shows a typical plot of skid index and traffic loads.

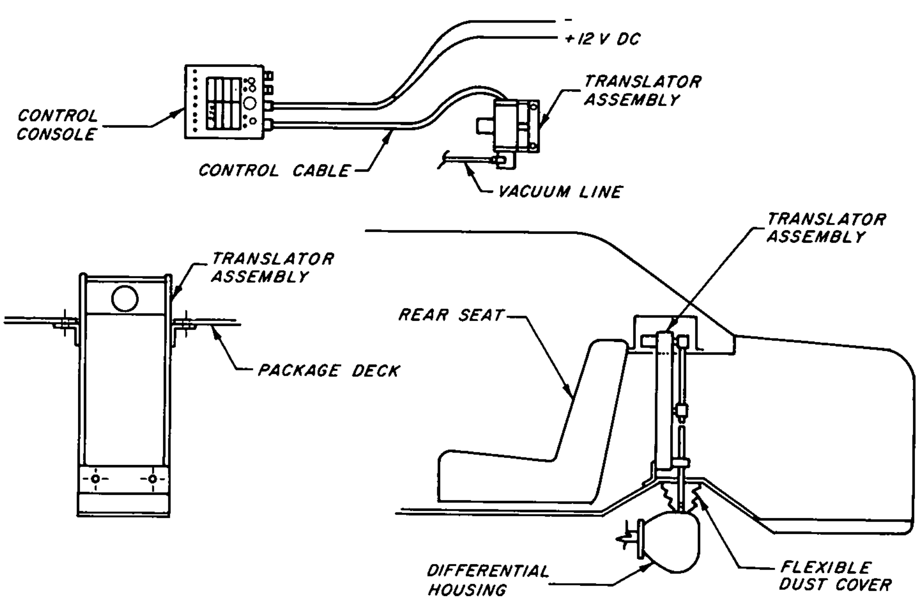

Figure 5. Schematic of PCA type of road meter used in Utah.

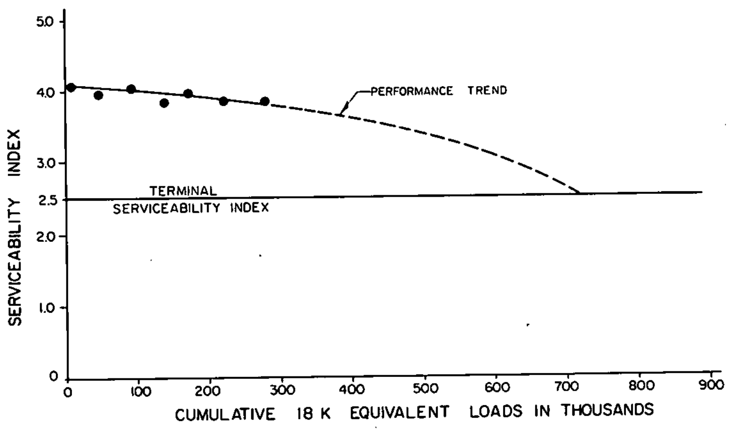

Figure 6. Performance curve for present serviceability index versus cumulative 18-kip equivalent axle loads.

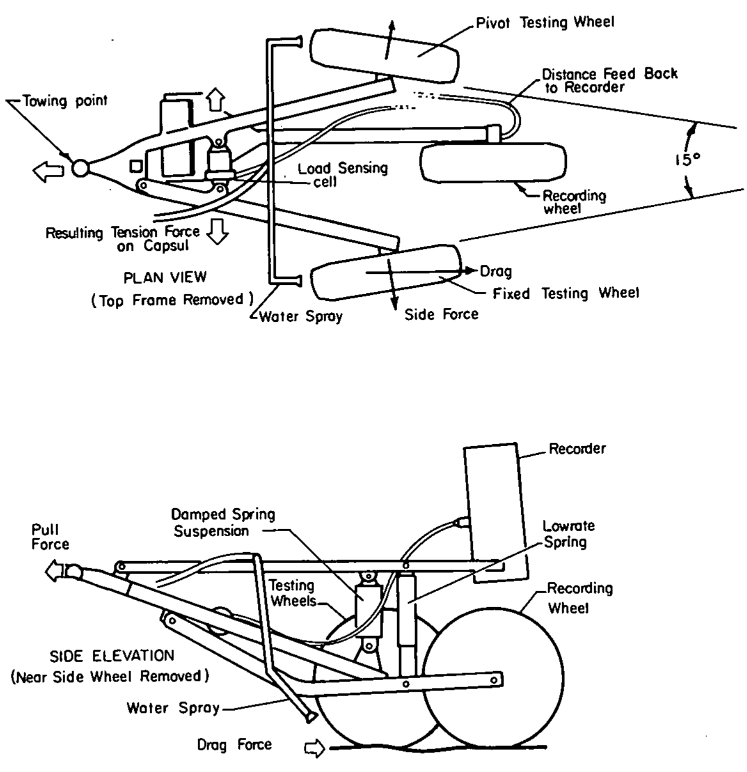

Figure 7. Schematic of Mu-meter.

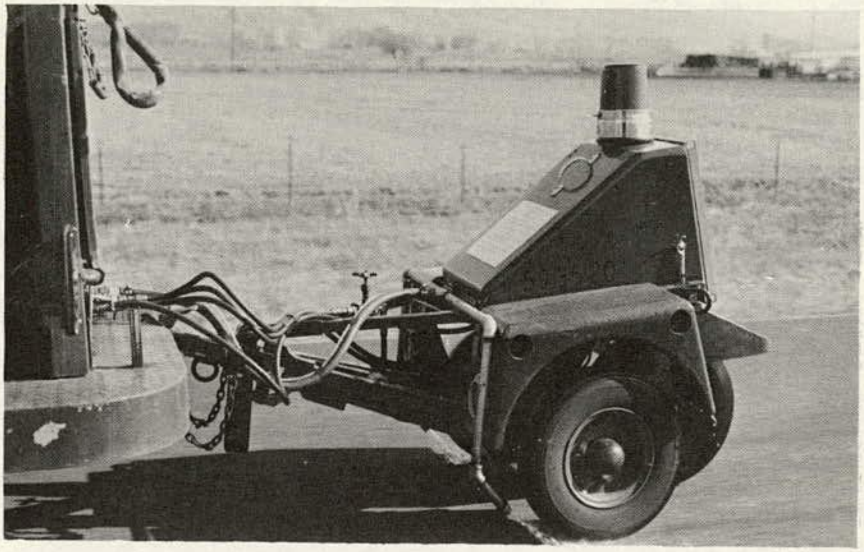

Figure 8. Mu-meter in operation on a pavement surface.

A pavement may not be equally deficient in all elements, so the improvement must be tailor-made for each section. Figure 10 shows how the present condition of the pavement in each element would be used in connection with required life from the sufficiency element in designing improvements. The sufficiency element determines time for reconstruction or major improvements. The correction is then designed on the basis of the other 3 elements and is programmed in advance of the predicted failure date. A design requiring additional structural strength would include an overlay and a skid resistance surface treatment. This would correct all 3 elements. A plant-mixed seal would correct serviceability and slipperiness, and a cover aggregate or chip seal would correct slipperiness.

Figure 11 is similar to Figure 10 except that it shows additional requirements to meet levels imposed by the budget. The recommended correction is then based on needs of all 4 elements.

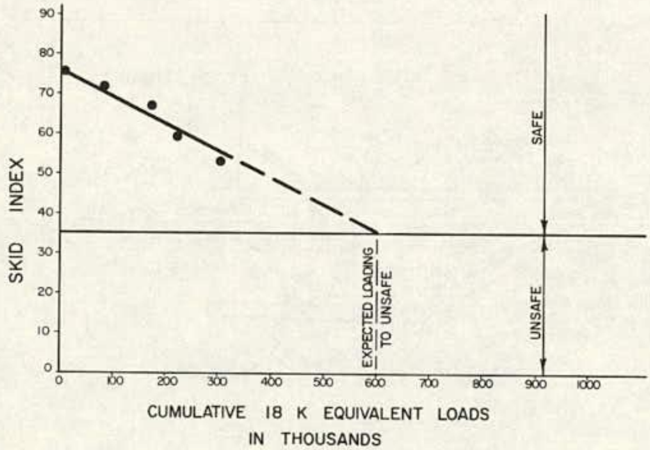

Figure 9. Skid-resistance performance curve.

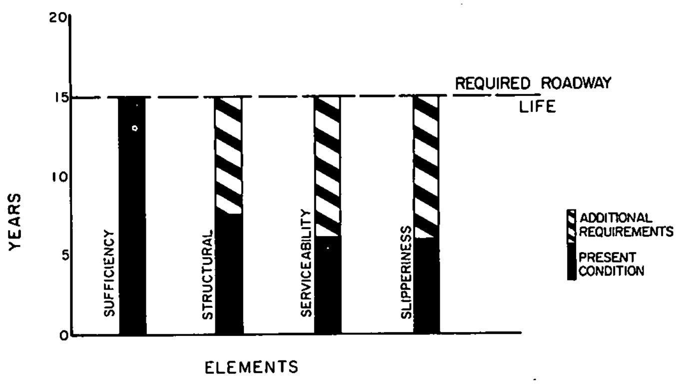

Figure 10. Relative performance requirements for various elements with no budget limitations.

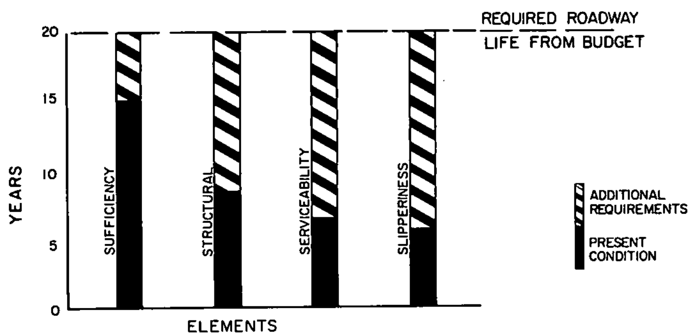

Figure 11. Relative performance requirements for various elements with budget limitations.

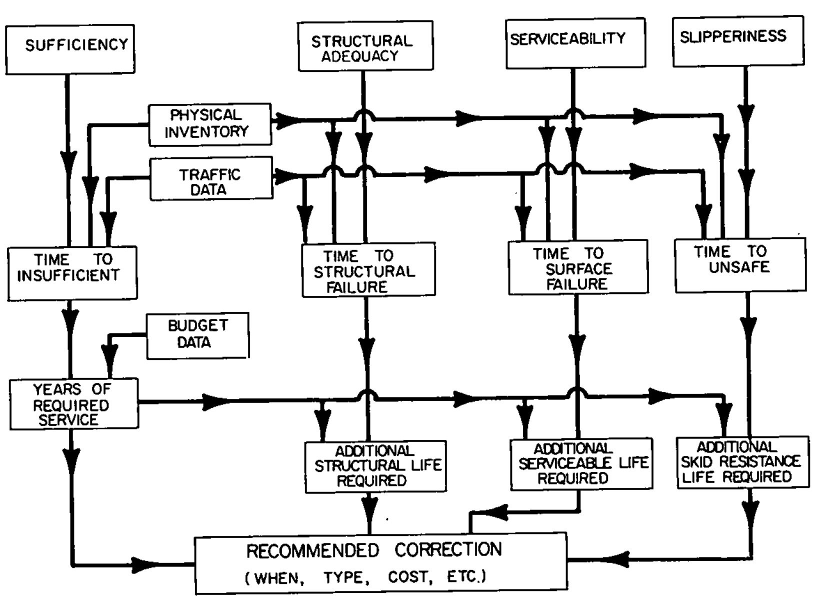

Figure 12. System for planning roadway improvements.

Figure 12 shows how all of the elements in the system are applied in determining final recommendations. This includes all of the required input along with steps required for a solution. The 3 main categories for improvements are reconstruction, major improvements, and maintenance improvements. It is desirable to correct a roadway before it becomes inadequate for the needs of the traffic. This system permits the questions of when, what, and how much to be answered.

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