Taxation Model for Road Vehicles in Saudi Arabia

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A taxation model for road vehicles in the Kingdom of Saudi Arabia has been developed on the hypothesis that vehicles should pay their fair share for roadway maintenance. A number of load- and traffic-counting stations were selected on the main highway network in the Eastern Province of the kingdom. Representative ranges of truck loads and dimensions, traffic volumes, and pavement deterioration were monitored at these stations. Data related to kilometers traveled per day were also collected on the basis of driver interviews. At all survey stations, a large number of trucks were found to exceed the load and dimensional limits of the Ministry of Communication. The pavement condition survey indicated a prevalence of load-associated damage. Assuming pavement maintenance costs for major and routine maintenance operations, a model to assess vehicle taxation in terms of an annual tax as well as a load violation charge is presented with illustrative examples. As a result of this study, 11 weight control stations have been installed on major truck routes in the kingdom. Early results of the weight control program are encouraging.

The transport sector of the Kingdom of Saudi Arabia is one of the most vital sectors of the Saudi economy; economic development of the kingdom relies heavily on its extensive road network. The kingdom today has about 100 000 km of roads, of which about 30 000 km is of high-specification asphalted roads. These roads were designed according to the AASHTO procedure for a specified number of 8.2-t (18-kip) equivalent axle load (EAL) applications anticipated during the design life of 20 years (*1*).

It is well known to highway engineers that pavement damage increases exponentially with axle loads. For example, AASHO road tests have shown that pavement damage is approximately proportional to the fourth power of the axle load (*2*). Thus, if an axle load is increased to twice the EAL, one application of the increased axle load will cause the same amount of damage to the pavement as 16 applications of the EAL. Applying this logic to lighter loads of passenger cars, it can be seen that a fully loaded truck may cause approximately 10,000 times more damage than a passenger car.

For economic reasons, there is a growing tendency toward increasing truck sizes and weights, and thereby toward increased axle loadings. Increased truck weights accelerate pavement damage and shorten the maintenance-free life of the pavement. Problems resulting from overweight trucks are being experienced worldwide. In the kingdom the problem is worse because much higher axle loads than the Ministry of Communication (MOC) legal limits are operating on the highway network (*3*). A number of major highways, expressways, and bridges in the kingdom are showing signs of structural distress much earlier than their design lives (*4–6*). Hence, if the large capital investment made in the highway network is to be protected, there is an immediate need to regulate axle loads and the gross weight of trucks.

One approach to alleviate the problem of overloading and meet the increasing budgetary needs for road maintenance is to introduce taxation for road vehicles commensurate with the damage they cause to the road pavements (*7,8*). The existing taxation policy in the kingdom needs refinement because it is not based on pavement wear. Placing higher taxes on trucks with higher axle loads would not only generate revenue for increasing maintenance needs but would also discourage use of trucks that do the most damage to the roads. A rational taxation model was formulated in which vehicles are charged equitably in accordance with the cost of roadway maintenance attributable to their operations. Field data related to operating traffic volumes, vehicle dimensions and loads, vehicle kilometers traveled, and pavement damage and maintenance, which constitute an important data base for the model development, were collected for certain primary highways in the Eastern Province of the kingdom.

MODEL DEVELOPMENT

The model is developed in two parts. Part I deals with the estimation of vehicle annual taxation covering the annual maintenance expenditure on the road system. This tax will be determined separately for each vehicle class on the basis of average values of vehicle attributes within the class. Part II deals with the estimation of additional taxation for overloaded vehicles that are violating the legal load limits. This tax will be determined separately for each individual vehicle and will be based on the degree of overloading by the vehicle and the average roadway use by the corresponding vehicle class.

For estimation of vehicle annual taxation, a distinction has to be made between the annual maintenance cost for routine maintenance and the equivalent annual major maintenance cost. Routine maintenance cost accounts for regular or normal maintenance such as roadway cleaning and repairs of minor pavement distresses, which are generally nonload associated. Routine repairs most commonly include crack sealing and

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patching. Major maintenance cost accounts for periodic pavement rehabilitation (i.e., overlays) due to load-associated pavement distresses. Because the routine maintenance cost is nonload associated, it is logical to distribute it among road vehicles in accordance with their base areas representing roadway occupancy area. The major maintenance cost, being load associated, is distributed among vehicles in proportion to the damage caused by their loads. Hence, the vehicle annual tax (VAT) is divided into two portions: annual major maintenance tax (AMMT) and an annual routine maintenance tax (ARMT).

Vehicle Annual Tax

Annual Major Maintenance Tax

Assuming that a road section requires an overlay after each n years and its estimated cost per lane-kilometer is CMM, the average annual major maintenance cost (AMMC) can be determined by the following:

$$\text{AMMC} = \text{CMM} \times C_{rf} \tag{1}$$

where

C_{rf} = capital recovery factor = $\dfrac{i\,(1+i)^n}{(1+i)^n - 1}$ and

i = interest rate per year.

The damage induced on a road section in 1 year is proportional to the amount of EAL applied on the road section during this period. Accordingly, the share of each EAL to the major maintenance cost in a year's time can be determined by the following:

$$\text{UMMC} = \frac{\text{AMMC}}{\text{total EAL passed on 1 lane-km/yr}} \tag{2}$$

where UMMC is the unit major maintenance cost per lane-kilometer per unit EAL.

Estimating the average annual kilometers (AKT) traveled by a vehicle, the AMMT accruing to the vehicle can be estimated by the following:

$$\text{AMMT} = \text{UMMC} \times \text{RDF} \times \text{AKT} \tag{3}$$

where the relative damage factor (RDF) of a vehicle on the basis of the EAL concept is given by the following equation:

$$\text{RDF} = \sum_{i=1}^{n} \text{EAL}_i \tag{4}$$

where

n = number of vehicle axles and

EAL_i = equivalent axle load of Axle i.

EAL_i is determined by the following equation:

$$\text{EAL}_i = \left(\frac{L_i}{L_s}\right)^4 \tag{5}$$

where

L_i = actual load of Axle i and

L_s = corresponding standard axle load.

L_s is assumed as 5.4 t for a single axle with single tires, 8.2 t for a single axle with dual tires, 13.6 t for a double axle with dual tires, and 18.5 t for a triple axle with dual tires (*2,6*). The RDF of any vehicle will be a function of the vehicle's axle load and is expected to vary in each operation. Legal RDF (RDF_0) is used in Equation 3, assuming that the vehicle is operating at MOC legal load limits. Legal axle loads (L_{i0}) and the corresponding RDFs for different vehicle classes on the basis of MOC legal load limits are presented in Table 1.

Annual Routine Maintenance Tax

It is assumed that routine maintenance needs are independent of the damage caused by vehicle loading. Other than the annual kilometers traveled by a vehicle, the ARMT of the vehicle should depend on the size of the vehicle, which represents its degree of occupying the road. For instance, assuming the kilometers traveled remain the same, a truck having a base area three times that of a passenger car should pay three times the car's share of the annual routine maintenance cost. Hence, to estimate ARMT, base areas of all vehicles are transformed into equivalent passenger car (EPC) units, defined by the following:

$$\text{EPC} = \frac{\text{base area of a vehicle}}{\text{base area of a passenger car}} \tag{6}$$

The share of each EPC unit to the routine maintenance cost per year per lane-kilometer is as follows:

$$\text{URMC} = \frac{\text{ARMC}}{\sum_{k=1}^{s} (N_k \times \text{EPC}_k)} \tag{7}$$

where

URMC = unit routine maintenance cost per lane-kilometer per unit EPC,

ARMC = average annual routine maintenance cost per lane-kilometer,

N_k = average annual volume of vehicles of Class k, and

s = total number of vehicle classes.

Therefore, the ARMT for a vehicle can be estimated by the following:

$$\text{ARMT} = \text{URMC} \times \text{EPC} \times \text{AKT} \tag{8}$$

Finally, the VAT covering both the routine and major maintenance is determined by combining Equations 3 and 8 as follows:

$$\begin{aligned}\text{VAT} &= \text{AMMT} + \text{ARMT}\\ &= (\text{UMMC} \times \text{RDF}_0 + \text{URMC} \times \text{EPC})\,\text{AKT}\end{aligned} \tag{9}$$

TABLE 1 RELATIVE DAMAGE FACTOR (RDF) FOR DIFFERENT TRUCK TYPES ON THE BASIS OF MOC LEGAL LOAD LIMITS

Truck Description	Truck Designation	Legal Axle Load in Tons and Corresponding EAL for Axle (i)	Legal Gross Load in Tons and Legal RDF (RDF_0)
Rigid Body with 2 Axles	RB2	6 - 13 (1.52) (6.32)	19 (7.84)
Rigid Body with 3 Axles	RB3	6 - 10 . 10 (1.52) (4.68)	26 (6.20)
Semi-Trailer with 3 Axles (2 in front)	S2.1	6 - 13 - 13 (1.52) (6.32) (6.32)	32 (14.16)
Semi-Trailer with 4 Axles (2 in front)	S2.2	6 - 13 - 10 . 10 (1.52) (6.32) (4.68)	39 (12.52)
Semi-Trailer with 4 Axles (3 in front)	S3.1	6 - 10 . 10 - 13 (1.52) (4.68) (6.32)	39 (12.52)
Semi-Trailer with 5 Axles (3 in front)	S3.2	6 - 10 . 10 - 10 . 10 (1.52) (4.68) (4.68)	46/40[a] (10.88)/(6.40)
Semi-Trailer with 5 Axles (2 in front)	S2.3	6 - 13 - 7 . 7 . 7 (1.52) (6.32) (1.66)	40 (9.50)
Semi-Trailer with 6 Axles (3 in front)	S3.3	6 - 10 . 10 - 7 . 7 . 7 (1.52) (4.68) (1.66)	47/40[a] (7.86)/(4.68)

[a] 40T is legal gross load limit.

The AKT values were estimated from driver interviews. The RDF and EPC values were determined from the vehicle weight and dimension surveys. Field data collection and data analyses are presented in the following section.

Load Violation Tax

Load violation can represent either gross load violation or axle load violation, or both. Axle load violation can be triggered without a gross load violation, if the payload is not well distributed over all the axles. Gross load violation, without an axle load violation, can be triggered only for S3.2 and S3.3 truck types; for these truck types the MOC gross load legal limits, as presented in Table 1, are lower than the corresponding sums of the axle load limits. If both violations exist, the vehicle is charged for only one of the two, whichever calls for greater taxation.

Gross Load Violation Tax

The gross load violation tax (GLVT) must be in proportion to the excess of RDF applied by the overloaded vehicle above the legal limit. If a vehicle has an extra gross load of L_g above the legal limit of L_{g0}, the new relative damage factor RDF_n corresponds to load ($L_g + L_{g0}$) and is related as follows:

$$\left(\frac{RDF_n}{RDF_0}\right) = \left(\frac{L_g + L_{g0}}{L_{g0}}\right)^4 \tag{10}$$

Accordingly, the increase in RDF units is as follows:

$$\Delta RDF = RDF_n - RDF_0 \tag{11}$$

The amount of extra maintenance cost for each kilometer of travel to be covered by the excess in RDF units should be equal to $\Delta RDF \times UMMC_n$.

The $UMMC_n$ value is the new unit major maintenance cost per kilometer for the illegal loading conditions.

Hence, the GLVT can be estimated by the following:

$$\begin{aligned} GLVT &= \Delta RDF \times UMMC_n \times \text{trip length} \\ &= (RDF_n - RDF_0) \times UMMC \times \left(\frac{RDF_n}{RDF_0}\right) \\ &\quad \times \text{trip length} \end{aligned} \tag{12}$$

The violation charge should be a function of the trip length each time the vehicle violates the legal load limits. Because estimation of actual trip length for each case is difficult, average distance traveled daily by each vehicle class is used, determined from driver interviews. The AKT used in Equation 9 was related to the average trip length (ATL) as follows:

$$AKT = 300 \times ATL \tag{13}$$

where 300 represents the number of working days per year.

Thus, the GLVT is as follows:

$$GLVT = RDF_0\left(\frac{RDF_n}{RDF_0} - 1\right) UMMC\left(\frac{RDF_n}{RDF_0}\right) ATL \tag{14}$$

The ratio of RDF_n to RDF_0 can be estimated by the fourth power of the ratio of the new illegal load to the legal load, as indicated in Equation 10. Accordingly,

$$GLVT = RDF_0\left[\left(\frac{L_g + L_{g0}}{L_{g0}}\right)^4 - 1\right] \times UMMC\left(\frac{L_g + L_{g0}}{L_{g0}}\right)^4 ATL \tag{15}$$

Axle Load Violation Tax

When the violation is due to axle load and not gross load, the same equation may apply using the EAL value for axles and not for the overall vehicle. Thus, for this case, the axle load violation tax (ALVT) is given by the following:

$$ALVT = EAL_{i0}\left[\left(\frac{L_i}{L_{i0}}\right)^4 - 1\right] \times UMMC\left(\frac{L_i}{L_{i0}}\right)^4 ATL \tag{16}$$

where EAL_{i0} is the legal equivalent axle load of Axle i.

FIELD DATA COLLECTION

Out of 16 major highways and expressways in the Eastern Province, 5 were selected for data collection in consultation with the Dammam Directorate of the MOC. The selected highways cover the range of construction materials, groundwater conditions, pavement age, cross sections, and distress manifestations typically encountered in the region. One load- and traffic-counting survey station was located on each selected highway for each direction of travel, at a place where the expected truck traffic was heaviest. Because the trucks had to be taken from the moving traffic stream and stopped for load measurements, careful planning of safety measures and the presence of traffic police were required to authorize truck stopping. Generally, a queue of trucks developed. While the trucks were waiting to be weighed, the truck drivers were interviewed to collect the trip length data and other crew members measured the trucks' dimensions.

Volume Data

Volume data were collected using manual counters. Classified volume data were recorded on specifically designed sheets. Two groups of data collectors were employed at each counting station, separately for daytime and nighttime counting. The observed average composition of truck traffic compared with that on freeways in Australia and in the United States is presented in Table 2 (*9,10*). The composition in Saudi Arabia is similar to that in the United States and Australia, except that more RB3s and less RB2s are observed in the kingdom. The table shows that the S3.3 is the most widely used truck in Australia, as opposed to the S3.2 in the United States and the kingdom. The S3.3 has better load distribution than the S3.2 due to its larger number of axles.

Load Measurement

Axle load measurements were made with the Trevor Deakin Portable Weighbridge designed by the U.K. Transport and Road Research Laboratory (TRRL). It comprises two lightweight weighpads with a separate electronic logaload readout unit having a digital printer. The vehicle is driven forward slowly; when the wheels are centered over the weighpads, the vehicle is stopped and the logaload displays the load applied. The vehicle is then driven until its next set of wheels is advanced to the weighpads and again weighed. The printout lists the load on each axle, gross weight, number of axles, ticket serial number, and date. A typical designed data sheet is presented in Table 3. Tire pressures were measured as supplementary information for the pavement design study. Analysis of axle loads revealed that overloading was most frequently encountered on triple axles—72 percent of them exceeded the legal limit. The other axle groups exceeding the legal limits were 55 percent of tandem axles, 43 percent of SS axles (single axle with single wheels) and 26 percent of SD axles (single axle with dual wheels).

Gross weights of loaded vehicles were analyzed in a similar manner as the axle loads. Gross overloading was encountered most frequently in the RB3 type (77 percent), followed by the S3.2 and S3.3 types (68 percent for each type). Further, 28 percent of the RB2 type and 25 percent of the S2.2 type were found to be exceeding their gross weight legal limits. The frequent overloading observed in the RB3 type may be attributed to the type of commodity (such as sand and ag-

TABLE 2 PERCENTAGE VOLUME COMPOSITION OF TRUCK TRAFFIC ON RURAL FREEWAYS AND EXPRESSWAYS

Truck Type	Percentage Volume Composition in		
	Saudi Arabia	Australia	U.S.A.
RB2	16	23	34
RB3	27	10	4
RB4	NA	4	1
	43	37	39
S2.1	NA	1	4
S2.2	11	6	8
S3.2	40	24	49
S3.3	6	32	NA
	57	63	61

NA = Not applicable

TABLE 3 TYPICAL AXLE LOAD DATA

SURVEY STATION: LC2 DATE: 24-09-85
HIGHWAY: FROM JUBAIL TO SAFWA TIME: 07:00 HRS.

Reg. No.	Truck Type	AXLE LOAD (TONS) AX1	AX2	AX3	AX4	AX5	AX6	Gross Wt. (Tons)	Tire Prs. (Kg/sqcm)	Comments
7057	S3.2	5.88	5.15	4.86	4.91	6.31		27.11		Container
7060	RB2	5.01	13.43					18.44	8.45	Container
7057	S3.2	6.04	7.60	8.04	8.51	8.38		38.57	9.16	Steel
7048	RB3	4.82	4.94	4.46				14.22		Empty
7136	RB3	5.66	12.90	13.28				31.84	7.04	Blocks
7106	S3.2	4.66	11.59	12.51	11.09	12.10		51.95		Equipment
7164	LT	1.85	3.69					5.54		Pipes
7136	RB3	6.58	10.91	11.76				29.25	6.34	Blocks
7077	S3.2	5.73	5.40	4.78	9.73	9.64		35.28		Tanker
7064	S3.2	6.25	8.00	7.03	8.13	8.12		37.53	7.04	Steel
7124	RB2	5.96	12.70					18.66		Tanker
7033	RB2	2.90	7.34					10.24	6.34	Container
7057	S3.2	6.18	7.82	7.12	7.98	8.34		37.44	7.04	Steel
7084	RB3	5.78	8.84	10.13				24.75		Tanker
7060	S3.2	4.88	10.38	10.20	12.76	12.27		50.49		Steel
7090	S3.2	6.40	12.54	11.94	18.11	20.85		69.84	10.57	Steel
7131	S3.2	6.30	12.00	12.55	17.81	17.40		66.06	8.45	Steel
7048	S3.2	6.30	15.10	14.67	17.91	18.83		72.81		Steel
7175	S3.2	6.20	13.43	12.61	16.47	18.16		66.87	9.86	Steel
7189	RB3	6.30	14.94	14.70				35.94		Aggregate
7041	RB2	5.15	9.57					14.72		Gas
7038	S3.2	7.12	12.42	11.74	14.68	13.90		59.86	8.45	Blocks
7184	S3.3	7.90	11.81	12.10	22.40	13.67	20.12	88.00		Aggregate
7067	S3.2	6.67	3.60	3.25	3.21	3.52		20.25		Pipes
7065	RB3	6.80	15.80	16.11				38.71	8.45	Aggregate

gregates) usually carried by it. Overloading in the S3.2 and S3.3 types may be due to the increased dimensions of these trucks and their increased empty weights. Mean empty weights of these two types were found to be 52.4 and 70.1 percent, respectively, of the corresponding loaded legal weight limits. The higher empty weights result in less payload limit if the legal weight limits are complied with, thereby making the operation of these truck types uneconomical to the operator. This situation leads to the overloading tendencies.

Dimensional Data

Measurements of dimensions of a number of passenger cars showed an average length of 3.4 m and an average width of 2.0 m, giving a base area of 6.8 m^2. This area was used for computing the EPCs of other vehicle classes. The 95th percentile values computed from the collected dimensional data are presented in Table 4, together with the current MOC dimensional limit and the dimensions of the corresponding AASHTO vehicles. For rigid trucks, the 95th percentile values for length and width exceed the corresponding MOC and AASHTO limits. For semitrailer trucks, the 95th percentile values of each element (i.e. length, width, and height) exceed the corresponding limits specified by MOC and AASHTO. Insufficient control of vehicle dimensions not only results in certain highway geometric design standards being inappropriate, but also contributes to the overloading problem. The combination of oversized and overloaded vehicles, operating at high speeds and poor levels of vehicle maintenance, contributes to increasing road accidents.

TABLE 4 COMPARISON OF DIMENSIONAL LIMITS

Vehicle Type	Dimension	Value (m) 95-Percentile	MOC Limit	AASHTO
Rigid Body Truck	Length	12.80	12.00[a]	9.10
	Width	2.75	2.50	2.60
	Height	3.88	4.00	4.10
Semi-Trailer	Length	20.00	18.00	17.00
	Width	3.10	2.50	2.60
	Height	4.70	4.00	4.10

[a] Length limit is 11.0 m for RB2

Average Trip Length Data

As mentioned earlier, the truck drivers were interviewed while they were waiting in queue for load and dimension measurements. The main purpose of the driver interviews was to collect information about average kilometers traveled per day. Supplementary data on types of commodity, routing (origin-destination), percent time the vehicle was operating at full load, and driving license and registration renewal were also sought. A separate interview sheet was completed for each truck. Because no passenger cars were stopped at the weighing stations, a separate interview survey was planned for them at selected gas stations—one on each selected highway. Only basic information related to the average distance traveled per day was collected from the car drivers.

Pavement Condition

The pavement rating (PAVER) technique developed by the U.S. Army, Corps of Engineers, was used to quantify pave-

ment distress (*11*). In this technique, pavement condition evaluation is based on a numerical rating of 100, called the pavement condition index (PCI). The PCI is a measure of the overall surface condition of a pavement combining all types of observed distress manifestations. The types of distresses encountered were bleeding, longitudinal cracking, weathering and raveling, patching, and rutting, with severity levels ranging from low to high. The PCIs and pavement condition ratings are presented in Table 5 by section. According to the PAVER technique, a decision may be made to rehabilitate a primary highway when its PCI falls to 60 (*11*). If this limit is applied to the selected highways, the sections in need of major maintenance are identified as shown in the table.

ILLUSTRATIVE EXAMPLES

Vehicle Annual Taxation

Taxation assessment requires estimation of AMMC and ARMC. On the basis of interviews with local contractors performing maintenance contracts for MOC, average values of AMMC and ARMC were assumed as SR 4,183, and SR 1,940 per lane-kilometer per year. The value of AMMC assumes a 5-cm overlay costing SR 32,300 per lane-kilometer, distributed over a period of 10 years at a compound interest rate of 5 percent.

UMMC and URMC values were computed for each selected highway using the corresponding volume data and the mean values of the other data for the five highways. The computer values of UMMC and URMC for each study location are presented in Table 6. Typical computations for VAT for Abu Hadriyah-Dammam Expressway are presented in Table 7. Because VAT within a province should not be a function of road location, overall average values of UMMC and URMC for all study locations were used to compute the annual taxes. The taxes for various vehicle classes are presented in Table 8.

TABLE 6 UNIT MAINTENANCE COSTS FOR SELECTED HIGHWAYS

Highway	UMMC (SR x 10^{-2})	URMC (SR x 10^{-2})
Dammam-Ras Tanura	0.32063	0.080323
Ras Tanura-Dammam	0.34295	0.07524
Safwa - Jubail	0.43438	0.12644
Jubail - Safwa	0.41171	0.11341
Dammam - Abu Hadriyah	0.36008	0.18127
Abu Hadriyah - Dammam	0.30972	0.15966
Dammam - Riyadh	0.49979	0.25997
Riyadh - Dammam	0.41559	0.21895
Dhahran - Abqaiq	0.18102	0.084027
Abqaiq - Dhahran	0.17168	0.074568
Average	0.34476	0.13738

Load Violation Tax

On the basis of the average value of UMMC, additional taxes for gross load violation and axle load violation can be calculated for each vehicle class and axle type using Equations 15 and 16, respectively. As mentioned previously, if both violations exist, taxation for only the greater of the two will apply. For example, consider a semitrailer S2.2 carrying gross overloading of 10 t. The GLVT can be estimated as follows: L_g = 10 t, L_{g0} = 39 t, RDF_0 = 12.52 (Table 1), UMMC = SR 0.34476 × 10^{-2} (Table 6), and ATL = AKT/300 = 525 km (Table 7). Substituting these values in Equation 15, GLVT = SR 84.

TABLE 5 PAVEMENT CONDITION INDEX OF SELECTED HIGHWAY SECTIONS

Highway	Section	Direction	PCI	Rating	Major Maintenance Need
Dammam-Ras Tanura	A	Northbound	85.6	Excellent	No
Dammam-Ras Tanura	B	Northbound	93.1	Excellent	No
Ras Tanura-Dammam	A	Southbound	82.7	V. Good	No
Ras Tanura-Dammam	B	Southbound	79.0	V. Good	No
Safwa-Jubail		Northbound	89.2	Excellent	No
Jubail-Safwa		Southbound	91.4	Excellent	No
Dammam-Abu Hadriyah	A	Northbound	89.4	Excellent	No
Dammam-Abu Hadriyah	B	Northbound	35.1	Poor	Yes
Abu Hadriyah-Dammam	A	Southbound	90.9	Excellent	No
Abu Hadriyah-Dammam	B	Southbound	26.0	Poor	Yes
Dammam-Riyadh		Westbound	82.5	V. Good	No
Riyadh-Dammam		Eastbound	95.1	Excellent	No
Dhahran-Abqaiq	A	Westbound	24.5	V. Poor	Yes
Dhahran-Abqaiq	B	Westbound	35.0	Poor	Yes
Abqaiq-Dhahran	A	Eastbound	43.5	Fair	Yes
Abqaiq-Dhahran	B	Eastbound	39.3	Poor	Yes

TABLE 7 ESTIMATION OF VEHICLE ANNUAL TAX CORRESPONDING TO ABU HADRIYAH-DAMMAM EXPRESSWAY

Vehicle Class	RDF_o	EPC	Annual Vol./Lane	AKT (km)	ΣEAL_j/Yr.	ΣEPC_j/Yr.	AMMT(SR)	ARMT(SR)	VAT (SR)
(1)	(2)	(3)	(4)	(5)	(6) = (2)x(4)	(7) = (3)x(4)	(8)	(9)	(10) = (8)+(9)
PC	0.00	1.0	135768	25338	0	135768	0	40	40
LT[a]	0.6263	2.5	14652	79570	9177	36630	155	317	472
BUS	3.0483	4.0	340	96725	1036	1360	913	617	1530
RB2	7.8400	3.0	14516	93440	113805	43548	2269	447	2716
RB3	6.2000	3.6	29487	100010	182819	106153	1921	574	2495
S2.2	12.5200	5.3	24740	157602	309745	131122	6113	1333	7446
S2.3	9.5000	5.3	326	157602	3097	1728	4638	1333	5971
S3.2	6.4000	6.4	105204	157602	673306	673306	3125	1610	4735
S3.3	4.6800	7.0	12212	157602	57152	85484	2285	1761	4046

[a]Light Truck

URMC = 1940/ΣCol(7) Col. (8) = UMMC. (2) . (5)
UMMC = 4183/ΣCol(6) Col. (9) = URMC . (3) . (5)

TABLE 8 TAXES BY VEHICLE CLASS

Vehicle Class	PC	LT	Bus	RB2	RB3	S2.2	S2.3	S3.2	S3.3
AMMT (SR)	0	172	1016	2525	2138	6804	5163	3478	2543
ARMT (SR)	34	273	531	384	494	1146	1146	1385	1514
VAT (SR)	34	445	1547	2909	2632	7950	6309	4863	4057

Assuming that the 10-t overloading occurs on the tandem axle group, the ALVT can be estimated as follows: L_i = 30 t, L_{i0} = 20 t, and EAL_{i0} = 4.68 (Table 1). Substituting these values in Equation 16, ALVT = SR 174.0. Because the ALVT is greater than the GLVT, the load violation tax in this case is SR 174.

The suggested taxation structure is tentative because of the limited data collected (*12*). As more data are collected over a longer period of time and over other major highways, the input values will be revised to predict more realistic trends in pavement maintenance and related vehicular data.

WEIGHT CONTROL PROGRAM ENFORCEMENT AND EVALUATION

As a result of this study, 11 weight control stations and a number of automatic counting stations have been installed by MOC on major truck routes in the kingdom. The Saudi experiences with weight control programs were reported by Mufti and Al-Rashid (*13*) and are briefly summarized here. In the initial stages of enforcement, extensive efforts were made to establish contacts with major trucking agencies, seeking their cooperation for compliance with the legal load limits. Numerous difficulties were encountered in the initial stages of program enforcement. These difficulties most commonly related to the collection of penalties and to avoidance of the weighing stations by drivers. When the penalties were high, they were difficult to collect. Police assistance was invariably required either to hold the trucks and release the drivers to allow them to obtain the money, or to reduce the penalties. Instances of weighing station avoidance were also frequent even though the station sites were carefully selected to avoid such incidents. Hence, traffic spot checks were routinely made on nearby routes, and trucks clearly avoiding the weighing stations were redirected. Due to the extent of complaints received and a fear of economic consequences on the trucking industry, a 1-year grace period was given to the truckers to allow them to comply with the legal load limits.

The effectiveness of the weight control program was evaluated on the basis of changes in the degree of overloading and percentages of overloaded trucks. Typical gross load data from the Taif weighing station during the later months of the grace period and the early months of the full weight control program were analyzed. The degree of overloading before enforcement frequently exceeded 200 percent. Five months after full enforcement, it was reduced to below 20 percent. Figure 1 shows the monthly percentage of overloaded trucks

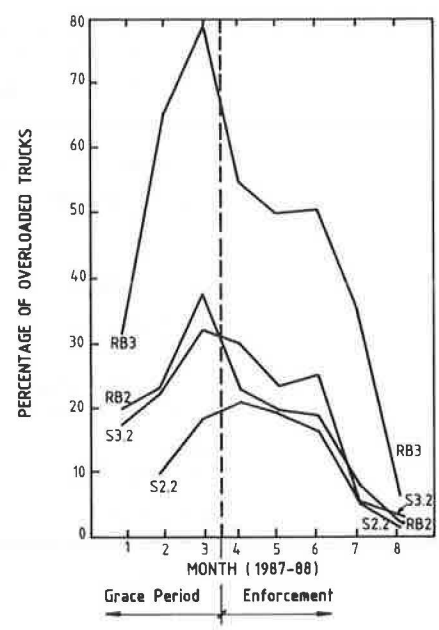

FIGURE 1 Percentage of overloaded trucks before and after enforcement.

of a given type relative to the total number of trucks of the same type passing the station during the same month. The percentages of overloaded trucks peaked at the end of the grace period and ranged from about 20 to 80 percent. These percentages declined sharply to as little as 2 to 6 percent by the end of the 5th month of the enforcement period.

SUMMARY AND CONCLUSIONS

A method of road vehicle taxation has been formulated in the Kingdom of Saudi Arabia on the basis of an economic rationale that roadway maintenance costs be equitably allocated among the vehicle classes in proportion to the damage they cause to the roads. Both major and routine maintenance costs have been considered for recovery through taxation. The input data needed for the model were generated through extensive field surveys and related to traffic volume, vehicle loads and dimensions, average daily kilometers, and pavement distress condition. The surveys were conducted at selected highways in the Eastern Province of the kingdom. Axle load and dimensional surveys revealed gross violation of the corresponding MOC limits. The proposed taxation model, which calls for higher taxes for trucks with heavier axle weights, would not only generate revenue for roadway maintenance but would also discourage use of trucks that do the most damage to the roads. As a result of this study, 11 weighing stations and a number of traffic-counting stations have been installed on major truck routes in the kingdom. Early results of the weight control program are quite encouraging. The proposed taxation structure will be revised, if necessary, as more data collected at the stations become available.

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