METHODS OF DETERMINING AND ANALYZING THE TRAFFIC INDEX ON CITY ROADS

A. R. Akhatov, B. Sh. Eshtemirov, F. M. Nazarov

Samarkand State University named after Sharof Rashidov
Samarkand, Uzbekistan

DOI: 10.24412/2073-0667-2025-1-18-28
EDN: XXXLMB

Traffic congestion has become a major issue impacting the economy, the ecology, and the general well-being of urban dwellers in the rapidly urbanizing 21st-century landscape. In order to effectively address and reduce the consequences of congestion, it is becoming more and more vital to develop and employ Road Congestion Index (RCI) calculations. The significance of RCI and its influence on the future of the city were examined in this article. For the purpose of analyzing traffic flow, the index of road congestion is crucial. Road congestion assessment, traffic planning and organization for road management, and the ability of drivers and passengers to make educated judgments on traffic are all dependent on the calculation and analysis of the congestion index. A number of assessment index approaches were examined. Traffic congestion affects the economy, the environment, public health, and general quality of life, hence it is imperative to address it for a number of reasons. Additionally, it decreases overall efficiency and wastes fuel and time. Because they make it easier for people and cars to move around, efficient triband systems are essential for economic expansion. Significant financial costs are also associated with traffic, such as higher fuel consumption, higher auto maintenance expenses, and longer freight delays, all of which can raise the price of goods and services.

Key words: Urban traffic, index of traffic jam, saturation degree, average velocity, speed interval, map show color.

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МЕТОДЫ ОПРЕДЕЛЕНИЯ И АНАЛИЗА ИНДЕКСА ДВИЖЕНИЯ НА ГОРОДСКИХ ДОРОГАХ

А. Р. Ахатов, Б. Ш. Эштемиров, Ф. М. Назаров

Самаркандский государственный университет,
140101, Самарканд, Узбекистан

УДК 65.012
DOI: 10.24412/2073-0667-2025-1-18-28
EDN: XXXLMB

Пробки на дорогах стали серьезной проблемой, влияющей на экономику, экологию и общее благополучие городских жителей в быстро урбанизирующемся ландшафте 21-го века. Для эффективного решения и уменьшения последствий пробок становится все более и более важным разрабатывать и использовать расчеты индекса загруженности дорог (RCI). Значимость RCI и его влияние на будущее города были рассмотрены в этой статье. Для анализа транспортного потока индекс загруженности дорог имеет решающее значение. Оценка загруженности дорог, планирование движения и организация управления дорогами, а также способность водителей и пассажиров принимать обоснованные решения о дорожном движении зависят от расчета и анализа индекса загруженности. Был рассмотрен ряд подходов к индексу оценки. Пробки на дорогах влияют на экономику, окружающую среду, общественное здравоохранение и общее качество жизни, поэтому крайне важно решать эту проблему по ряду причин. Кроме того, это снижает общую эффективность и приводит к потере топлива и времени. Поскольку они облегчают передвижение людей и автомобилей, эффективные трехполосные системы имеют важное значение для экономического роста. С дорожным движением также связаны значительные финансовые затраты, такие как повышенный расход топлива, более высокие расходы на техническое обслуживание автомобилей и более длительные задержки грузов, что может привести к повышению цен на товары и услуги.

Ключевые слова: городские пробки, индекс пробок, степень насыщенности, средняя скорость, интервал скорости, цвет отображения карты.

Introduction. Millions of people see traffic congestion every day; they are now an unavoidable aspect of living in a contemporary metropolis. Traffic congestion will continue to have negative effects as cities expand and become more crowded. The ramifications of traffic congestion are felt in many facets of our life, from environmental concerns to economic ones. Although it may just appear to be a small annoyance, traffic congestion has far-reaching and complex effects. The knock-on effects of traffic include everything from health issues to environmental deterioration and economic downturns [2]. Urban planning, funding for public transportation, and the implementation of economical and environmentally friendly transportation options are all necessary components of a comprehensive strategy to address these issues. Traffic congestion affects the economy, the environment, public health, and general quality of life, hence it is imperative to address it for a number of reasons. Additionally, it decreases overall efficiency and wastes fuel and time. Because they make it easier for people and

Table 1

Traffic congestion level 5

		UB	BU	MiC	MoC	SC
SI	**H, E**	$(65, 300)$	$(50, 65]$	$(35, 50]$	$(20, 35]$	$[0, 20]$
	MR	$(40, 300)$	$(30, 40]$	$(20, 30]$	$(15, 20]$	$[0, 15]$
	SR, B	$(35, 300)$	$(25, 35]$	$(15, 25]$	$(10, 15]$	$[0, 10]$
CV		$(0, 20)$	$(0, 20)$	$[20, 40)$	$[40, 60)$	$[60, 80)$
MShC		**LG**	**G**	**Y**	**R**	**DR**

UB — Unblocked, BU — Basic Unblocked, MiC — Mild Congestion, MoC — Moderate Congestion, SC — Serious Congestion, SI — Speed Interval (km/h), H — Highways, E — Expressways, MR — Main Road, SR — Secondary Roads, B — Branches, CV — Congestion Value, MShC — Map Show Color, LG — Light green, G — Green, Y — Yellow, R — Red, DR — Deep red

cars to move around, efficient triband systems are essential for economic expansion. Significant financial costs are also associated with traffic, such as higher fuel consumption, higher auto maintenance expenses, and longer freight delays, all of which can raise the price of goods and services. An indicator used to assess the degree of traffic congestion in a given location — typically an urban area or a particular road — is the Traffic Congestion Index (TCI) [1]. This is a figure that represents the efficiency of the traffic flow and is typically given as a percentage or score. The index considers a number of variables that contribute to traffic jam, such is the amount of vehicles on the route., the infrastructure's capacity, and the effectiveness of the transportation system. Prolonged traffic jams can lengthen travel times, increase fuel consumption, and decrease the effectiveness of transportation as a whole. Travel time data, traffic volume data, and road infrastructure data are typical components of the congestion index calculation procedures used by many authorities and organizations. Urban planners, transportation authorities, and policy makers frequently utilize this index to pinpoint high-traffic regions and devise solutions, including enhancing public transportation, increasing road capacity, or adjusting traffic signal timing, to mitigate traffic issues.

1. Traffic congestion index. There is no clear standard definition of traffic congestion. Through significant investigation and understanding of road characteristics, a congestion evaluation index in the range of [0,100] is developed. According to him, if the speed is 0, it means that the highway is very triband, that is, the value of road traffic is equal to 100 [2–4]. If the speed has an infinitely large value, then the value of traffic congestion will be equal to 0. Accordingly, traffic congestion can be divided into 5 levels (Table 1).

In this case, the relationship between the traffic index $D(z)$ and the vehicle speed $z\,(z \geq 0)$ can be expressed as follows:

$$D(z) = 100 - \left(\frac{1}{1 + e^{-\alpha z}} - \frac{1}{2}\right) * 200 \tag{1}$$

The α parameter in this formula varies with different road levels. Traffic at the same pace will vary on main routes, thoroughfares, main routes, secondary routes, branches, and other road levels. However, if the speed is the same, a road with a higher grade will also have a higher congestion index. So, the α parameter is used to reflect the impact of route levels on the traffic indication. Use the trained model to predict green building prices for new data.

Table 2

α values at different path levels

H, E	MR2	SR, B
0.052	0.052	0.065

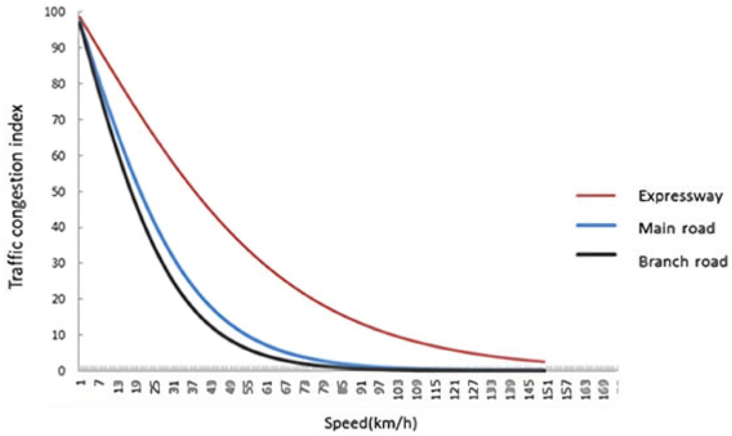

Fig. 1. The relationship between road equivalent and trafic congestion index

The following table shows the value of α on roads of different levels (Table 2) [5–7]:

Where H — Highways, E – Expressways, MR — Main Roads, SR — Secondary Roads, B — Branches. As shown in Fig. 1, the higher the road equivalent, the higher the congestion figure at the same speed.

2. Calculation of traffic congestion index in relation to travel time. When calculating the congestion index, it is calculated based on the average speed of the flow of vehicles on the road, which can be used to estimate road congestion [7–8]. This is calculated as follows:

1. In this, M is divided into days, each day is divided into N time intervals, and there are SR paths.

2. Two movement parameters are defined,V_{kij} is the acceptable movement speed and V'_{kij} is the minimum movementspeed. In this case, it is possible to refer to Table 3 that k is selected on the road section, i is a day and j is a time interval.

3. The speed of each road section can be determined based on statistical data [9]. Let's compare V^R_{kij} with V_{kij}. If it is $V^R_{kij} > V_{kij}$, there is no traffic congestion and the traffic index is $I_{kij} = 0$; if $V^R_{kij} \leq V_{kij}$, the path is triband and $I_{kij} = 10$. In addition, the function of the traffic index is as follows:

$$I_{kij} = \frac{V_{kij} - V^R_{kij}}{V_{kij} - V'_{kij}} \times 10 \tag{2}$$

4. The traffic index of I^d_{ki} for i days on road section $k$is calculated as follows:

$$I^d_{ki} = \sum_{j=1}^{N} b^d_j \times I_{kij} \tag{3}$$

where b^d_j is the ratio of traffic volume during the whole day to j.

Table 3

Rate of traffic flow estimation using average speed

RT	SL				
	1	2	3	4	5
E	>85	(70,85]	(55,70]	(40,55]	≤ 40
AR	>65	(55,65]	(45,55]	(35,45]	≤ 35
SR	>55	(45,55]	(35,45]	(30,35]	≤ 30
BR	>55	(45,55]	(35,45]	(30,35]	≤ 30

Where, RT — Road Type, SL — Speed Level, E — Expressway, AR — Arterial road, SR — Secondary Roads, B — Branches Road.

Table 4

Traffic congestion index based on traffic flow rate

Time interval	**7am–8am**	**8am–9am**	**9am–10am**	**10am–11am**	**11am–12am**	**12am–1pm**
Average speed (km/h)	13.70	19.10	22.40	50.30	61.10	52.10
Congestion index	8.60	7.90	7.10	2.10	0.10	1.30
Time interval	**1pm–2pm**	**2pm–3pm**	**3pm–4pm**	**4pm–5pm**	**5pm–6pm**	**6pm–7pm**
Average speed (km/h)	58.30	60.10	61.03	53.20	49.40	52.90
Congestion index	0.10	0.21	0.32	0.02	0.00	0.01

5. The traffic index I_i^don the ith day in a certain area is expressed as follows:

$$I_i^d = \sum_{k=1}^{SR} a_k^d \times I^d \tag{4}$$

where a_k^d is proportional to the flow rate in the knd part of the entire path. Similarly, the congestion index of I_{Area}^d is defined as [10–11]:

$$I_{Area}^d = \sum_{i=1}^{M} q_i \times I_i^d \tag{5}$$

where q_i is proportional to the flow rate of the ind day of the entire research period.

Since the same j-road section is explored on the same i-day, the membership function of the traffic index $C1_k$ in the time interval k — can be constructed as follows in the time interval k.

$$C1_k = I_{kij} = \begin{cases} 0, & V_{kij} > 50 \\ \frac{50- V_{kij}}{40}, & 10 < V_{kij} \leq 50 \\ 10, & V_{kij} \leq 10 \end{cases} \tag{6}$$

Table 4 shows the traffic index at different time intervals.

Traffic congestion index based on road saturation level. There is a concept of the average level of saturation of city roads. If the speed of traffic on the road is 60 km/h, the power

Table 5

Calculation values of the traffic index based on the saturation level of the road are presented

Time interval	**7am–8am**	**8am–9am**	**9am–10am**	**10am–11am**	**11am–12am**	**12am–1pm**
Flow rate (veh/h)	3354	3078	3246	2676	2070	2688
Saturation degree, x2	1.20	1.10	1.16	0.96	0.74	0.96
Congestion index, C2	9.90	9.70	9.83	9.19	5.10	8.90
Time interval	**1pm–2pm**	**2pm–3pm**	**3pm–4pm**	**4pm–5pm**	**5pm–6pm**	**6pm–7pm**
Flow rate (veh/h)	2417	2312	2203	2514	2385	2311
Saturation degree, x2	0.83	0.82	0.75	0.89	0.86	0.82
Congestion index, C2	6.90	7.30	5.80	8.10	7.80	7.50

of the road will be 1400 veh/h [12–14]. The level of saturation is directly proportional to the level of traffic, and as the level of road saturation increases, so does the level of congestion and vice versa. The degree of saturation can be divided into 6 parts and calculated in the range [0,10]. Using the saturation level x_2, the traffic congestion index $C2$ membership function can be calculated. In this case, the evaluation function can be expressed as follows:

$$C2 = \begin{cases} \frac{x_2}{0.4} * 2, \; x_2 \leq 0.4 \\ \frac{x_2 - 0.4}{0.2} * 2 + 2, \; 0.4 \leq x_2 \leq 0.6 \\ \frac{x_2 - 0.6}{0.15} * 2 + 4, \; 0.6 \leq x_2 \leq 0.75 \\ \frac{x_2 - 0.75}{0.15} * 2 + 6, \; 0.75 \leq x_2 \leq 0.9 \\ \frac{x_2 - 0.9}{0.2} * 2 + 8, \; 0.9 \leq x_2 \leq 1 \\ 10, \; x_2 > 1 \end{cases} \tag{7}$$

Table 5 shows the traffic index according to the degree of saturation of the road in the period of 12 hours (7–19).

Calculation of congestion index based on comprehensive parameters.

In this case, the traffic index can be determined by several parameters. All of them can be obtained through video footage [15].

Create membership functions. The lower speed ratio can be divided into 3 levels:

a) lower;

b) medium;

c) high.

A low level of congestion means that it will last for a short time and the traffic flow on the road is ideal, and conversely, if the traffic flow is high, it means that the congestion situation will last for a long time. Fig. 2 shows the graph of the dependence of the membership function on the lower speed ratio.

The corresponding membership function of the lower speed ratio can be expressed as:

$$\mu_l = \begin{cases} 1, \; K \leq 0.1 \\ \frac{0.2 - K}{0.1}, \; 0.1 < K < 0.2 \\ 0, \; K \geq 0.2 \end{cases} \tag{8}$$

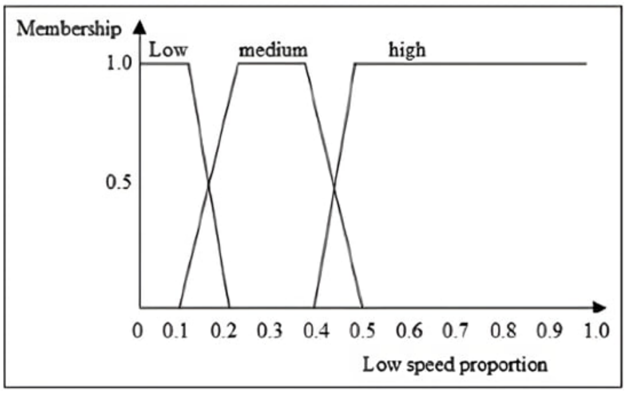

Fig. 2. Membership function graph of travel productivity

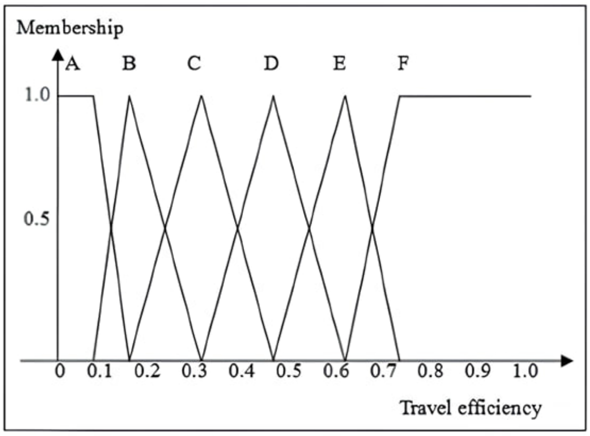

Fig. 3. The degree of membership of the saturation level

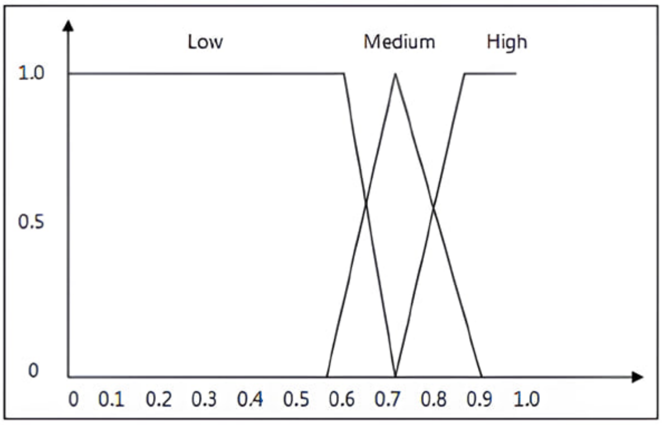

Fig. 4. Lower speed ratio membership level

$$uM = \begin{cases} 0, \ K \le 0.1 \\ \frac{K-0.1}{0.1}, \ 0.1 < K \le 0.2 \\ 1, \ 0.2 < K \le 0.4 \\ \frac{0.5-K}{0.1}, \ 0.4 < K \le 0.5 \\ 0, \ 0.5 < K \le 1 \end{cases} \tag{9}$$

$$\mu_h = \begin{cases} 0, \ K \le 0.4 \\ \frac{K-0.4}{0.1}, \ 0.4 < K < 0.5 \\ 1, \ K \ge 0.5 \end{cases} \tag{10}$$

where K is the lower speed ratio, μ_l is the corresponding membership for the lower level, uM is the corresponding membership for the middle level, and μ_h is the corresponding membership for the higher level.

In the same way, the membership function can be constructed when the degree of saturation is divided into three levels as in Fig. 3 [18–21].

For example, if the low-speed travel speed is 0.14, the corresponding low, medium, and high travel efficiency vectors are (0.6, 0.4, 0) [16–17].

Travel productivity can be conveniently divided into 6 levels: A, B, C, D, E and F. In this case, the interval [0,1] can be adjusted as follows (A,0) and (F,1) Fig. 4.

Table 6

Membership level of each index

Time	**Traffic flow (veh/h)**	**Average speed (km/h)**	**Saturation degree**	**Travel efficiency**	**Membership of saturation degree**	**Membership of travel efficiency**
7am–8am	3451	15.06	1.18	0.76	1.01	1.01
8am–9am	3473	13.34	1.13	0.70	1.10	1.02
9am–10am	3241	19.87	1.09	0.68	1.02	0.32
10am–11am	2076	46.13	0.96	0.31	1.20	0.38
11am–12am	2671	57.95	0.75	0.20	0.67	1.12
12am–1pm	3583	45.58	0.94	0.28	1.06	0.33
1pm–2pm	2124	57.16	0.77	0.13	0.45	1.07
2pm–3pm	2382	60.36	0.79	0.04	0.47	1.04
3pm–4pm	2124	58.12	0.78	0.01	0.59	1.13
4pm–5pm	2665	58.76	0.85	0.19	0.27	0.21
5pm–6pm	2316	51.40	0.83	0.23	0.35	0.32
6pm–7pm	2494	49.32	0.78	0.17	0.38	0.19

The measured traffic data and index membership levels are presented in Table 6.

Conclusion. In the context of rapid urbanization and the complexity of modern transportation, the Road Traffic Index has emerged as an important tool for urban planners and citizens. Its importance is not only in diagnosing the problems caused by traffic, but also in taking strategic measures, supporting sustainable mobility solutions and shaping the future of urban transport. As technologies continue to evolve, the role of RCI calculations will become more important, contributing to the development of sustainable, efficient and human-centered urban environments. Embracing and improving the use of RCI will be integral to creating cities that are not only well-connected, but also sustainable and livable for generations to come.

In conclusion, solving traffic congestion is important for promoting economic development, protecting the environment, ensuring public health and safety, and improving the overall quality of life for people. Addressing congestion has often shown to require a multi-pronged approach, including investment in public transport, infrastructure improvements, smart urban planning and the adoption of sustainable transport alternatives.

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Ахатов Акмаль Рустамович — e-mail: `akmalar@rambler.ru`, тел: +998902716418. Д-р техн. наук, профессор, проректор по международному сотрудничеству Самаркандского государственного университета имени Шарофа Рашидова по специальности 05.01.02 — «Системный анализ, управление и обработка информации». Количество опубликованных научных работ — более 100. Область научных интересов: обработка данных, повышение и обеспечение достоверности этого процесса, автоматизация процессов принятия решений и управления при обработке информации, системы искусственного интеллекта и большие данные.

Akmal Rustamovich Akhatov — e-mail: `akmalar@rambler.ru`, phone: +998902716418. Doctor of technical sciences, professor, vice-rector for international cooperation of Samarkand State University named after Sharof Rashidov, specialty 05.01.02 — "Systematic analysis, management and information processing". The number of published scientific works is more than 100. Field of scientific interests: data processing, increasing and ensuring the reliability of this process, automation of decision-making and management processes in information processing, artificial intelligence systems and Big Data.

Эштемиров Бунед Шерали ўғли — e-mail: `eshtemirov23@gmail.com`, тел.: +998979120814. Аспирант Самаркандского государственного университета имени Шарофа Рашидова. Количество опубликованных научных работ — более 10. Область научных интересов: большие данные, технологии распределенных вычислений, оптимизация систем управления данными, искусственный интеллект, технологии программирования, веб-технологии.

Eshtemirov Bunyod Sherali o'g'li — e-mail: `eshtemirov23@gmail.com`, phone: +998979120814. A doctoral student of Samarkand State University named after Sharof Rashidov. The number of published scientific works is more than 10. Field of scientific interests: Big Data, distributed computing technologies, optimization of data management systems, artificial intelligence, programming technologies, web technologies.

Назаров Файзулло Махмадиярович — e-mail: `fayzulla-samsu@mail.ru`, тел: +9989944798640. Канд. техн. наук, доцент, декан факультета интеллектуальных систем и компьютерных технологий Самаркандского государственного университета имени Шарофа Рашидова по специальности 05.01.02 — «Системный анализ, управление и обработка информации». Количество опубликованных научных работ: более 50. Область научных интересов: искусственный интеллект, информационная безопасность, технология Blockchain, технологии программирования, технология больших данных, технологии распределенных вычислений.

Nazarov Fayzullo Makhmadiyarovich — e-mail: `fayzulla-samsu@mail.ru`, phone: +9989944798640. PhD, associate professor, dean of the faculty of Faculty of Intelligent Systems and Computer Technologies of Samarkand State University named after Sharof Rashidov, specialty 05.01.02 — "Systematic analysis, management and information processing". The number of published scientific works is more than 50. Field of scientific interests: Artificial intelligence, information security, Blockchain technology, programming technologies, Big Data technologies, distributed computing technologies.

Дата поступления — 02.07.2024