INTERACTIVE APPLICATION FOR THE EVALUATION OF THE PEAK HOUR FACTOR USING WEIGH-IN-MOTION TRAFFIC DATA

Nicolae CIONT[1], Rodica Dorina CADAR[2], Mihai ILIESCU[3], Diana Angela LASLĂU[4]

This paper presents an interactive electronic application designed to study the Peak Hour Factor (PHF). The application processes the traffic data collected by a weigh-in-motion system in the city of Cluj Napoca, Romania. PHF evaluation was carried out considering five and 15-minute intervals for the rate of flow. The application identifies both peak hours and peak five and 15-minute sub-hourly intervals. Calculus was done for morning, noon and evening times of day, for both working days and weekends. The results show significant differences between different rate of flow approaches.

Keywords: peak hour factor, weigh-in-motion, database, electronic application

1. Introduction

Traffic stream parameters represent a quantitative measure used by engineers to better understand and describe traffic flow [1]. Volume and rate of flow are macroscopic traffic stream parameters, used to describe the traffic stream as a whole [2]. The relations between these two parameters are among the most important in transportation engineering [3]. For a carriageway section, traffic volume is the total number of vehicles passing it during a specified time interval, whereas flow rate represents an equivalent hourly volume at which vehicles travel during a sub-hourly time interval [3]. Rates of flow are variable during an hour and they are usually evaluated for one, five or 15-minute intervals.

The peak hour factor (*PHF*) is defined by eq.(1), as the ratio of the total hourly traffic volume (*V*) to the maximum rate of flow within that hour (*v*) [3]:

$$PHF = \frac{V}{v} = \frac{V}{4 \cdot V_{15}} \tag{1}$$

[1] PhD student, C.F.D.P. Dept., Technical University of Cluj Napoca, Romania, e-mail: nicolaeciont@yahoo.com

[2] Lect., C.F.D.P. Dept., Technical University of Cluj Napoca, Romania, e-mail: rodica.dorina@cfdp.utcluj.ro

[3] Prof., C.F.D.P. Dept., Technical University of Cluj Napoca, Romania, e-mail: mihai.iliescu@cfdp.utcluj.ro

[4] Engineer, e-mail: diana_laslau@yahoo.com

Standard design and analysis practices [2][3][4] calculate *v* based on the volume during the peak 15-minute interval within the analysis hour, V_{15} (eq.(1)). However, the use of five-minute flow rates has recently increased [2]. The dynamic relationship between volume and rate of flow is analysed through the Peak Flow Factor (PFF) [5]. The peak hour volume is a critical input in road design and other operational analysis [1]. PHF is mainly used to evaluate traffic conditions on a certain road sector, through the concepts of capacity and Level of Service (LOS) [6]. It can also be used to quantify the effects of short time traffic peaking, leading to congestion [7], and also to study traffic safety. Milton & Mannering [8] used PHF and other traffic data to show that a negative binomial regression is a useful predictive tool for accident-analysis research.

In Romania, the 50th busiest hour of the year is considered the relevant hourly volume (Q_C) [4]. In other countries, such as Germany, Q_C is defined as the 30th busiest hour of the year [9]. Establishing Q_C and PHF can be done using a continuous traffic monitoring system, such as weigh-in-motion (WIM). When this is not available, Q_C is estimated based on PHF [4].

WIM is a fast, useful and unobtrusive traffic engineering tool [10], used to continuously measure different traffic parameters without stopping vehicles. However, it is an intrusive traffic monitoring technology, because it requires to be practically installed in the pavement itself [11]. This type of monitoring system is used worldwide for applications such as: pavement design and research, traffic engineering and weight enforcement [12]. Traffic monitoring systems are extensively used to collect data in highly developed countries (e.g. U.S.A., Germany, France etc.), as well as in developing ones, such as India, Vietnam or the U.A.E. [13]. In Romania, loop detectors are installed on the national roads network, but their use is rather limited to vehicle counts. The use of WIM systems would lead to: sustainable traffic planning, lighter vehicle loads, increased traffic safety and efficiency. In Chile for example, WIM has successfully been used for over 30 years to sustain the government's strict policy towards weight enforcement [13]. In the UK, the Vehicle and Operator Services Agency uses WIM systems to identify overweight vehicles [14], and examples could go on.

Where PHF cannot be calculated using measured traffic data, standard approximate values can be used. HCM 2000 [15] and HCM 2010 [3] recommend PHF values of 0.92 and 0.88 for urban and rural areas, respectively. Values higher than 0.95 are encountered in congested areas [3]. For motorways, AND [4] suggests a PHF value of 0.94, as well as Zegeer et al. do [16]. In the case of four-lane roads passing suburban areas, PHF should be 0.95 [4]. HPMS [17] proposes a range of values applicable to motorways in urban and rural areas. Research on PHF sampling and modelling has been conducted since the late 1980s [18]. A series of studies [7][19][20] established mathematical equations to estimate PHF based on traffic volume, population or volume-to-capacity ratios. Most PHF models show that an increase in traffic volume leads to higher PHFs [6].

The main purpose of this paper is to present the PHF function of an electronic application. This application processes the daily traffic data collected by a WIM system and automatically evaluates the daily peak hours and PHFs, using peak five and 15-minute flow rate periods. The average PHF values obtained are compared to the ones provided by standards [3][4]. This ITS-based application is quite new in Romania and represents a basis for traffic engineering studies. Worldwide, similar programs are associated with WIM systems. The Maryland Department of Transportation uses such an application to evaluate different traffic factors using data collected from 79 traffic counting systems [21].

2. Data collecting system

For this study, the traffic data continuously collected by a WIM system was used. This device is installed on the European E60 road (DN1 National Road), at the Western edge of the city of Cluj Napoca, Romania. The studied road sector consists of a single carriageway with 4 (four) traffic lanes. The used WIM system has a piezo-loop-piezo configuration. The system has been functional since late April, 2013. Downloading the stored traffic data on a PC may be done either on site or through a modem and telephone line. The system's electronic application converts the information into Microsoft Access (MS Access) format.

3. Designed electronic application

The main purpose of the designed electronic application is to provide a useful tool for the processing, analysis and reporting of the collected WIM traffic data. The input files are analysed and processed using the MS Access 2010 database management system. The system is based on the Visual Basic for Applications (VBA) programming language. One of the application's main functions is centred on evaluating the PHF, based on WIM data. As the studied road sector has an East-West layout, the function provides the peak hours and their corresponding volumes, per both directions separately, as well as altogether. The basic application flowchart begins with collecting the WIM traffic data and converting it to the MS Access file format (Fig. 1).

The size of the MS Access input files is considerable (about 22 MB per daily file). Therefore, the file reading process has been optimised through the use of a selective database browsing, according to the user's choice of function to run at a given moment (Fig. 1). Otherwise, time consumption and memory usage would be unnecessary high.

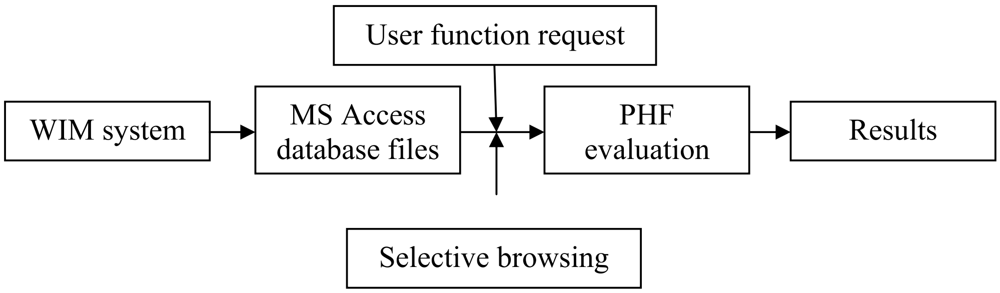

Fig. 1. Application flowchart

It is not always certain the peak 15-minute interval within the analysis hour is one of the four main quarters of an hour. It could be any sub-hourly interval of 15 consecutive minutes. This aspect is not specifically mentioned in the HCM [3] or AASHTO [22] indications, although they recommend using the worst 15 minutes of the considered design or peak hour. The application identifies the peak interval and then evaluates the PHF, for the established daily peak hours, in 3 (three) different ways (Table 1).

Table 1

PHF evaluation intervals

No.	PHF mode	Shortcut	Characteristics
1	5-minute intervals	p5	the application identifies the peak 5-minute interval during the analysis hour, out of the twelve main 5-minute intervals (00-05, 05-10, 10-15 etc.);
2	peak 15-minute intervals	p15	the application identifies the peak 15-minute interval during the analysis hour, out of the following 15-minute intervals: 00-15, 05-20, 10-25, 15-30, 20-35, 25-40, 30-45, 35-50, 40-55, 45-60;
3	main 15-minute intervals	m15	the application identifies the peak 15-minute interval during the analysis hour, out of the four main 15-minute intervals: 00-15, 15-30, 30-45, 45-60.

A print screen of the application (Fig. 2) shows the main steps in PHF evaluation: WIM data loading, identifying the peak hours, computing the PHFs and displaying the results.

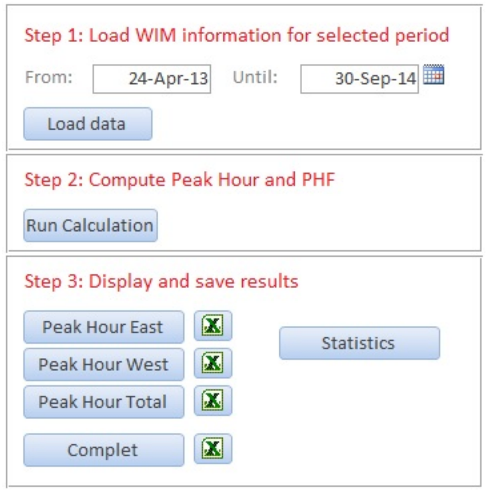

Fig. 2. Application print screen

4. Data processing and results

In this paper, the WIM traffic data collected between April 24, 2013 and September 30, 2014 was used. The study was divided into two parts: working days (Monday-Friday) and weekends (Saturday-Sunday), because traffic stream characteristics are different during these types of days. Using the designed electronic application, the average hourly traffic volumes for the studied period was obtained, per direction and per type of day (Fig. 3). The studied road sector is intensely used by commuters [23], whose main travel directions are Eastbound in the morning and Westbound in the afternoon.

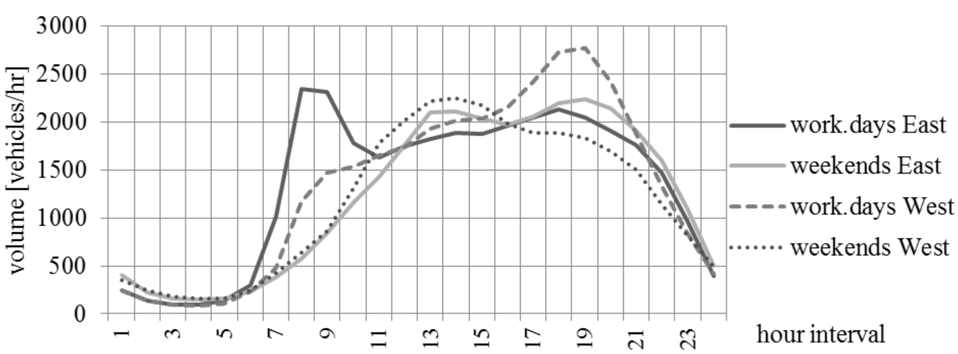

Fig. 3. Average hourly volumes, 24/04/2013 – 30/09/2014

To evaluate the PHF in a useful and suggestive manner, the 24 hours of a day were divided into five intervals: 0:00:00 – 4:59:59 (night), 5:00:00 – 9:59:59

(morning), 10:00:00 – 14:59:59 (noon), 15:00:00 – 19:59:59 (evening), 20:00:00 – 23:59:59 (late evening). For this study, only the morning, noon and evening intervals were considered relevant. Using the specific functions of the electronic application, the MS Access database files were used to evaluate the PHF and other traffic and statistical parameters (Table 2):

Table 2

Evaluated traffic parameters

No.	Hour intervals	Filter	Evaluated parameters
1	5:00:00–9:59:59 10:00:00–14:59:59 15:00:00–19:59:59	East West Total	daily PHFs, using the three PHF calculation modes: p5, p15 and m15 (Table 1);
2			mean, median and mode for the obtained PHF set of values, for the selected time period;
3			most often encountered morning, noon and evening peak hours, and their percentile occurrence;
4			for the peak hours mentioned in row no.3, the most often encountered peak 5-minute intervals, peak 15-minute intervals and main 15-minute intervals (Table 1), and their percentile occurrence.

Table 3

Results – average PHFs (mean values)

Days	Hour interval	Direction								
		East			West			Total		
work days	5-10	0.861	0.921	0.938	0.841	0.914	0.921	0.870	0.917	0.926
	10-15	0.863	0.928	0.944	0.873	0.934	0.949	0.902	0.949	0.962
	15-20	0.868	0.929	0.948	0.888	0.937	0.949	0.909	0.950	0.961
	ave.	0.864	0.926	0.944	0.867	0.928	0.940	0.894	0.939	0.950
week ends	5-10	0.791	0.858	0.873	0.749	0.813	0.818	0.795	0.842	0.847
	10-15	0.868	0.930	0.943	0.875	0.932	0.946	0.901	0.946	0.956
	15-20	0.867	0.925	0.937	0.866	0.924	0.938	0.900	0.943	0.954
	ave.	0.842	0.904	0.918	0.830	0.890	0.901	0.865	0.910	0.919
PHF mode (Table 1)		p5	p15	m15	p5	p15	m15	p5	p15	m15

Table 4

Most often encountered peak hours

Days	Hour interval	Direction					
		East		West		Total	
		peak hr.	occurrence [%]	peak hr.	occurrence [%]	peak hr.	occurrence [%]
work days	5-10	7-8	67	9-10	74	8-9	96
	10-15	13-14	53	14-15	73	14-15	61
	15-20	17-18	76	18-19	75	17-18	61
week ends	5-10	9-10	46	9-10	46	9-10	46
	10-15	12-13	22	13-14	22	12-13	22
	15-20	18-19	16	15-16	28	15-16	13

For the studied period (24/04/2013 – 30/09/2014), daily PHF values were obtained, separately for the morning, noon and evening intervals, per direction. They were divided into working days and weekend PHFs. The average values (Table 3) for the daily set of factors were obtained. Based on WIM data, the electronic application also identifies the most often encountered peak hours, as well as their percentile occurrence (Table 4). Similarly, the application looks for the frequently encountered peak sub-hourly intervals and their occurrence.

5. Conclusions

An electronic application which uses WIM traffic data to evaluate PHF-related traffic parameters was designed. Among other functions, the application identifies the peak five and 15-minute intervals during the studied hours and offers a clear image of the traffic stream characteristics on the studied road sector.

The results show that the highest PHF values are obtained using the main 15-minute flow rate intervals (Table 1), and they are between 1 and 2% higher than the ones obtained using peak 15-minute intervals. However, for working days, the peak 15-minute interval does not coincide with the main 15-minute interval in 78% of cases. For weekends, this ratio is reduced to 22%. Average PHFs obtained using the peak 5-minute periods are 6 to 8% lower than the maximum ones, thus corresponding to a rural area [3][4][15], which is inaccurate in this case. Weekend PHFs are 3% lower than the working day ones.

For the studied type of road (four-lane road in suburban area), the maximum average PHF for working days is 0.950. This coincides with the standard value in Romania [4]. However, it is often exceeded at noon and during the evening, indicating the area is slightly congested, according to HCM [3][15].

The central tendency of a series of indicators that describe the middle values of a frequency distribution was measured. The results for the PHF mean (Table 3), median and mode show both unimodal and multimodal frequency distributions. PHF values are asymmetrical to the left (negative skewness).

The application can be used to provide traffic reports based on WIM data processing and analysis. It can also be used to evaluate traffic conditions on a road, its capacity, its LOS and to quantify the effects of short time traffic peaking.

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