Preparing Data for Calibration of Mechanistic-Empirical Pavement Design Guide in Central Saudi Arabia

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***Abstract*—**Through progress in pavement design developments, a pavement design method was developed, which is titled the Mechanistic Empirical Pavement Design Guide (MEPDG). Nowadays, the evolution in roads network and highways is observed in Saudi Arabia as a result of increasing in traffic volume. Therefore, the MEPDG currently is implemented for flexible pavement design by the Saudi Ministry of Transportation. Implementation of MEPDG for local pavement design requires the calibration of distress models under the local conditions (traffic, climate, and materials). This paper aims to prepare data for calibration of MEPDG in Central Saudi Arabia. Thus, the first goal is data collection for the design of flexible pavement from the local conditions of the Riyadh region. Since, the modifying of collected data to input data is needed; the main goal of this paper is the analysis of collected data. The data analysis in this paper includes processing each: Trucks Classification, Traffic Growth Factor, Annual Average Daily Truck Traffic (AADTT), Monthly Adjustment Factors (MAFi), Vehicle Class Distribution (VCD), Truck Hourly Distribution Factors, Axle Load Distribution Factors (ALDF), Number of axle types (single, tandem, and tridem) per truck class, cloud cover percent, and road sections selected for the local calibration. Detailed descriptions of input parameters are explained in this paper, which leads to providing of an approach for successful implementation of MEPDG. Local calibration of MEPDG to the conditions of Riyadh region can be performed based on the findings in this paper.

***Keywords*—**Mechanistic-empirical pavement design guide, traffic characteristics, materials properties, climate, Riyadh.

I. Introduction

THE American Association of State Highway and Transportation Officials AASHTO (1961-1993) developed empirical design method for designing pavement structures. This empirical design method has a number of limitations because it is based on performance measurements in one climatic zone, one subgrade type, over two years of testing, and under slightly two million axle load applications [1]. Due to these limitations, the AASHTO Joint Task Force on Pavements (JTFP) updated the empirical method to the mechanistic-empirical method to develop a more accurate design guide. The NCHRP and the AASHTO developed the MEPDG and its software under NCHRP Project 1-37A. The MEPDG program has two modules (mechanistic and empirical). The mechanistic module in the MEPDG program calculates the stresses, strains, and deflection at critical locations in a pavement structure for various loads, materials, and environmental inputs. The empirical module (distress models, also known as the performance prediction models) computes predicted physically distresses such as roughness (International Roughness Index - IRI), rutting, and cracking based on the stresses and strains as well as traffic, materials and environmental inputs. Therefore, extensive and more detailed data are needed for input data in MEPDG. Quantities of data required are vast when comparing with the previous conventional design method (AASHTO 93). Furthermore, to improve the design accuracy, the MEPDG considers the input parameters which effect on the pavement performance including traffic characteristics, environmental condition, and materials properties, as well as the MEPDG approach is a flexible method which allows using local information such as traffic, climate, and materials data [2].

In Saudi Arabia (especially the capital of Riyadh), the recent economic revival has led to an increase in the traffic flow, which in turn, requires the development of a road network. Therefore, The Saudi Ministry of Transportation is currently in the process of implementing the MEPDG for the design of a flexible pavement. The distress models were calibrated using data related to several conditions from across the United States. Calibrating distress models under the local conditions is necessary in order to implement MEPDG for local pavement design. Local data collection is considered the first stage in the MEPDG implementation approach for pavement design. The collected data are used as input data in MEPDG for design procedures and the support process of local calibration together. This paper explains the executed work to obtain local data from the Riyadh region to be used as input data in the MEPDG. Almost of the collected data are needed to be processed to be suitable for input data in MEPDG, and thus, this paper also presents the procedures of collected data modifying. Like Saudi Arabia, the MEPDG has been implemented in many countries. Delgadillo et al. [3] collected local data (such as axle load distributions, weather, and material characteristics) for input data and calibration of MEPDG in Chile. The local traffic data for the design was collected, local weather was used, and material properties were obtained for implementation in MEPDG in India [4]. Zhao et al. [5] determined the axle load distribution factors and number of axles per truck for input traffic data of MEPDG in China. For Costa Rica, Loria et al. [6] presented Costa Rica's experience for the materials properties which are used

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in the MEPDG calibration. Traffic, climate, and materials local data were evaluated and prepared by Caliendo [7] to be used as input data in MEPDG for Flexible Pavement Design in Italy. Depending on the Qatar Highway Design Manual, the materials properties were selected, local traffic loading and environmental conditions were set by Sadek et al. [8] for MEPDG in Qatar.

II. Objectives

The main purpose of this paper is to present a framework to implement the MEPDG for flexible pavements of the Riyadh region and to improve the accuracy of MEPDG pavement performance predictions.

In order to accomplish the main purpose of this paper, the specific objectives are:

– Collecting local data of the flexible pavement such as traffic, environment conditions, materials properties, and pavement performance data from local sources in the Riyadh region.
– Preparing collected data to be suitable as input data for MEPDG and support process of local calibration together.

III. Collection of Local Data

The data collection represents a great part of the study since it plays a significant role in the accuracy of the calibration process. They also require high effort and time because they should be collected from various sources. The required data were collected from the Saudi Ministry of Transportation and Presidency of Meteorology and Environment in Riyadh. In order to use the input parameters that reflected local Riyadh conditions as much as possible, this paper focused on main roads in the Riyadh region which are Riyadh-Wadi Duwaiser, Riyadh-Taif, Riyadh-Qassim, and Riyadh-Dammam. These roads join the Riyadh region with other regions and have the biggest traffic volume, and therefore, they are important.

A. Traffic Data

The MEPDG requires four basic categories of traffic data for the structural pavement design.

1) Traffic volume of base year. AADTT of Vehicle Classes four through 13 is essential data in this category. This information can be derived from vehicle count data.
2) The AADTT of base year should be modified by using adjustment factors such as monthly, hourly, and vehicle class distribution factors. These factors can be calculated from data which is obtained from vehicle count data.
3) The axle load distribution factors (also called axle load spectra) can be determined only from weight stations data.
4) General traffic inputs including number of axles per truck, axle configuration, and wheelbase [9].

The Saudi Ministry of Transportation has advanced electronic devices for counts the traffic volume and classifies the vehicles which contain of Piezoelectric and Scanning Sensors. This process is performed in the permanent traffic counting stations which are located along the main road in the Riyadh region.

The General Directorate of Operation and Maintenance in the Saudi Ministry of Transportation is operating these stations and collects traffic data as a database for the pavement management system. In this paper, traffic data was obtained from the General Directorate of Operation and Maintenance in the Saudi Ministry of Transportation.

The collected data from the permanent traffic counting stations contains the Average Annual Daily Traffic (AADT), hourly distribution traffic volume, percentage of vehicle types, number of lanes, and vehicle classification.

The Average Annual Daily Traffic (AADT) in the year 2012 and percentage of trucks of each road are given in Table I. The number of lanes was three of each road. The dates of the construction of each road (traffic opening) were obtained from the Execution Department in the Saudi Ministry of Transportation as shown in Table I.

TABLE I
AADT, Percent of Trucks, and Dates of Construction

No.	Road Name	AADT (2012) (veh/d) 2 Directions	Percent trucks (%)	Date of construction
10	Riyadh-Wadi Duwaiser	20745	29	1981
40	Riyadh- Taif	30510	31	1981
65	Riyadh- Qassim	22245	22	1982
40	Riyadh- Dammam	19350	44	1981

Truck weigh stations were designed to record the weight of axles and gross weight of the moving vehicle (especially trucks). Truck weigh station provide extensive traffic data which include truck classification, the number of axles, and weight of the axles, distances between the axles, truck length, and gross weight of the truck. Truck weigh stations consist of bending plates, hydraulic load cells, and piezoceramic cables [2]. The General Directorate of Operations and Maintenance in the Saudi Ministry of Transportation operates the truck weigh stations, and takes data from these stations and documents the data to use in pavement management.

In this paper, truck weigh data were obtained from the General Directorate of Operations and Maintenance. These data include the trucks classification, truck length, number of axles, and weight of each axle, as well as the axle distances, and the gross weight of the trucks.

Al-Mansour et al. [10] conducted the tire pressure measurements of the trucks using a pressure gauge with a scale ranging from 0 to 160 psi. Reference [10] shows the distribution of tire pressure values of all trucks and indicates that the range between 120-130 psi was highest. Therefore, tire pressure of 125 psi is used.

B. Selection of Road Sections

The maintenance data of four roads: Riyadh-Wadi Duwaiser, Riyadh-Taif, Riyadh-Qassim, and Riyadh-Dammam were obtained from the General Directorate of Operations and Maintenance that contain the date of maintenance, maintenance type, and location of maintenance works. Subsequently, pavement sections are selected from these roads. The road sections are selected by considering the following criteria: (1) sections with critical distresses, (2) sections with no overlay and no rehabilitation, and (3) sections with age more than 5 years [11]. Sections with severe distress were defined as having total rutting greater than 6 mm, and IRI value greater than 2.72 m/km. According to the maintenance data, the road sections that have not been maintained are shown in Table II.

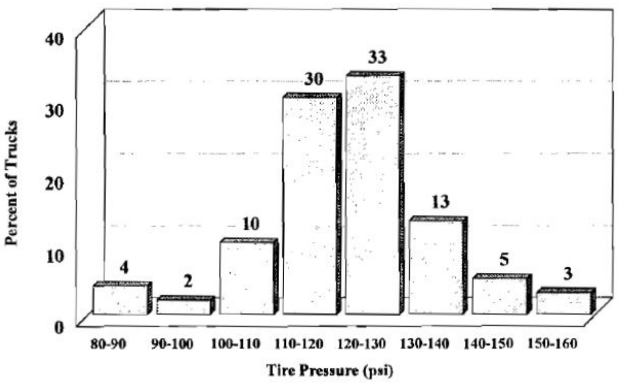

Fig. 1 Distribution of tire pressure values

TABLE II
ROAD SECTIONS THAT HAVE NOT BEEN MAINTAINED

Road Name	From	To	From	To
Riyadh- Wadi Duwaiser	400	572	777	790
	660	663	845	850
	720	730	895	995
	755	757	1010	1039
Riyadh- Taif	730	670	810	765
Riyadh- Dammam	875	840	1020	1015
	980	940		
Riyadh- Qassim	185	180	441	345
	265	225		

C. Pavement Performance

Surveys of the pavement conditions are used to evaluate the pavement performance on the highway network. Automated pavement condition surveys are conducted by using a technologically complex vehicle which has the ability to collect data related to the road's surface distresses, and IRI. The General Directorate of Operations and Maintenance in the Saudi Ministry of Transportation has a project to survey and evaluate the roads which is called the Surveying and Evaluation of the Roads Project. This project uses a complex vehicle (Hawkeye 2000) to measure the road surface distresses using laser technology and digital cameras. The vehicle (Hawkeye 2000) is equipped with a Digital Laser Profiler with 13 laser sensors which can be measured at 10 cm on the road surface, a digital camera on the front part of the vehicle to take images of all right of the road (panorama), a digital camera on the rear of vehicle to take images of the road surface, a device to measure the vehicle's height above the roadway (longitudinal profile) to calculate IRI, and a GPS device. In this paper, the performance data were obtained from the surveying and evaluation of the roads project.

D. Climate Data

Environmental conditions have a significant impact on the performance of flexible pavements because the pavement is exposed to the changes in environmental conditions during the design period. The Enhanced Integrated Climatic Model (EICM) is associated entirely with MEPDG to include the impact of the environmental conditions and seasonal change on pavement performance. The EICM is used to predict the temperature profile through the depth of the pavement with moisture content in the unbound layers. The predicted temperature in flexible pavement correlates directly with the stiffness of the asphalt concrete (AC) layer, and thus, it is important to rutting and thermal cracking. The EICM uses data from climatic files which contain hourly ambient temperature and relative humidity, precipitation, percent of cloud cover, and wind speed [12].

In the Riyadh region, there is a Meteorology and Environment Station at King Khalid International Airport which measures weather conditions. The measurement of weather condition data includes hourly temperature, humidity, wind speed, precipitation, and sky cover (clouds cover), and hence, it is documented in the connecting system with the Presidency of Meteorology and Environment in Jeddah. In this paper, the climate data in the Riyadh region for a period of 25 months (September 1st, 2009 until September 14th, 2011) were obtained from the Presidency of Meteorology and Environment. Groundwater level depths underground vary in the different boreholes in the Riyadh region. In the upper basins, the water level ranges between 40 m and 45 m. From the lower basins, the water level ranges from 30 m to 35 m [13]. Thus, a groundwater depth of 40 m is used for the Riyadh region.

E. Pavement Structure

In the Saudi Ministry of Transportation there was one standard for the structure of flexible pavement of a main road. The typical cross section for the main sections of flexible pavement containing asphalt wearing course with a thickness of 5 cm, asphalt base course with thickness of 20 cm, and a granular base course with a thickness of 12 cm over subgrade [14].

F. Materials Properties

The materials properties were obtained from the Materials and Research Department in the Saudi Ministry of Transportation. This department produced the Saudi Highway Materials Manual which contain the specifications of materials for each layer of a pavement, and will be discussed in accordance with each layer.

1. Asphalt Wearing and Base Course

Based on the Saudi Highway Materials Manual, penetration grade of asphalt binder is 60/70 pen, the percent retained of the sieve analysis for HMA aggregate is given in Table III, and mixture volumetric data are given in Table IV [14].

Reference [15] shows a Poisson's Ratio of 0.35 is used in Riyadh. Typical values of Thermal Conductivity (K) for

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asphalt concrete range from 0.44 to 0.81 btu/hr-ft-˚F. A default value of 0.67 btu/hr-ft-˚F is assumed for all of the sections. Typical values of Heat Capacity (Q) for asphalt concrete range from 0.22 to 0.40 btu/lb-˚F. A default value of 0.22 btu/ lb-˚F is assumed for all of the sections.

TABLE III
HMA AGGREGATE GRADATION

Sieve No.	Asphalt Wearing course	Asphalt Base course
Cumulative % retained 19 mm (3/4") sieve	**0**	**27**
Cumulative % retained 9.5 mm (3/8") sieve	**24**	**47**
Cumulative % retained 4.75 mm (#4) sieve	**48**	**61**
% passing (#200) sieve	**5**	**5**

TABLE IV
MIXTURE VOLUMETRIC DATA

Material Property	Asphalt Wearing course	Asphalt Base course
Voids in the mineral aggregate -VMA (%)	11.85	11.8
Air voids - Va (%)	4.15	3.97
Effective asphalt content (%)	7.7	7.83
Bulk specific gravity - Gmb	2.41	2.36
Total unit weight (density) mix (pcf)	150.46	147.34

2. Granular Base

According to the Saudi Highway Materials Manual, the soil classification of the granular base is "A-1-a" based on the AASHTO Soil Classification System. The value of modulus is 48,700 psi. The Plastic Index is six as a maximum.

3. Subgrade

Al-Suhaibani et al. [16] investigated subgrade soil of all roads in Saudi Arabia. They found properties of subgrade soil in the Riyadh region: soil classification is "A-2-4" based on the AASHTO Soil Classification System. The value of modulus is 14,200 psi [16].

IV. DATA ANALYSIS

The collected data need to be developed to be suitable as input data for MEPDG. The development of the input data parameters is described in the next paragraphs.

A. Traffic Characteristics

1. Vehicle Classification

The MEPDG uses as default the Federal Highway Administration (FHWA) standard classification scheme that classifies vehicles into 13 different classes. Based on this classification, vehicle class 1 is motorcycles, vehicle class 2 is passenger cars, vehicle class 3 is pickup trucks, vehicle class 4 is buses, and vehicle classes 5 through 13 are trucks [17]. The Saudi vehicle classification standard in traffic counting stations classifies vehicles into 15 classes. According to this classification, class 1 is passenger cars and pickups, classes 2 through 14 are trucks, and class 15 is unclassified vehicles.

The Saudi trucks classification is unlike the default truck classification in MEPDG. Therefore, the adaption of Saudi truck classification to the MEPDG default is needed. The differences between the Saudi trucks classification and the MEPDG default classification were minimized based on truck type, the number of axles, and axle distances (single axle, tandem axle, tridem axle). Subsequently, Saudi trucks classification was converted as MEPDG default.

Also, the Saudi truck classification in truck weigh stations was converted to the default truck classification in MEPDG, as it is different from both the Saudi trucks classification in traffic counting stations and the MEPDG default classification. Table V shows the Saudi trucks classification converting to the MEPDG default.

TABLE V
CONVERTING OF SAUDI TRUCKS TO FHWA TRUCKS CLASSIFICATION

MEPDG trucks classification	Saudi trucks classification	Saudi trucks weight stations classification	No. Axles
4	2	--	3
5	3	1	2
6	5	2	3
7	6+10	9+10	4
8	4+7	3+4+6	3+4
9	9	7	5
10	11+12+14	8	6
11	8	5	5 (Trail+3)
12	–	–	6 (Trail+4)
13	13	99	7 (Trail+5)

The last Saudi vehicles classification is unclassified vehicles, where the traffic count device failed to identify the vehicle types based on the integrated criteria. They include only the number of vehicles without any other measurements such as axle number and axle distances. The possible reason for this is that it includes irregular trucks. Unclassified vehicles should not be neglected as they affect the pavement design, and therefore, their volumes were added to the total truck volumes [18].

TABLE VI
TRAFFIC GROWTH FACTOR

Year	AADT	Growth Factor
2011	82847	
2012	92850	1.121
2013	96983	1.045
2014	99681	1.028
2015	104298	1.046
	AVR.	1.060

2. Traffic Growth Factors

The annual average daily traffic (AADT) for the period 2011 to 2015 were obtained from the permanent traffic counting stations and average growth factors were developed as shown in Table VI.

3. Annual Average Daily Truck Traffic

It is the average volume of truck traffic (heavy vehicles classes 4 to 13 in the traffic stream) passing a point or segment of a road in both directions over a period of 24-hours. The MEPDG allows for traffic input to be either entered directly as Average Annual Daily Truck Traffic (AADTT) or can be calculated using the AADTT calculator, where the Average

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Annual Daily Traffic (AADT) and percent of trucks are multiplied [19].

The Average Annual Daily Traffic (AADT) in the year 2012 for each road was obtained from the General Directorate of Operations and Maintenance in the Saudi Ministry of Transportation. Thereafter, it was converted to the AADT of the base year by using (1), as shown in Table VII.

$$AADTT_{BY} = AADTT_X \div (GR)^n \quad (1)$$

where $AADTT_{BY}$ *is* annual average daily truck traffic at age X, $AADTT_X$ is base year annual average daily truck traffic, *n* is the number of years from the base year (date of construction) to the year 2011, and *GR* is the traffic growth rate of 1.06.

TABLE VII
CONVERSION OF AADT 2012 TO THE AADT OF BASE YEAR

No.	Road Name	AADT (2012) (veh/d)	Date of const.	AADT of base year (veh/d)	Trucks (%)	AADTT (veh/d)
10	Riyadh-Wadi Duwaiser	20745	1981	3407	29	988
40	Riyadh-Taif	30510	1981	5011	31	1553
65	Riyadh-Qassim	22245	1982	3873	22	852
40	Riyadh-Dammam	19350	1981	3178	44	1398

4. Percent of Trucks in Design Direction

The percent of trucks is commonly assumed to be 50 percent when the AADT and AADTT are given in two directions as it is used [9].

5. Percent of Trucks in the Design Lane (LDF)

The design lane is typically the outside lane of a multilane highway. The default values recommended for use are [9]:

- Single-lane roadways in one direction, LDF = 1.00
- Two-lane roadways in one direction, LDF = 0.90
- Three-lane roadways in one direction, LDF = 0.60
- Four-lane roadways in one direction, LDF = 0.45

The chosen roads in Riyadh region have three lanes in each direction, so the lane distribution factor (LDF) is 0.60.

6. Vehicle Operational Speed

Reference [20] shows the classification of operational speed on highway type. So, the vehicle operational speed of 100 km/hr (60 mph) is selected for the Riyadh region.

7. Monthly Adjustment Factors

It is defined as the monthly variation in truck traffic throughout the entire year. Equation (2) was used to calculate these factors for Riyadh region which can be shown in Fig. 2.

$$MAF_i = \frac{AMDTT_i}{\sum_{i=1}^{12} AMDTT_i} \times 12 \quad (2)$$

where *MAFi* is monthly adjustment factors for month*i*, and *AMDTTi* is average monthly daily truck traffic for month*i*.

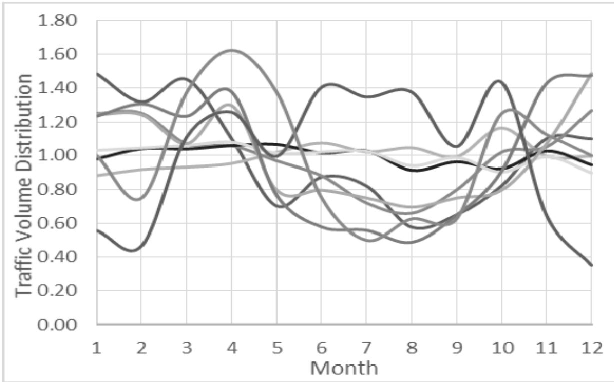

Fig. 2 Monthly Adjustment Factors Variation

Fig. 2 shows that the fewer trucks travel during periods of poor driving conditions in the summer season due to high temperatures, and most trucks travel during good driving conditions.

8. Vehicle Class Distribution

Vehicle class distribution factors represent the percent of each truck class type within the AADTT. The vehicle class distribution for the Riyadh region was calculated by (3).

$$VCD_i = \frac{AADTT_i}{AADTT} \times 100 \quad (3)$$

where VCD_i is the vehicle class distribution factor for vehicle class*i*, $AADTT_i$ is the annual average daily truck traffic for class*i*, and $AADTT$ is annual average daily truck traffic for all classes.

Practically, when the calculation has been completed for all the vehicles classes, the sum of all the vehicle class distributions should be equal 100% [21]. If this is not achieved, there may be an error in data collection or analysis.

Fig. 3 depicts the vehicle class distribution which is selected for use in the MEPDG in the Riyadh region.

As can be seen, vehicle class 5, 7, and 8 were noted to be the most common in the Riyadh region highway system.

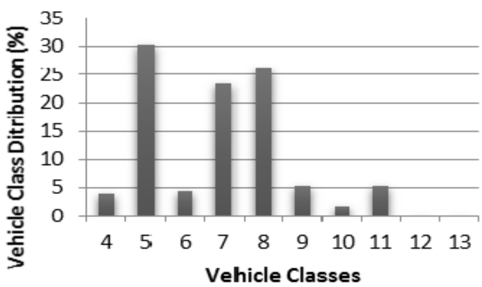

Fig. 3 Riyadh Region Vehicle Class Distribution

9. Truck Hourly Distribution Factors

Equation (4) was used to compute the hourly distribution factors for Riyadh region.

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$$HDF_i = \frac{AAHT_i}{\sum_{i=1}^{24} AAHT_i} \times 100 \quad (4)$$

where *HDFi* is hourly distribution factor for *i*th one-hour time period, and *AAHTi* is annual average hourly traffic for *i*th one-hour time period.

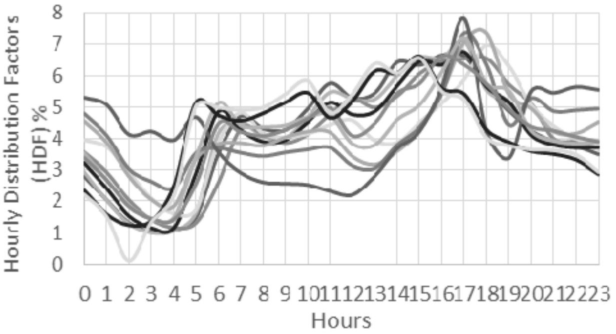

Fig. 4 The Variations of the Hourly Distribution Factors

The *HDFi* are input into the MEPDG as a percent. Therefore, the summation of the 24-hourly distribution factors must be equal to 100.

Fig. 4 shows the variations of the hourly distribution factors at the site and indicates the highest value of these factors at the hour of 17 for most months.

10. Axle Load Distribution Factors

The axle load distribution factors (axle load spectra) represent the percent of the axles that are sorted with each load increments for each axle type (single, tandem, tridem, and quad) and vehicle class (classes 4 through 13).

The load ranges and intervals for each axle type are:

- Single axles – 1361 kg to 18597 kg at 454 kg intervals.
- Tandem axles – 2722 kg to 37195 kg at 907 kg intervals.
- Tridem and quad axles – 5443 kg to 46266 kg at 1360 kg.

Equation (5) was used to calculate the axle load distribution for the Riyadh region.

$$ALDF_{ijk} = \frac{\text{No. of axles}_{ijk}}{\text{Total No. of axles}_{ij}} \times 100 \quad (5)$$

where *ALDF* is axle load distribution factor, *i* represents the vehicle class (4 through 13), *j* the month (1 through 12) and *k* the load range (1361 kg to 18597 kg at 454 kg intervals for single axles). This is done for each axle type (single, tandem, tridem, and quad). These procedures were performed for each month (January to December), each class of trucks (4 - 13), and each type of axles (single, tandem and tridem). Fig. 5 shows the examples of the axle load distributions calculated for the month of January. In these procures, the vehicles with quad axles were not found within the obtained data from trucks weight stations, so the quad axle load distribution factors were set equal to zero. In addition, the buses (trucks class 4) were not measured in these stations, and therefore, the default axle load distribution factors are used for this class. Furthermore, the truck class 12 does not exist in the Saudi trucks classification, thus the axle load distribution factors of this class were set to zero.

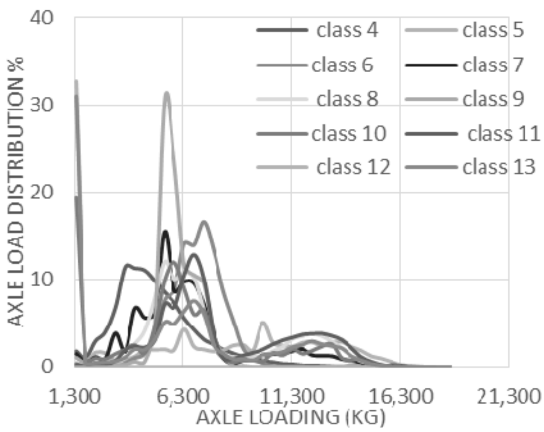

Fig. 5 Single Axle Load Distributions for January month

11. General Traffic Inputs

- Mean Wheel Location: This is the distance from the outer edge of the wheel to the lane longitudinal pavement marking. The MEPDG default value of 460 mm is used for the Riyadh region inputs.
- Design Lane Width: The design lane width is the actual traffic lane width defined by the distance between the pavement markings on both sides of the design lane. In the Riyadh region, the design lane width is 3.65 m.
- Number of Axle Types per Truck Class: The number of axle types per truck class is the average number of individual axles for each truck class for axle type (single, tandem, tridem, and quad). This number was calculated by dividing the sum of each axle type for each truck class by sum of the trucks in that class. This procedure was performed for single, tandem, and tridem axles for each truck class (5-13) and each month (January to December) as can be seen in Table VIII. The number of axles for class 4 was not measured, so the default value of MEPDG is used.

TABLE VIII
THE NUMBER OF AXLE TYPES PER TRUCK CLASS FOR RIYADH REGION

Truck Class	Number of Single Axles per Truck	Number of Tandem Axles per Truck	Number of Tridem Axles per Truck	Number of Quad Axles per Truck
4	1.62	0.39	0.00	0.00
5	2.00	0.00	0.00	0.00
6	1.00	1.00	0.00	0.00
7	1.76	0.27	0.56	0.00
8	2.00	0.98	0.00	0.00
9	1.20	1.19	0.03	0.00
10	2.25	0.50	0.77	0.00
11	2.01	0.17	0.99	0.00
12	0.00	0.00	0.00	0.00
13	3.99	0.58	0.53	0.00

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– Axle Configuration: This input includes several variables:

- ❖ Average axle width (m): It is the distance between two outside edges of an axle. MEPDG default value of 2.60 m is used as the average axle width.
- ❖ Dual tire spacing (mm): It is the distance between the centers of a dual tire. MEPDG default value of 305 mm is used in the pavement sections.
- ❖ Tandem axle spacing (mm): It is the center-to-center longitudinal spacing between two consecutive axles in a Tandem configuration. The local value of 2.5 m is used in the Riyadh region inputs.
- ❖ Tridem axle spacing (mm): It is the center-to-center longitudinal spacing between two consecutive axles in a tridem configuration. The local value of 2.5 m is used in the Riyadh region inputs.

These variables are important in describing the loads applied to the pavement because pavement structure is sensitive to the distance between wheels and axles within a truck.

– Wheelbase: The wheelbase refers to the distance between the steering axle and the first axle of the truck. It has been characterized as short, medium, and long axle spacing.

The average spacing of short axles (m): This defines the average longitudinal spacing of short axles. MEPDG default value of 3.66 m is used.

The average spacing of medium axles (m): This defines the average longitudinal spacing of short axles. MEPDG default value of 4.6 m is used.

The average spacing of long axles (m): This defines the average longitudinal spacing of short axles. MEPDG default value of 5.49 m is used.

The details of the wheelbase of the truck are needed for use in computing pavement responses.

Typically, short trucks are Class 5, medium single unit trucks are Class 6 and Class 7, and long trucks are Classes 8 to 13. The Percent of trucks for wheelbase as can be seen in Table IX.

TABLE IX
PERCENT OF TRUCKS FOR WHEELBASE

Type	Percent of trucks
Short	32.75 %
Medium	35.74 %
Long	31.51 %

B. Climate Information

The data for hourly temperature, wind speed, precipitation and relative humidity can be directly used from the obtained data. The data for cloud cover needs to be transposed. The MEPDG climate input requires a percent of cloud cover, but the Presidency of Meteorology and Environment in Riyadh uses the okta unit to define cloud cover. An okta is a measurement unit which is used to represent the quantity of cloud cover. In this scale, the sky is divided into eights parts and the cloud cover are estimated in term of how many oktas (eights) the cloud cover the sky, ranging from 0 (completely clear sky) through to 8 oktas (completely overcast), as shown in Fig. 6 [22].

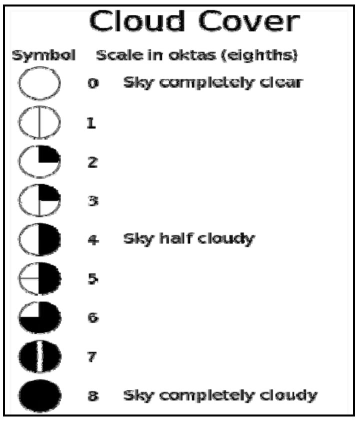

Fig. 6 Scale of cloud cover measured in Oktas (eighths)

In this paper, the one okta was considered 12.5% to convert okta unit into percentage to define cloud cover. This means, 1 okta is 12.5%, 2 okta are 25%, 3 okta are 37.5%, 4 okta are 50%, 5 okta are 62.5%, 6 okta are 75%, 7 okta are 87.5%, and 8 okta are 100%. A simple excel sheet was designed for Riyadh climate data and it was converted to a text-file with an extension ".hcd" as required in the MEPDG.

V. CONCLUSIONS

The conclusions from this paper are:

1) The Saudi trucks classification is unlike the default truck classification in MEPDG, and therefore, the Saudi truck classification was modified to the MEPDG default based on the number of axles and axle spacing.
2) Truck class 12 in MEPDG default was not used because it does not exist in the Saudi truck classification.
3) Unclassified vehicles should not be neglected as they effect the pavement design, and so, he unclassified vehicle volumes were added to the total truck volumes.
4) The monthly adjustment factors indicate that the truck traffic increases in the winter season and conversely in the summer season, this means that fewer trucks travel during periods of poor driving conditions of the summer season due to the high temperature, and most of them travel during good driving condition.
5) Vehicle class distribution indicates that the vehicle classifications 5, 7, and 8 are the most common in the Riyadh region highway system.
6) Truck Hourly Distribution denotes that most trucks travel at 5:00 pm for most months.
7) Through the processing of axle load distribution factors (axle load spectra), the trucks with quad axles were not found within the obtained data from truck weight stations, so the quad axle load distribution factors are set equal to zero.
8) The buses (trucks class 4) were not measured in the truck weigh stations and therefore, the default axle load distribution factors are used for this class.

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