2. The Truck Weight Problem in Highway Transportation. HRB, Bull. 26, July 1950, 172 pp.
3. Vernon's Annotated Revised Civil Statutes of the State of Texas. West Publishing Company, St. Paul, Vol. 19 1/2, Parts 1 and 2, 1977.
4. J. Brown and others. Effects of Heavy Trucks on Texas Highways. Texas State Department of Highways and Public Transportation, Austin, Sept. 1978.
5. D.S. Paxson and J.P. Glickert. Value of Overweighting to Intercity Truckers. TRB, Transportation Research Record 889, 1982, pp. 33-37.
6. C.M. Walton and D. Burke. Truck Sizes and Weights: A Scenario Analysis. TRB, Transportation Research Record 747, 1980, pp. 78-83.
7. C.M. Walton and O. Gericke. An Assessment of Changes in Truck Dimensions and Highway Geometric Design Principles and Practices. Center for Transportation Research, Univ. of Texas, Austin, Res. Rept. 241-2, June 1981.

*Publication of this paper sponsored by Committee on Motor Vehicle Size and Weight.*

# Impact of Oil Field Truck Traffic

JOHN M. MASON, JR.

**Oil field truck traffic is identified in this paper as a special highway user, and an estimate of the annual cost associated with reduced pavement serviceability on thin surface-treated pavements is provided. Identification of oil field traffic through site-specific observation provides the basis for the investigation. The study includes a description of traffic during the development of an oil well, an estimate of reduced pavement service under these operating conditions, and an estimate of increased annual pavement cost due to oil well traffic. Three main components of the analysis procedure include a pavement analysis, a traffic analysis, and an estimate of traffic generated by an oil well. The AASHTO concept of pavement serviceability was used to determine a reduction in pavement service life due to this concentrated traffic demand. Photographic documentation of the evolution of an oil well provided both an axle count and a description of the physical characteristics of the vehicles. Axle weights were estimated by using standard state loadometer data. Estimates indicate a 50 percent loss of service life due to this special-use industry (considering only one well) as compared with the expected service life if the road had continued to serve its intended purpose. An increased annual cost of $16,500/km was determined for a low-volume, light-duty pavement section. The increase in annual cost is a separable cost attributable to the concentration of a special-user activity.**

Continued interest in determining the effects of truck traffic on highways has prompted individual states to investigate future impacts of vehicle size and weight limits on pavement service life. Such investigations (1-4) have generally addressed statewide needs to justify corresponding increases in revenues required to meet the costs of new construction and rehabilitation. However, there have been limited studies to assess the site-specific impacts created by specialized industrial development.

Walton and Burke (2), in an unrelated study, discuss the lack of commodity information and the nature of economic (industrial) activities in assessing the economic efficiency of large vehicles. Although special-use industries need to be identified in order to differentiate highway costs and corresponding savings in truck operating costs, additional quantitative estimates are also needed. Among the important estimates are the effects on accident rates and severity, geometric and cross-section improvements, load zoning, truck route delineation, and efficient maintenance of traffic in construction and work zones.

## SCOPE

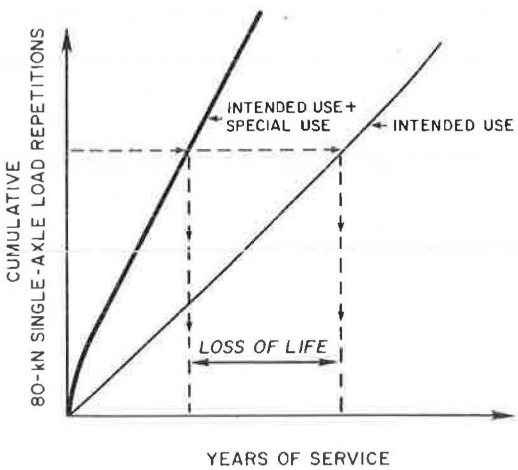
The first phase of a study conducted for the Texas State Department of Highways and Public Transportation (TSDHPT) is presented in this paper. The purpose of the initial research was to characterize oil field truck traffic and develop a preliminary estimate of the potential effects of this traffic on light-duty pavements (Figure 1). This special-use industry can conservatively reduce the expected intended-use service life of a thin pavement by approximately 50 percent or more. Although the successful ventures of oil production efforts have resulted in the benefits of economic growth, the adverse effect of this intense concentrated activity has caused the physical destruction of the pavement surface on the highways that serve the entire oil-producing area (Figure 2).

County roads, state farm-to-market and secondary roads, and city streets in many oil-producing areas were not initially constructed to endure the concentration of intense oil field truck traffic, some of which is well above legal load limits. The responsible road agency (city, county, or state) had not anticipated the resulting persistent rehabilitation under normal (intended-use) operating situations, and a restoration cost was not normally accounted for in the planning of maintenance expenditures. As a result the burden of associated costs has fallen on the public agency that is already obligated with the maintenance responsibilities.

**Figure 1. Light-duty pavement section.**

Figure 2. Effect of oil field use on light-duty pavement section.

Figure 3. Comparison of intended-use and special-use service life.




EVALUATION CONCEPT

Investigations that compare intended use versus special use are of primary concern to state legislators and highway department administrators, city councils, county administrators, and others who must secure and provide resources for maintaining a safe and concomitant road network. Inherently, roadways throughout the nation carry numerous types of commercial vehicle traffic, and each commodity shares in the cost of providing an acceptable roadway pavement. The design, or intended use, of a particular pavement assumes that the facility will serve its original intent for some period of time.

Figure 3 depicts the argument of the intended-use versus unpredicted special-use concept. Although the highway system can fail due to numerous environmental conditions, it is in serious jeopardy when subjected to traffic conditions well beyond its intended purpose. The acceptance of this contention can assist in justifying a redistribution of available funds to areas affected by industries that have heavy special-use traffic demands. Alternative measures such as general revenue increases or a special-use tax levy can also find support in this evaluation concept.

The fundamental concept of this evaluation technique is the identification of separable cost. This economic concept is most closely aligned with the theory of incremental cost, which seeks to "distribute equitably the cost of a basic road suitable for passenger cars among all classes of users, but to assign the heavier or larger vehicles all costs for which they are solely responsible" (5). The difficulty associated with the application of the incremental cost theory has been the inability to determine various costs due to the incomplete data relative to each of the various groups of users.

Oil field traffic is but one industrial activity that can have an impact on the highway system. Special activities with unique traffic characteristics must be assessed to determine what effects their specific site operations have on existing or intended-use roadways. These activities must be identified, their developmental operations defined, resulting traffic characteristics described, and the consequences analyzed on an equivalent basis with all other roadway users.

All levels in the transportation network hierarchy are similarly affected in every state. Industries that produce high concentrations of special-use trucks include mining, agriculture, timber, energy, gravel production, and others. These site-specific activities pose unique problems to local administrators, design engineers, and maintenance personnel. The consequences span the areas of planning, design, construction, operation, safety, and maintenance of the road and street network. Therefore, a need exists to identify the industries that produce these concentrations of heavy loads and assess their respective contributing impact on the expected life of the road system.

The goal of this study is to provide a basic framework for analyzing other unique traffic demands in pursuit of more complete data that relate vehicle axle repetitions to highway cost under a separable user-cost concept. Although this study does not assess separable costs as an analytic alternative, it does demonstrate the potential utility that such a concept may have in further special-use analyses. Because light-duty pavements were failing rapidly under excessive heavy axle load repetitions, these pavements were the first to be addressed in this project.

OBJECTIVES

Specific objectives of the initial phase included

1. Identification of the primary stages in the evolution of an oil well;
2. Description of the vehicle mix during the development of an oil well; and
3. Estimation of increased annual cost associated with reduced pavement serviceability on a low-volume, light-duty roadway pavement.

STUDY PROCEDURE

The transportation-related activity that occurs during the evolution of an oil well was established through a process of continuous photographic monitoring. Monitoring also included daily site visits to talk with servicing companies and oil field representatives. The developmental stages of an oil well were documented with traffic counts of vehicles entering and leaving a site. Specific information was provided by using a concealed camera to photograph vehicles as they entered or left a site. The camera, actuated by a pneumatic road tube across the entrance, signaled individual frame exposures. This procedure provided a count of the number of axles and an identification of vehicle characteristics.

In addition to the movie camera, a total-count traffic counter was installed at each observation site. The traffic counts were later used to check

the reliability of the reduced film counts. A historical evolution of each oil well site was finally determined based on the filmed data, conversations held at the sites with operating personnel, and supplemental photographs taken for the duration of the project.

### Study Sites

Five general activities typically comprise the sequential development of an oil well. These include site preparation, rigging-up, drilling, completion (rigging-down), and production. Each fundamental stage of oil well activity develops unique traffic. Specifically, the vehicle mix includes a disproportionate frequency of large vehicles as compared to typical operating conditions on most low-volume, light-duty, farm-to-market (FM) roads, and city streets.

Three oil well sites were secured within an 8-km radius of each other. Each study site was virtually access controlled. Entrance to the drilling platforms could only occur at the points where the monitoring equipment had been installed.

The well sites are situated in a rural area (Figure 4) on open pasture; no other commercial or industrial activity existed in the general vicinity. Filming was maintained for approximately 2 months at well sites 1 and 2. A photographic record was available for only 28 days at well site 3 due to theft of equipment. The depth of drilling governs duration of activity and was found to be similar at each site. Production generally occurred after 2590 m of drilling. Traffic count monitoring is continuing and has been in operation for 18 months.

**Figure 4. Typical rural oil well site.**

**Table 1. Vehicles defined according to axle combination and corresponding vehicle type code.**

| Axle Combinations | Vehicle Type Code for Axle Combination |
|---|---|
| Single-unit vehicles | |
| Passenger car | PC |
| 2 axles, 4 tires (pickup truck) | PU-1 |
| 2 axles, 6 tires (pickup truck) | PU-2 |
| 2 axles, 6 tires | SU-1 |
| 3 axles | SU-2 |
| Multiunit vehicles | |
| 2-axle tractor, 1-axle semitrailer | 2-S1 |
| 2-axle tractor, 2-axle semitrailer | 2-S2 |
| 3-axle tractor, 1-axle semitrailer | 3-S1 |
| 3-axle tractor, 2-axle semitrailer | 3-S2 |
| 2-axle tractor, 3-axle semitrailer | 2-S3 |
| 3-axle tractor, 3-axle semitrailer | 3-S3 |
| 2-axle truck, 1-axle balance trailer | 2-1 |
| 2-axle truck, 2-axle full trailer | 2-2 |
| 2-axle truck, 3-axle full trailer | 2-3 |
| 3-axle truck, 2-axle full trailer | 3-2 |
| 3-axle truck, 3-axle full trailer | 3-3 |
| 3-axle truck, 1-axle balance trailer | 3-1 |
| 2-axle tractor, 1-axle semitrailer, 2-axle full trailer | 2-S1-2 |
| 3-axle full trailer, 1-axle semitrailer, 2-axle full trailer | 3-S1-2 |

### Data Reduction

Because a single frame was exposed on each axle application, a valid count of axles was possible and a daily record of vehicles was established. The vehicles observed entering and leaving the site were classified according to axle combination. The data in Table 1 give the vehicles defined by axle combination and corresponding vehicle type code. The vehicle code type generally follows the AASHTO classification for axle combinations; the code type was eventually used to assist in assigning vehicle load weights to various axle configurations. Samples of the unique truck traffic serving a well site are shown in Figure 5.

## ANALYSIS

The effect of oil field truck traffic was evaluated based on pavement seviceability. After the traffic characteristics associated with an oil well were determined, a comparison of annual costs to provide a suitable pavement surface was made. The comparison was between an intended-use design traffic volume and the observed oil field demand volume. The conceptual framework of the analysis is shown in Figure 6. The three main components include a pavement

**Figure 5. Special-use trucks serving oil well sites.**

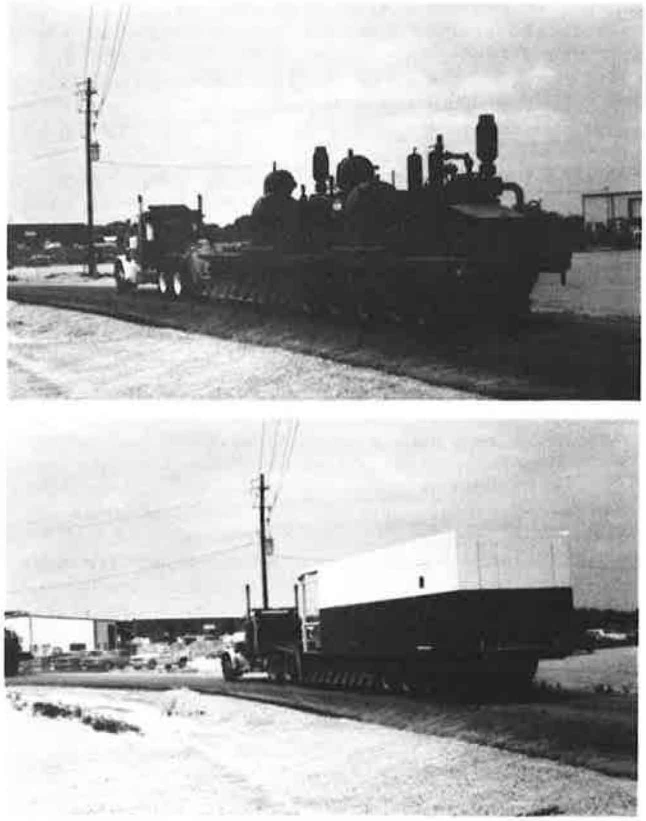
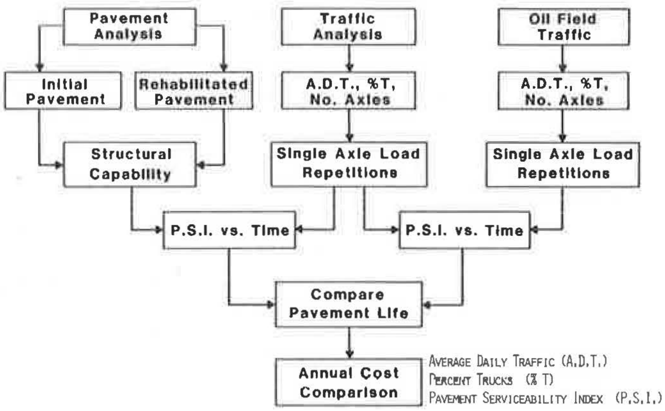


Figure 6. Flowchart of analysis procedure.




analysis, a traffic analysis, and an estimate of traffic generated by an oil well.

Basically, the structural capabilities of a bituminous surface-treated pavement were determined for an intended-use situation. A projected traffic demand was then estimated for a typical low-volume, light-duty pavement. Respective 80-kN single-axle load (SAL) repetitions were calculated for each analysis. A rehabilitation interval was established for a bituminous surface-treated pavement. This was done by comparing the estimated cumulative traffic demand with the terminal pavement serviceability of the intended-use pavement section.

The traffic characteristics of an oil well served as the basis for defining the anticipated traffic attracted to a new well. These characteristics were used to estimate the associated axle load repetitions. An estimate of 80-kN SAL repetitions was calculated for an oil well. Cumulative 80-kN SAL values were established for a light-duty pavement serving an oil well site over the analysis period. Because the roadway pavement must continue to serve both the intended-use traffic and the attracted oil field traffic, the 80-kN SAL intended-use repetitions were combined with the oil field traffic repetitions to represent the total 80-kN SAL applications on the assumed pavement section.

Comparison of the resurfacing intervals over an expected design period indicated a reduction in pavement life. A further comparison was made of the respective total annual costs. The difference between the estimated total annual costs constituted a unit capital loss due to increased traffic, namely, oil field truck traffic. This loss of value represents a consumption, or expenditure, of capital that must be borne by a public agency. These costs considered only the cost of an initial pavement structure and seal coat resurfacing and did not include costs associated with a complete pavement reconstruction, vehicle damage, or accidents.

## Pavement Analysis: Intended Use

Light pavements built for an intended use are characterized by low traffic volumes and lightweight vehicles. These pavements are typically constructed as a bituminous surface-treated pavement. This analysis assumed a 12.7-mm crushed stone bituminous surface course (seal coat) on a 152.4-mm foundation base course as a representative initial pavement structure. A seal coat then served as the intended rehabilitation.

One traditional procedure for defining a pavement's ability to serve traffic is the calculation of a serviceability index (6); the serviceability-performance concept is the basic philosophy of the AASHTO guide for the design of pavement structures. Under this concept pavements are designed for the level of serviceability desired at the end of a selected analysis period or after exposure to a specific total traffic volume.

By using the AASHTO equation, 1,420 80-kN SAL repetitions were determined for the initial pavement structure. An additional 2,180 80-kN SAL repetitions were calculated considering a seal coat rehabilitation. An estimated total of 3,600 80-kN SAL repetitions was considered the anticipated capacity of a typical FM road under intended-use conditions.

## Traffic Analysis: Intended Use

The traffic analysis assumed a low traffic volume condition. An average daily traffic (ADT) of 250 was selected and considered representative of a low-volume, intended-use traffic condition. Additional specific assumptions included 1 percent heavy trucks, 3 percent annual growth rate, and a 50/50 traffic split on the two-way roadway. These assumptions resulted in 456 trucks in the design lane per year.

The intended-use 456 trucks were distributed across approximate axle load ranges developed from the Department's loadometer data. Converting these truck axle repetitions to SAL equivalents indicated that an estimated 445 80-kN SAL repetitions can be assumed during the first year of service. Cumulative 80-kN SAL repetitions for an 8-year period are shown in Figure 7. Given the assumptions of the traffic analysis, 1,420 80-kN SAL are accumulated after approximately 3.2 years, and 3,600 80-kN SAL are accumulated after 7.5 years. These values correspond to the respective initial life and first rehabilitation life of a typical low-volume, light-duty pavement serving its intended-use condition.

## Oil Field Traffic: Specific Use

Traffic characteristics at the three well sites were found to be similar in distribution. Average values were used in the initial analysis. A total of 10,353 vehicles were recorded by the camera. The ADT was approximately 150 vehicles, with peak volumes of 325 vehicles/day. Traffic counts of up to 200 vehicles/day were recorded during the actual drilling process of a single well. Note that these volumes are generally considered as the typical ADT of a low-volume roadway serving only its intended-use traffic.

Distribution of vehicles by code type classification is shown in Figure 8. Passenger cars and pickup trucks comprised approximately 86 percent of the

Figure 7. Intended-use service life.

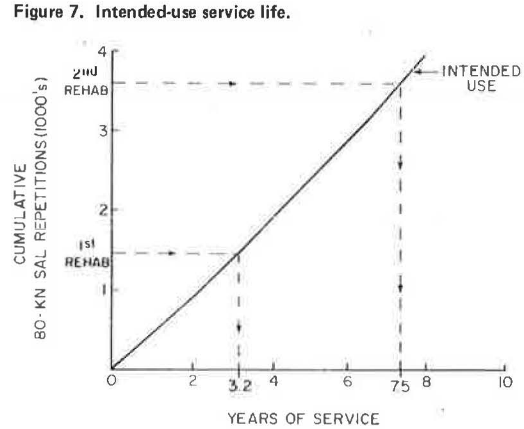


Figure 8. Percentage of vehicles by code type classification.

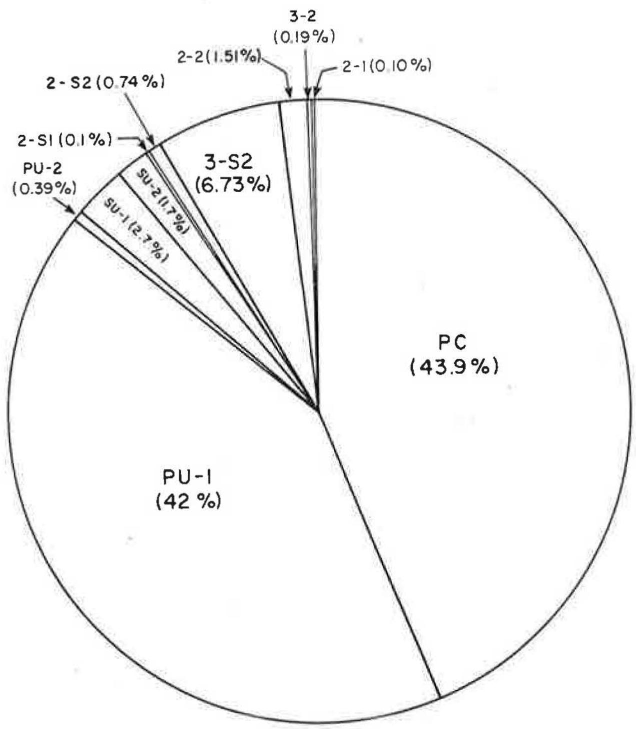
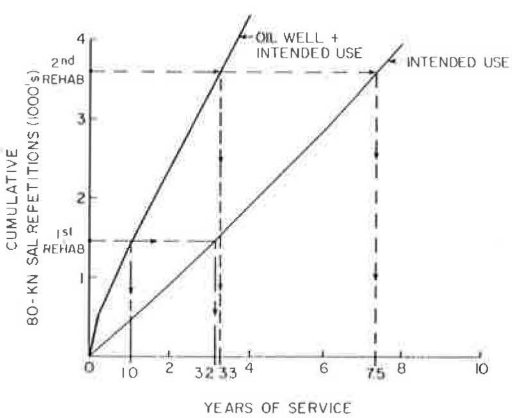



Figure 9. Reduction in service life.




total vehicle mix; truck combinations comprised approximately 14 percent, with almost 7 percent consisting of the 3-S2 (semitrailer) type. The total truck percentage is almost 3 times the anticipated truck percentage on low-volume rural roadways. A total of 1,327 trucks were observed during the drilling phase, and 876 trucks were calculated for oil well production activity during the first year. The total--2,203 heavy trucks--is approximately 5 times the estimated annual truck combinations of the intended-use traffic condition.

The total truck counts were distributed across axle load ranges that corresponded to statewide loadometer data. This approach prevented biasing the oil field truck traffic because actual axle weights were not taken. The method was considered conservative because it assumed the axle weight distribution of oil trucks was typical of all other truck combinations operating on the Texas highway system. Comparison and interpretation of the findings are therefore not biased.

Oil well traffic for one well results in 945 80-kN SAL during the first year of development. Extending production beyond the first year increases axle repetitions by approximately 500 80-kN SAL/year for one well. The loss in pavement use from such traffic is shown in Figure 9. If no additional wells are drilled during the expected service life (7.5 years), the net effect of the drilling and producing of one well is a reduced service life of 4.2 years. In another manner the first rehabilitation is required in year 1.0 rather than year 3.2, and a second rehabilitation is needed in 3.3 years instead of 7.5 years.

## Annual Cost Comparison

This reduction in service life was further examined by estimating the annual cost of providing a suitable light-duty pavement surface. This cost considers only the investment cost of the roadway pavement structure and does not include costs associated with vehicle wear, accidents, or other related adverse consequences of a vehicle operating on an unsuitable pavement surface.

The annual cost formula selected for analyzing the pavement service life is given as (7)

$$C = CRF_n [I + (R_1 \times PWF_{n1})] \quad (1)$$

where

- C = annual cost for pavement per kilometer,
- n = analysis period, i.e., time between initial construction and second resurfacing (years),
- CRF = uniform capital recovery factor,
- I = initial cost of pavement per kilometer ($37,965/km),
- $R_1$ = first resurfacing cost per kilometer ($5,344/km),
- $n_1$ = number of years between initial construction and first resurfacing, and
- $PWF_{n1}$ = single pavement present worth factor.

An interest rate of 12 percent was used in all calculations. (Note that the costs for I and $R_1$ are from 1981 TSDHPT data for unit costs for a typical surface-treated cross section.)

The estimated annual cost for a 250 ADT light-duty pavement roadway is $8,700/km. For a 250 ADT FM roadway that also serves one oil well, the annual cost is $16,500/km, a doubling of the intended-use investment. The difference results in an increase in annual pavement cost of $7,800/km. This cost reflects the impact of one oil well on a low-volume, light-duty pavement section.

Although this increase in annual cost demonstrates the effect of one oil well, the practical impact must also be addressed. It is unrealistic to consider restoring a pavement to its intended-use condition. Once a "find" is made, an oil field is vigorously developed and the demand traffic volumes simultaneously increase as ultimate development is pursued. If the axle repetitions are simply considered multiplicative, the end result is a losing battle when using minimal maintenance techniques.

In reality, it becomes necessary to determine what pavement structure is required in a design situation so as to provide an acceptable level of service for future demand. The future demand must consider both the growth in intended-use traffic as well as ultimate development of a particular field.

These considerations are the primary objectives of the ongoing research effort.

The next phase of the research project is examining the effects of multiple wells by using pavement distress equations for bituminous surface-treated pavements. Specific investigations are being performed on roadways with varying ADT ranges, percentages of trucks, and pavement thicknesses in the intended-use condition. These efforts will provide data to assist in the planning, design, and maintenance of the roadways that exist in the region of this special-use industry. Expected information includes developing impact contours that delineate the radius or zone of special-use influence and projections of drilling and production activity for several levels of development. Anticipating this concentration of unique truck traffic is beneficial in scheduling resurfacing, restoration, and rehabilitation strategies on primary, secondary, and local roads.

## CONCLUSIONS AND RECOMMENDATIONS

Roadway networks throughout the nation carry numerous types of industrial traffic, and each activity shares in the cost of providing an acceptable roadway pavement. The design, or intended-use, of a particular pavement assumes that the facility will serve its original intent for some period of time. Although the system can fail due to numerous environmental conditions, it is in serious jeopardy when subjected to a traffic condition well beyond its intended purpose.

Attempts at predicting and anticipating needed financial resources and expenditures will aid in the planning and distribution of allocated funds. Although the estimates developed in this study provide site-specific information to assess the impact of oil field traffic on low-volume, light-duty pavements, the analysis procedure can be applied to other special-use industrial concentrations.

Practical applications of the results of this research are possible at various agency levels. In counties and cities where construction and maintenance capabilities may be limited or near impossible with current budget restraints, this technique can be used to respond to unexpected special-use demands. Administrative, maintenance, and design engineers can each use the approach or findings reported in this research to anticipate the consequences of an increased concentration in traffic demand. Implementation is possible when planners, designers, and administrators use the best estimates available.

Although a reduction in pavement life is inevitable on any road, the effects of increased cost attributable to a special user should not be ignored in times of financial austerity. If rational analysis is coupled with convincing evidence, public agencies will be able to justify additional allocations to maintain their existing system.

## ACKNOWLEDGMENT

This paper has been developed as part of an ongoing research project entitled "Effects of Oil Field Development on Rural Highways" sponsored by TSDHPT. The findings are the result of the phase 1 efforts to identify oil field traffic characteristics and estimate the reduction in pavement serviceability on low-volume, rural, FM roadways. A technical advisory committee acted as an integral part of this study; their continuous guidance and support are greatly appreciated.

The views, interpretations, analysis, and conclusions expressed or implied in this report are mine. They are not necessarily those of TSDHPT.

## REFERENCES

1. Mississippi State Highway Commission. A Special Report on the Highway Weight Limit. Mississippi Legislature, Jackson, Senate Resolution 31, Nov. 1976.
2. C.M. Walton and D. Burke. Highway Economic Effects of Increased Truck Size and Weight. Compendium of Technical Papers, ITE, Washington, D.C., 1980.
3. R.F. Carmichael III, F.L. Roberts, P.R. Jordahl, H.J. Treybig, and F.N. Finn. Effects of Changes in Legal Load Limits on Pavement Costs--Volume 1: Development of Evaluation Procedure. FHWA, Rept. FHWA-RD-78-98, Sept. 1978.
4. J.L. Brown, D. Burke, F.L. Roberts, and C.M. Walton. The Effects of Heavy Trucks on Texas Highways. Texas State Department of Highways and Public Transportation, Austin, Res. Rept. 231, Sept. 1978.
5. C.H. Oglesby. Highway Engineering, 3rd ed. Wiley, New York, 1975.
6. Interim Guide for Design of Pavement Structures, 2nd ed. AASHTO, Washington, D.C., 1974.
7. L.J. Pignataro. Traffic Engineering, Theory and Practice. Prentice-Hall, Englewood Cliffs, NJ, 1973.

*Publication of this paper sponsored by Committee on Vehicle Size and Weight.*