



DIRECTIONAL DISTRIBUTION ON TWO-LANE RURAL HIGHWAYS - SOME ANALYSIS AND RECOMMENDATIONS

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Abstract

Capacity analysis is one of the most important steps in designing new or improving existing two-lane rural highways. Essential input is directional design hourly volume (DDHV). DDHV requires precisely determined K (proportion of AADT occurring in the peak hour) and D (proportion of peak-hour traffic in the peak direction) factor. The K factor is much better explained in the literature than the D factor. Directional distribution can change annually, hourly, daily, and seasonally. Development in the vicinity of highway facilities often changes the directional distribution. Therefore, this paper presents the results of certain analyses of the D factor values on different road segments in different prevailing conditions, as well as the D factor values over time at the same location. The data were taken from counting stations where permanent traffic counting is carried out (8,760 hours). The aim of the paper is to point out the importance of directional distribution, which is often neglected, even in traffic counting publications.

Key words: directional distribution, analysis, recommendation

1 Introduction

In road network transport planning models, the basic unit of traffic volume is the Average Annual Daily Traffic (AADT), expressed in vehicles per day (veh/day). In capacity analyses of functional elements within the road network, the fundamental unit is the hourly volume (veh/h). Every country conduct traffic counting and publishes annual reports of the results. This article focuses on presenting the results of continuous automatic traffic counting on two-lane rural roads, which are presented similarly across most publications. In this part of Europe, the following data are typically displayed graphically [1, 2]:

- traffic distribution by days of the year
- hourly distribution throughout the year, showing hourly traffic as a percentage of AADT
- average hourly traffic during the day (0–24h)
- average hourly traffic by days of the week
- distribution of the 200 peak hours, showing hourly traffic by rank
- distribution of the 200 peak hours by time of day
- distribution of the 200 peak hours by days of the week
- distribution of the 200 peak hours by months of the year.

From the above, it is evident that there is no information regarding directional distribution, despite the fact that all type of counters operates in a way that measurements are performed separately for each direction. As stated in the Highway Capacity Manual (HCM), directional distribution is a critical parameter in highway capacity analysis, especially for two-lane rural highways.

Capacity and Level of Service (LOS) vary significantly with directional distribution due to the interactive nature of opposing flows on such facilities – the flow in one direction directly affects overtaking opportunities in the other. Therefore, procedures for the analysis of two-way highways include explicit consideration of directional distribution [3, 4]. For this reason, through specific analyses of data obtained from continuous traffic counting sites, this article aims to highlight the necessity of including directional distribution data. Furthermore, it proposes potential methods for its presentation, as this issue remains insufficiently explained in both literature and professional practice.

2 Directional distribution

All modern methodologies for capacity analysis of two-lane rural highways require a separate analysis for each direction of travel. The first step in such an analysis is determining the design-hour volume for both the analyzed and the opposing direction:

$$DDHV = AADT \cdot K \cdot D \quad (1)$$

where is:

DDHV – directional design-hour volume [veh/h]

AADT – annual average daily traffic [veh/day]

K – proportion of AADT occurring in the peak hour [decimal]

D – proportion of peak-hour traffic in the peak direction [decimal].

The D-factor represents the proportion of traffic moving in the peak direction of travel on a given roadway during peak hours. A common problem in practical application is that AADT is defined for both directions combined, while there is often insufficient data to accurately determine the D-factor. Most capacity analysis methodologies assume this as an input parameter, i.e. a result of traffic counting. Generally, for the rural road network, it is determined based on multi-year data from continuous count sites or short-term count sites. The importance of directional distribution and the extent of its impact on two-lane roads can be demonstrated through a simple example. The HCM provides a table titled “Generalized Daily Service Volumes for Two-Lane Highways” (Exhibit 15-30, HCM 2010), which is used in planning analysis. Table 1 shows values only for D-factors of 50% and 65% to highlight the impact of directional distribution. Furthermore, values for LOS B and LOS E are omitted due to the well-known fact that two-lane roads require improvements long before reaching full capacity. At Level of Service D, overtaking is practically impossible due to the increased opposing flow.

Looking at the differences in daily service volumes for Class I roads in rolling terrain, it is evident that a D-factor of 65% reduces the daily service volume by approximately 40% for both Levels of Service (LOS). It is also interesting to note that the D-factor remains constant for different K-factor values. Regarding this part of Europe, current regulations and guidelines do not specify a method for determining directional distribution [6-8]. Only the Serbian regulation [9] provides indicative values based on the character of dominant traffic flows (table 2), stating that it should be determined based on research results from network studies or individual projects.

Table 1 Daily service volume for two-lane highways (modified Exhibit 15-30, from [5])

K factor	D factor	Class I: Level terrain				Class I: Rolling terrain				Class I: Rolling terrain			
		LOS C		Ratio 50/65%		LOS D		Ratio 50/65%		LOS C		Ratio 50/65%	
		LOS C	Ratio 50/65%	LOS D	Ratio 50/65%	LOS C	Ratio 50/65%	LOS D	Ratio 50/65%	LOS C	Ratio 50/65%	LOS D	Ratio 50/65%
9%	50%	9.3	1.18	16.5	1.28	8.4	1.42	15.7	1.38	9.8	1.66	18.2	1.38
	65%	7.9		12.9		5.9		11.4		5.9		13.2	
10%	50%	8.4	1.18	14.8	1.28	7.6	1.43	14.2	1.38	8.8	1.66	16.3	1.37
	65%	7.1		11.6		5.3		10.3		5.3		11.9	
12%	50%	7	1.19	12.4	1.29	6.3	1.43	11.8	1.39	7.4	1.68	13.6	1.37
	65%	5.9		9.6		4.4		8.5		4.4		9.9	
14%	50%	6	1.18	10.6	1.29	5.4	1.42	10.1	1.38	6.3	1.66	11.7	1.38
	65%	5.1		8.2		3.8		7.3		3.8		8.5	

Note: Volumes are thousands of vehicles per day

Table 2 Directional distribution dependence on character of traffic demand [9]

Dominant character of traffic flow	D-factor
Suburban - urban	0.55 - 0.60
Intercity	0.60 - 0.65
Intercity - tourist	0.65 - 0.70

From the definition of the D-factor, it is concluded that it is determined during peak hours. In literature, it is often denoted as D_n , where the index n represents the n -th hour, similar to the K-factor. This means the directional distribution factor is determined within the range of the selected n -th hour. Typically, publications display the 200 peak hours of the year. The manual [10] suggests calculating D_{30} as the average of 5 hours (ranks 28–32), always using directional values greater than 50%, while D_{100} is the average of 5 hours (ranks 90, 95, 100, 105 and 110), again taking values above 50%. The method defined in [11] is generally acceptable: values for the peak direction (greater than 50%) are always taken, as values exceeding 50% occur in both directions. At continuous count sites, the D-factor is the median for the highest 200 hours (D_{median}). If such data is unavailable, short-term counts are conducted, and the D-factor is determined as follows, provided it is checked to ensure it falls within the allowable range:

$$D_{factor} = \frac{\max(Volume_{Peak1}, Volume_{Peak2})}{Combined\ Peak\ Hour\ Volume} \quad (2)$$

In this paper, only continuous counting sites are of interest. For the purpose of comparison, two values of the D factor were determined. D_{30} according to [10] and D_{median} according to [11].

3 Analysis of collected data

As previously mentioned, directional distribution is a variable parameter across hours, days, and seasons. For the rural road network, it is typically determined based on multi-year data from continuous automatic traffic counting (ATC), where it is necessary to extract directional distributions for the 200 highest-volume hours in a year.

Table 3 Available data from continuous count sites in B&H and Croatia

Type of traffic demand and road name		Count station number, name	AADT	S factor		
Road types in terms of traffic demand character	Tourist	M2	538 Neum	5692	1.86	
		D8 (CRO)	D8 (Croatia) Rogotin	7436	1.76	
	Tourist - intercity	M17	516 Salakovac	7845	1.57	
		R435	R435 Konjic	1868	1.45	
		M17.4	579 Cerno	5808	1.42	
		R425	R425a Međugorje	4930	1.34	
		R418	R418 Prozor	1952	1.29	
		M17	557 Donja Vraca	11762	1.24	
		Intercity	M17	525 Maglaj	9568	1.19
			M17.4	659 Čule	6378	1.15
	R435a		R435a Potoci	1344	1.11	
	R418b		R418b Konjic	973	1.11	
	R425		R425 Čitluk	5017	1.06	
	M6.1	519 Polog	7940	1.02		
			Max	11762	1.86	
		Min	973	1.02		

The sample consists of traffic count data from main (M) and regional (R) roads where continuous automatic counting is performed (table 3), with the following objectives:

- To cover a broad range of traffic volumes – AADT ranging from a minimum of 973 to a maximum of 11.762 veh/24h.
- To include a wide range of seasonal variation factors (referred to as the S-factor in this paper), representing the ratio ASDT/AADT, ranging from 1.02 to 1.86. ASDT is the Average Summer Daily Traffic for July and August (62 summer days).

Based on the S-factor values, the roads are classified into three categories:

- intercity: S factor ≤ 1.2
- intercity - tourist: $1.2 < \text{S factor} \leq 1.6$
- tourist: S factor > 1.6 .

The K and D factors were taken for the 30th and 100th hours. The D factor was determined as follows:

- for D_{30} , as the average of 5 hours (ranks 28–32) [10]
- for $D_{100} = D_{\text{median}}$, as the median of all 200 highest-volume hours [11].

Since the D-factor calculation always utilizes the percentage of the peak direction (> 50%), the last column in table 4 shows the number of hours where Direction 1 was > 50% (out of a total of 200 hours). It is important to emphasize that this method of determining the D-factor implies that the resulting directional distribution can occur in either direction. Presented results confirm this statement. In this sample of 14 counting sites, Direction 1 was dominant at 6 sites, while Direction 2 was dominant at 8 sites. It is generally recommended that D factor be monitored over a multi-year period at each individual count station.

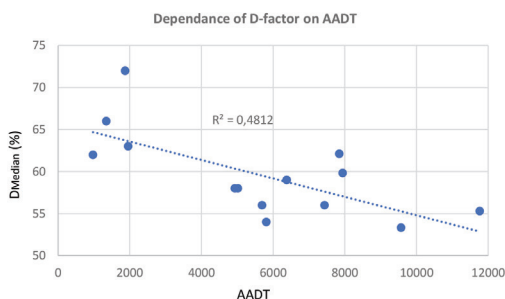


Figure 1 Relationship between AADT i D_{median}

Table 4 Calculated values of K and D factors

Nature of traffic demand	Count station name & number	AADT	S-factor	K_{30}	K_{100}	D_{30} [%]	D_{median} [%]	$N_{D>50\%}$ of 200
Dominant tourist	M2 Neum 1	5692	1.86	0.167	0.145	56	56	108
	D8 (RH) Rogotin 2	7436	1.76	0.156	0.137	54	56	112
Tourist - intercity	M17 Salakovac 3	7845	1.57	0.135	0.120	61	62	19
	R435 Konjic 4	1868	1.45	0.172	0.14	74	72	103
	M17.4 Cemo 5	5808	1.42	0.124	0.112	59	54	82
	R425a Medugorje 6	4930	1.34	0.108	0.099	56	58	113
	R418 Prozor 7	1952	1.29	0.134	0.112	58	63	89
	M17 Donja Vraca 8	11762	1.24	0.096	0.089	58	55	28
Intercity	M17 Maglaj 9	9568	1.19	0.093	0.086	54	53	62
	M17.4 Čule 10	6378	1.15	0.095	0.090	58	59	104
	R435a Potoci 11	1344	1.11	0.116	0.094	64	66	95
	R418b Konjic 12	973	1.11	0.107	0.092	67	62	88
	R425a Čitluk 13	5017	1.06	0.100	0.090	57	58	18
	M6.1 Polog 14	7940	1.02	0.109	0.103	62	60	138
	Max	11762	1.86	0.172	0.145	74	72	138
Min	973	1.02	0.093	0.086	54	53	18	

As expected, the obtained D factor values do not show significant collinearity with other parameters. Unlike the K-factor [12], the D-factor shows no correlation with seasonal variation (S-factor), which deviates from the recommendations in [9]. Furthermore, the results confirm that there is no dependence between the K and D factors, as also indicated by the data in table 1. The graph in figure 1, however, indicates a possible dependence of the D-factor on flow volume. As flow volume increases, the D-factor tends to decrease. While many factors influence directional distribution, the data for the D_{median} suggests that it does not change significantly over the years (table 5). Additionally, in almost all cases (except for M17-526 Karuše), it shows a slight downward trend as traffic volume increases.

Table 5 Calculated values of D factors for available years (2005-2014)

Count station	D-factor	Years									
		2005	2006	2008	2009	2010	2011	2012	2013	2014	
M17.4/R424 Čule	AADT	5353	5490	5904	6092	6201	-	6040	6340	6378	
	D_{Median}	60	59	61	62	60	-	59	59	59	
M17.4/R424 Cerno	AADT	-	4748	5219	5396	-	5538	5315	5758	5808	
	D_{Median}	-	55	55	54	-	53	54	54	54	

Table 6 Calculated values of D factors for available years (2014-2024)

Count station	Traffic parameters	Years									
		2014	2015	2016	2017	2018	2019	2021	2022	2023	2024
M17-516 Salakovac	AADT	6282	6858	7378	7543	7845	8034	7757	-	8903	9234
	D_{Median}	62	63	62	61	62	62	61	-	58	59
M6.1-519 Polog	AADT	6995	7228	7575	7742	7940	-	-	8136	-	8936
	D_{Median}	60	60	60	61	60	-	-	57	-	61
M17-525 Maglaj	AADT	-	8177	8728	-	9568	9360	-	-	12982	13215
	D_{Median}	-	54	54	-	53	54	-	-	53	54
M17-557 Donja Vraca	AADT	-	-	-	12025	11762	-	12625	13070	14046	14894
	D_{Median}	-	-	-	55	55	-	54	55	55	54
M17-526 Karuše	AADT	-	8816	9485	9755	10094	-	10099	10803	12018	12459
	D_{Median}	-	54	53	53	53	-	53	54	53	54

Below is an example of a possible method for graphically displaying directional distribution data for two counting sites with different D-factors. The proposal is to add this, or a similar ninth diagram, to the existing eight typically found in publications (as listed in the introduction).

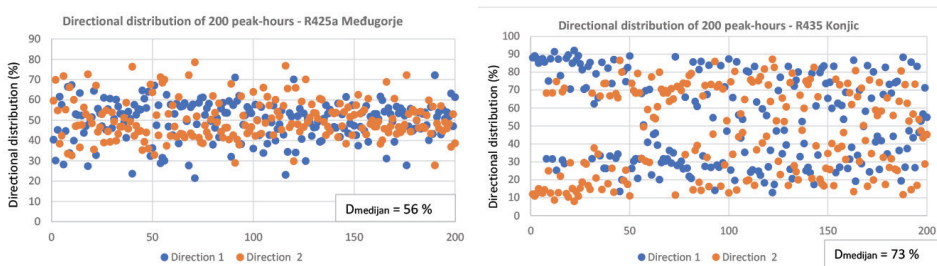


Figure 2 One possible way to graphically display directional distribution data

If directional distribution data were publicly available in this (figure 2) or a similar format - and if the sample for this article had been larger – the results of the analysis would undoubtedly be even more robust.

4 Conclusion

Based on the analysis presented in this paper, the following conclusions can be drawn:

- Directional distribution is a critical influential variable, particularly for two-lane rural highways.
- It depends on numerous factors, making it difficult to establish simple correlations, which is one reason for the lack of focus in existing literature.
- Although automatic counters provide all output data separately by direction, these details are often not published or publicly available. This is especially important for the 200 peak hours required for capacity analysis, as demonstrated in this study.
- It is essential to make directional distribution data publicly accessible. Prior to this, a clear methodology for determining the D-factor and standardized data visualization methods must be adopted.

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