Quality Assessment of Long-Term Traffic Data Collection by Video Detection Technique in a Busy Urban Intersection

Jenitta Pragalathan and Dieter Schramm
University of Duisburg-Essen, Chair of Mechatronics, Duisburg, Germany
Email: {jenitta.pragalathan, dieter.schramm}@uni-due.de

***Abstract*—This paper examines the performance of video detection technology by comparing the traffic flow data collected through this method with the data obtained by induction loop detectors. The data collection was conducted by using manual counting, inductive loop detectors and video detection technique. Then the quality of inductive loops was analyzed by comparing the traffic data from three short-term random loop datasets with original ground truth data ("Manual Count Made Easy [1]"). The analysis confirmed that the loop data is much reliable to be used for quality assessment of video detection (Vehicle Counter) for long-term continuous data collection. In the next phase of analysis, the data collection was done for the time period of a week and the percentage error values for every one-hour period were calculated. Following this, the trendline of error values were drawn and observed to find the effect of time of day, sunny/cloudy day, location of virtual sensors and type of turning movement. It was found that the daytime data from video detection is within the acceptable range of percentage error (5%). Hence neglecting the night time data, percentage distribution of error values was determined. The evidence from the study confirmed the importance of location of cameras and underlined the efforts needed to configure the virtual sensors and gates.**

***Index Terms*—traffic data collection, performance analysis, video detection, manual counting tool, vehicle counter, MCME, urban intersection, influence of sunlight**

I. Introduction

There are various traffic data collection methods which have been evolved from years. Video Detection is one of the recent advancements in traffic data collection field which is capable of giving microscopic level of data. But when considering long-term continuous data collection within an urban area, the accuracy will be affected due to uncertainties and various dynamic field aspects. Several studies have been done in the past to analyze the accuracy of this method and the impact of external factors. However, there is still a need for discussion on the cause of accuracy loss due to factors like e.g. weather, sunny or cloudy days. Hence in this study, the focus is given to do simultaneous data collection by using inductive loop detectors and video detection technique for seven days and assess the quality of video detection technique. The study investigates the trend of change in error values due to varying external factors (like lighting, time of day, sunny or cloudy day and weather).

It is well known that accurate and reliable traffic data is needed for Intelligent Transportation Systems, traffic management strategies and updating of real time traffic information. Henceforth this study is important for transport planners and local authorities to assess the quality and reliability of video detection technique and inductive loop detectors.

II. Literature Review

Several documents have reported the evolution of traffic data collection methods. Among them reports in [2], [3] gave the list of available traffic monitoring systems. The reports also overviewed the application and data collection methods and compared each of them according to data requirement and suitability of usage at the field. The paper [2] reviewed the traffic data collection methods used in country wise manner (Europe, United States). In more specific, the study [3] listed out the manufacturers and limitation of all the intrusive and non-intrusive methods and conducted a survey for validating the accuracy of each method. It was found in [3] that Inductive loops were most accurate device among the listed methods.

The work reported in [4] reviewed and compared three methods for microscopic traffic data collection and stated that the video recording method is suitable for analyzing lane changing behavior. It also reported the limitations of video recording due to area of coverage for study, difficulties of mounting the camera at proper height and evaluation of speed and acceleration. Reference [5] did a similar assessment of accuracy for microwave sensors. The accuracy evaluation was done at an intersection by considering turning movements.

A video-based detection technique was developed in [6] for real time traffic monitoring. The authors focused on finding vehicle classification (e.g. truck data) based on vehicle length. They also stated that loop detectors are not capable of such recognition of a vehicle based on vehicle length. In our study, a similar tool named as Vehicle Counter is used. A similar evaluation of accuracy

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of traffic flow at freeways and urban streets, is done in [7] for non-intrusive overhead and intrusive detectors in ground. In addition, they also studied the speed data by using a probe vehicle in the traffic.

In [8], various non-intrusive technologies were analyzed for different data requirement and under different field condition like heavy rain, snow, fog. The case study [9] analyses the influence of geometric, traffic and environmental factors over the accuracy of video detection. The authors compared the video detection data with ground truth data that were collected by using manual counting from video recordings. The methodology formulated in the present study was inspired by the work of [9]. The variation in our work is that data collection was done for seven days and the performance analysis was done based on available loop data at the intersection. In addition, the comparative analysis will be done in two stages by using manual counting tool (MCME), inductive loop detectors and video image processing software (VC) which will be explained in methodology.

III. Background

A brief summary about the software used in this study is given in this section.

A. Manual Count Made Easy(MCME)

MCME is a tool developed at IIT Madras, India [1]. It is used for advanced manual counting from video recordings which can store the time of passage and the type of vehicle. It works based on human interference by speech recognition. MCME can be used when there is possibility to record a video and when there is a need for microscopic level of traffic data. A test bed like urban intersection with complex turning movements can be studied easily with this software. Since the video is recorded, it is possible to recheck the error due to human negligence. The tool is also useful to find other traffic parameters like time headway, ratio of turning movement and vehicle composition.

B. Vehicle Counter (VC)

VC is a traffic monitoring application developed by Magenta srl, Italy [10]. This software can be installed in external surveillance cameras and it is working based on virtual sensors that are defined within the camera frame. It is a non-intrusive type of traffic data collection method which needs a camera to be installed on a signal post or any higher location. The accuracy of data might be affected by the position of camera mounting and the location of the lanes within the frame. The advantages are that a single camera can collect data from several lanes and also with different direction of traffic. Hence for a busy intersection it is suitable to collect data of different turning movements. It is also possible to trigger events like sending a mail or recording the video when needed at a situation to find traffic rule offenders. On the other hand, it also has its disadvantages due to loss of accuracy due to external atmospheric factors.

C. Inductive Loop Detectors (ILD)

It is a common method of intrusive traffic data collection where the inductive loops are installed for each lane under the roadway [2], [3]. The accuracy level is much higher than that of non-intrusive methods but at the same time it needs proper maintenance which requires cost investment and traffic lane closures. For a busy intersection it gives actuated traffic values based on which the traffic signal programs can be updated from time to time. Based on the passage of vehicle and its duration of crossing a detector, the other parameters like occupancy and speed of vehicle can also studied. It is also possible to know the waiting time of the first vehicle that stops over the detector.

IV. Methodology

The methodology was developed to do comparative analysis of traffic flow data collected by three different methods. With this in mind, a busy urban intersection in Duisburg, Germany was selected. The selected test bed has already inductive loop detectors installed in it and in active usage condition. Fig. 1 shows the layout of the selected intersection and the location of the loops. The approach from eastbound is numbered as approach 1, southbound as approach 2, westbound as approach 3 and northbound as approach 4.

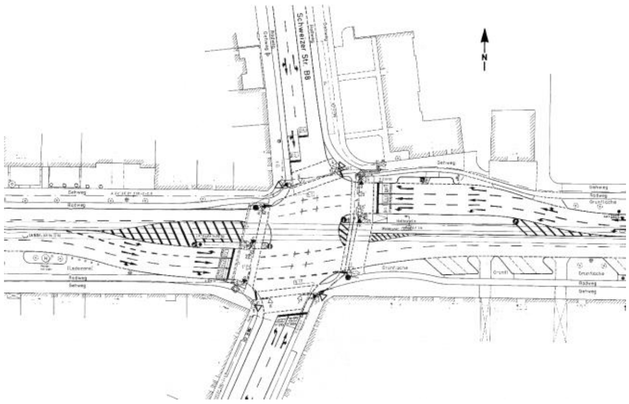

Figure 1. Test bed with location of detectors (Source: WB Duisburg).

It was decided to conduct two phases of data analysis (short-term random traffic data and long-term continuous traffic data). In the first phase, the accuracy of data from inductive loops were assessed with ground truth data collected by MCME. Three random samples of traffic data were collected for short period on different days (two 10 mins sample on 05.03.2019 and a 15 mins sample on 29.04.2019). Then the vehicle count from MCME was compared with loop data and the percentage error values were found.

The next phase of data analysis examines the data from VC and ILD. Traffic data were collected for one-week duration (02.04.2019 to 08.04.2019) to study the trend of percentage error on each day. After mounting the cameras, the definition and configuration of virtual sensors as in Fig. 2 within VC took rigorous trials.

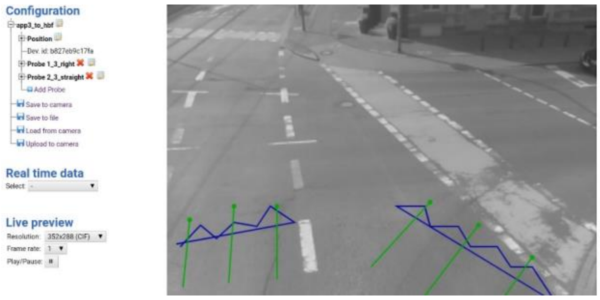

Figure 2. Configuration of virtual sensors for approach 3 in VC

The virtual sensors were defined for each lane at an optimum position to reduce error due to nearby lanes and gates for each virtual sensor were defined to initiate the data collection at a particular direction. The vehicle counts were stored in a database (without the video recordings of corresponding data for reasons of privacy). The raw vehicle count data were extracted from ILD. Time synchronization between two sensors were done carefully and the absolute error values for every one-hour data was calculated.

V. Results

A. *Phase1: MCME Versus ILD Data*

Table I. shows the analysis of vehicle counts from three random samples collected by MCME and ILD.

From the Table I., it is significant that except 3 all the other of the listed 11 lanes were error-free (i.e., as accurate as the ground truth data). The remaining 3 lanes have percentage error values which were less than the acceptable error range (i.e., 5%). Based on these observations, ILD data were considered as original level data for comparison with VC data to find corresponding percentage error values.

TABLE I. PERCENTAGE ERROR VALUES OF ILD DATA

Date	Time(hrs) From	Time(hrs) To	Duration (mins)	Approach No.	Lane / Detector No.	MCME counts in numbers	Loop data counts in numbers	Percentage Error (%)
05.03.2019	15:00	15:10	10	3	right / D5.1	25	24	4.00
				3	straight / D5.2	49	49	0.00
				4	straight/right / D3	56	56	0.00
				4	left / D4	14	14	0.00
05.03.2019	15:13	15:23	10	2	straight/right / D7	60	61	1.67
				2	left / D8	5	5	0.00
29.04.2019	10:25	10:40	15	1	straight / D1.2	44	44	0.00
				3	straight / D5.2	75	75	0.00
				3	left / D6	16	16	0.00
				4	straight/right / D3	74	75	1.35
				4	left / D4	18	18	0.00

B. *Phase 2: ILD Data Versus VC Data*

Collecting data by the manual counting method for several days is a tedious job. Hence to study the accuracy of VC, the ILD data were considered as original data for comparison with VC data to find absolute error values. Table II, Table III. and Table IV. give the results of vehicle counts and its corresponding hourly absolute error values that were calculated for three different lanes. Every time value gives the evaluation of previous one-hour data. Variation in color scale from green-yellow-red is used to represent the acceptable data with low error values and data prone to high error.

TABLE II. ABSOLUTE ERROR VALUES FOR RIGHT TURNING LANE

Time (hrs)	Vehicle counts and Absolute Error values for D5.1:Approach 3 Right Turning																				
	02/04/2019			03/04/2019			04/04/2019			05/04/2019			06/04/2019			07/04/2019			08/04/2019		
	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error
	(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)		
1.00	3	3	0	5	2	3	9	4	5	9	6	3	32	17	15	33	15	18	7	4	3
2.00	5	3	2	7	3	4	8	3	5	5	1	4	21	10	11	17	9	8	5	3	2
3.00	3	1	2	0	0	0	3	1	2	5	1	4	2	2	0	12	5	7	0	0	0
4.00	1	1	0	4	3	1	5	3	2	5	3	2	9	5	4	14	9	5	4	3	1
5.00	6	3	3	6	2	4	7	4	3	7	2	5	8	5	3	4	2	2	8	4	4
6.00	36	17	19	37	17	20	40	21	19	36	20	16	12	6	6	6	3	3	36	17	19
7.00	83	49	34	69	38	31	73	41	32	82	52	30	22	12	10	19	10	9	90	54	36
8.00	88	82	6	84	82	2	105	100	5	116	104	12	15	13	2	4	5	1	92	97	5
9.00	123	112	11	98	108	10	96	103	7	89	93	4	25	25	0	19	18	1	88	92	4
10.00	82	80	2	72	67	5	72	75	3	102	110	8	73	72	1	37	37	0	68	106	38
11.00	61	62	1	92	91	1	71	68	3	71	68	3	89	85	4	50	45	5	80	72	8
12.00	76	77	1	80	77	3	72	77	5	86	85	1	90	92	2	90	74	16	61	80	19
13.00	71	73	2	93	93	0	86	83	3	91	92	1	88	85	3	102	101	1	88	82	6
14.00	77	76	1	89	85	4	77	77	0	98	111	13	68	67	1	114	110	4	90	85	5
15.00	113	110	3	92	92	0	100	103	3	181	177	4	91	88	3	100	93	7	132	128	4
16.00	167	181	14	137	139	2	143	155	12	156	157	1	133	131	2	97	108	11	160	151	9
17.00	207	200	7	195	191	4	235	224	11	156	155	1	90	87	3	106	104	2	149	141	8
18.00	155	169	14	148	181	33	172	187	15	133	137	4	90	90	0	89	93	4	169	161	8
19.00	105	113	8	106	130	24	113	119	6	107	106	1	87	92	5	119	108	11	123	119	4
20.00	66	66	0	104	94	10	99	95	4	89	84	5	59	61	2	71	69	2	73	71	2
21.00	74	58	16	74	51	23	70	53	17	77	44	33	47	35	12	56	42	14	62	45	17
22.00	76	37	39	47	23	24	84	41	43	78	41	37	80	38	42	42	19	23	96	42	54
23.00	53	26	27	42	22	20	37	22	15	68	36	32	71	33	38	37	17	20	33	15	18
24.00	11	6	5	16	10	6	22	12	10	60	25	35	38	19	19	11	7	4	18	8	10

TABLE III. ABSOLUTE ERROR VALUES FOR STRAIGHT LANE

Time (hrs)	Vehicle counts and Absolute Error values for D5.2 :Approach 3 Straight																				
	02/04/2019			03/04/2019			04/04/2019			05/04/2019			06/04/2019			07/04/2019			08/04/2019		
	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error
	(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)		
1.00	55	33	22	53	24	29	29	25	4	35	26	9	116	80	36	174	111	63	64	39	25
2.00	33	20	13	25	14	11	21	18	3	30	20	10	76	52	24	121	78	43	27	19	8
3.00	17	12	5	17	13	4	18	14	4	10	8	2	51	36	15	77	46	31	20	13	7
4.00	13	9	4	6	6	0	14	8	6	14	8	6	24	16	8	48	32	16	6	5	1
5.00	31	21	10	19	13	6	27	17	10	18	14	4	11	7	4	35	22	13	30	17	13
6.00	127	75	52	113	77	36	134	78	56	111	63	48	40	23	17	30	19	11	105	62	43
7.00	344	221	123	302	205	97	329	212	117	323	208	115	33	26	7	22	17	5	288	211	77
8.00	455	435	20	434	426	8	450	436	14	430	422	8	93	91	2	29	27	2	441	414	27
9.00	471	453	18	459	455	4	454	449	5	436	413	23	126	121	5	52	48	4	438	427	11
10.00	305	280	25	313	303	10	312	311	1	335	292	43	172	184	12	90	78	12	362	321	41
11.00	306	266	40	278	274	4	262	260	2	257	247	10	222	223	1	174	130	44	316	285	31
12.00	286	246	40	254	246	8	233	226	7	249	251	2	242	236	6	227	176	51	270	239	31
13.00	227	223	4	219	221	2	229	225	4	237	235	2	272	267	5	258	181	77	343	272	71
14.00	229	228	1	251	246	5	262	260	2	272	271	1	248	242	6	254	204	50	269	232	37
15.00	275	270	5	275	272	3	303	298	5	314	309	5	260	255	5	288	241	47	286	283	3
16.00	361	362	1	291	291	0	346	345	1	354	348	6	257	246	11	272	245	27	401	379	22
17.00	406	403	3	369	365	4	378	375	3	363	363	0	231	224	7	327	287	40	542	405	137
18.00	518	404	114	362	360	2	398	387	11	332	330	2	278	258	20	380	280	100	504	367	137
19.00	334	313	21	320	322	2	304	304	0	250	249	1	250	235	15	326	260	66	285	284	1
20.00	249	226	23	203	200	3	226	223	3	218	215	3	204	191	13	197	188	9	213	208	5
21.00	199	151	48	242	161	81	232	178	54	233	151	82	201	140	61	202	157	45	213	157	56
22.00	216	129	87	201	111	90	252	145	107	223	128	95	233	141	92	251	144	107	253	144	109
23.00	194	107	87	174	101	73	169	103	66	190	119	71	230	138	92	134	93	41	173	101	72
24.00	68	47	21	94	63	31	90	63	27	183	109	74	186	107	79	98	64	34	86	57	29

TABLE IV. ABSOLUTE ERROR VALUES FOR LEFT TURNING LANE

Time (hrs)	Vehicle counts and Absolute error vlaues for D8 :Approach 2 Left Turning																				
	02/04/2019			03/04/2019			04/04/2019			05/04/2019			06/04/2019			07/04/2019			08/04/2019		
	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error	VC	ILD	Error
	(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)			(counts in numbers)		
1.00	9	4	5	3	5	2	8	6	2	13	7	6	34	17	17	54	29	25	21	10	11
2.00	5	3	2	5	4	1	13	7	6	18	10	8	20	11	9	39	21	18	4	2	2
3.00	1	1	0	3	3	0	4	3	1	3	3	0	14	10	4	19	13	6	4	3	1
4.00	1	0	1	1	1	0	1	0	1	4	0	4	19	9	10	17	11	6	1	1	0
5.00	13	6	7	9	4	5	8	4	4	13	6	7	15	9	6	20	13	7	12	5	7
6.00	49	18	31	41	18	23	45	13	32	34	12	22	25	8	17	12	7	5	39	10	29
7.00	44	24	20	38	14	24	53	20	33	65	39	26	28	9	19	14	8	6	45	19	26
8.00	72	51	21	75	64	11	71	68	3	66	54	12	29	22	7	14	10	4	73	56	17
9.00	84	73	11	77	66	11	76	70	6	103	94	9	37	32	5	24	21	3	79	72	7
10.00	77	68	9	74	63	11	82	65	17	78	72	6	65	57	8	32	27	5	102	67	35
11.00	89	79	10	91	74	17	83	74	9	90	76	14	79	74	5	44	37	7	97	80	17
12.00	93	69	24	91	77	14	107	91	16	78	77	1	81	89	8	55	49	6	96	80	16
13.00	104	87	17	85	70	15	100	91	9	99	87	12	115	111	4	60	51	9	102	90	12
14.00	75	73	2	80	71	9	89	79	10	101	82	19	82	80	2	66	56	10	101	83	18
15.00	102	87	15	85	84	1	86	71	15	111	96	15	90	85	5	56	42	14	81	71	10
16.00	84	72	12	104	89	15	80	75	5	92	73	19	113	112	1	55	62	7	81	85	4
17.00	87	74	13	83	68	15	94	87	7	76	81	5	95	88	7	68	55	13	98	87	11
18.00	89	83	6	95	85	10	76	68	8	98	102	4	69	77	8	59	50	9	87	91	4
19.00	78	68	10	80	73	7	96	94	2	93	88	5	75	69	6	63	59	4	100	80	20
20.00	64	60	4	182	76	106	79	68	11	82	84	2	74	64	10	65	61	4	73	66	7
21.00	63	43	20	156	51	105	80	58	22	87	61	26	75	54	21	68	49	19	79	60	19
22.00	67	42	25	114	35	79	70	37	33	86	48	38	84	48	36	65	36	29	89	43	46
23.00	32	29	3	95	29	66	57	32	25	45	26	19	31	38	7	60	27	33	65	36	29
24.00	32	23	9	29	7	22	38	19	19	55	27	28	0	23	23	23	12	11	36	17	19

VI. DISCUSSION

From the results in the tables, it is observed that the same virtual sensor gives acceptable accurate values for a certain time period of the day (e.g. from 8am to 8pm) even with increased traffic flow. There are certain situations that even during day time, there is a loss of accuracy because of sunlight. This indicates the error due to shadows of vehicles in nearby lane. When carefully looking at the absolute error values, there is always increase in error at night time (after 9pm) in all the three lanes.

This varying accuracy is denoted by the trendline of percentage error values drawn for each lane as in Fig. 3, Fig. 4 and Fig. 5. This indicates the effect of lighting on the performance of video image processing. Especially in the Fig. 4, it is obviously visible that the error in day time is increasing on 02.04.2019, 07.04.2019 and 08.04.2019.

On these days it is sunny while the other days were cloudy with moderate sunlight.

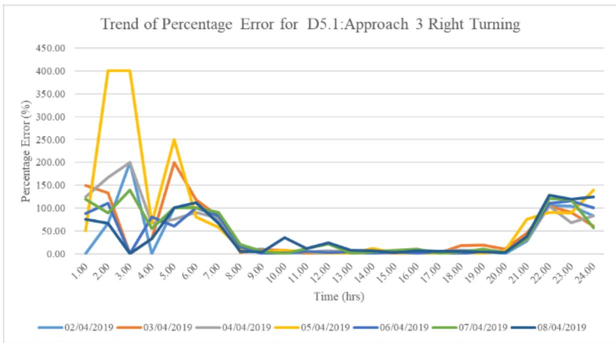

Figure 3. Trend of percentage error for right turning lane

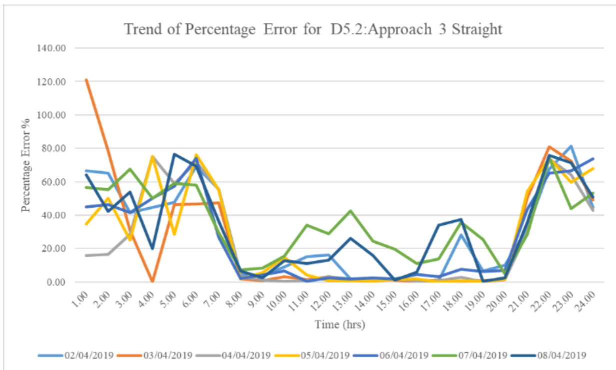

Figure 4. Trend of percentage error for straight lane

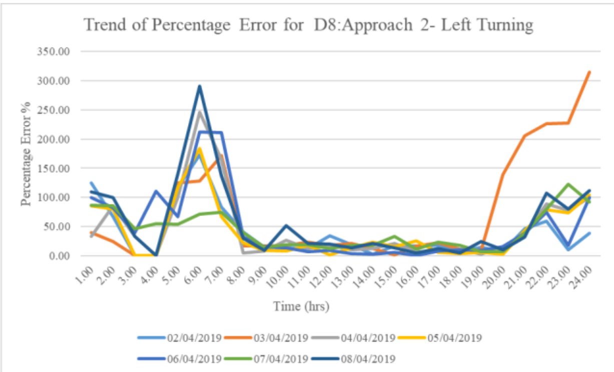

Figure 5. Trend of percentage error for left turning lane

Since the error values between 9 pm to 7 am are higher due to poor lighting, they are neglected for distribution analysis. The distribution of percentage error values is found only for the day time for each turning movement as in Table V. The percentage values signify that only 15% of right turning day time data is having higher error values while for left turning day time data its 66%. Hence the lane which is directly below the camera gives more accurate values than the left turning lane which is at the corner of the camera frame. There are also circumstances where we can find zero percent error (8% at right lane and 3% at straight lane). The distribution also proves that with proper definition and position of virtual sensors and calibration of the gates, the performance of the data collection by video detection increases.

TABLE V. DISTRIBUTION OF PERCENTAGE ERROR VALUES

% Error range		Distribution of percentage error (%)		
From	To	Right turning	Straight	left turning
Equal to	0.00	8	3	0
0	5.00	53	60	13
5.00	10.00	24	12	21
>	10.00	15	24	66

VII. CONCLUSIONS

The evidence from the study is in line with previous works stating that the camera has to be mounted at an optimum location to increase the performance. The frame of the camera should be carefully focused to avoid the error due to corner effect. Proper care must be taken while doing configuration of virtual sensors with a greater number of trials. In the software VC, the length of gates should also be defined with maximum care which influences the performance of the data collection. In general, the results indicate that it is possible to get reliable data from video detection technique during day time. The error due to poor lighting during night time can be rectified by using a thermal camera [11]. If the error due to the above-mentioned reasons are rectified, then video detection technique with virtual sensors can be used instead of several inductive loop detectors that has to be installed for each lane.

VIII. FUTURE SCOPE

To further the research, the evaluation of performance of video detection has to be done under rain, fog, and other climatic conditions. The study concludes that there is influence of external factors on the performance of data collection by video image processing. Hence, the further work needs to be done to rectify such influences. Since there is also speed data and vehicle type data available from VC, the evaluation of their accuracy also must be determined. The error values during night time is mainly due to double or triple storage of a single vehicle passage and also due to false positives. Hence, data pre-processing methods (data filtering and cleaning) has to be formulated to use the available night time traffic flow data.

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Jenitta Pragalathan is a Ph.D. student in the University of Duisburg-Essen, focusing on urban traffic simulation. She has received her bachelor's degree in Civil Engineering from Coimbatore Institute of Technology, India and master's degree in Transportation Engineering from National Institute of Technology Karnataka, India. Her research interests are real time traffic data collection, modelling of urban traffic flow and driving simulators.
Mrs. Pragalathan also worked as a Project Officer under projects related to map matching and Intelligent Transportation Systems in Indian Institute of Technology Madras, India.

Dieter Schramm is a Professor and head of the Chair of Mechatronics at the University of Duisburg-Essen. He is graduated in mathematics at the University of Stuttgart in 1981, worked there from 1981-1986 as a research assistant and received his PhD in Engineering in 1986. From 1986-1998 he worked at Robert Bosch GmbH as group leader and department head.
Prof. Dr.-Ing. Dr. h.c. Schramm joined Tyco Electronics Ltd. in 1999 and held the positions of Director Global Automotive Engineering and later CEO of Tyco Electronics Pretema GmbH until 2003. In 2004 he was appointed Full Professor and head of the Chair of Mechatronics at the University of Duisburg-Essen and since 2006 elected Dean of the Faculty of Engineering. His current research interests are electrified and alternative fuel driven automobiles, driver assistance systems, vehicle dynamics and cable driven manipulators. In 2015 he was awarded Dr. h.c. by the University of Miskolc, Hungary. Along with his research activities, he is director and partner of several companies in the field of research and post graduated education.