

Determining the Response Speed of Fire Rescue Vehicles in Arriving at the Emergency Scene

Doniyorov Azizbek Narzulla o'g'li

Center for Advanced Training of Employees of the Ministry of
Poverty Reduction and Employment

Javliyev Asomiddin Elmirzaevich

Center for Advanced Training of Employees of the Ministry of
Poverty Reduction and Employment

Abstract:

The rapid response of fire and rescue units is one of the most essential parameters in restricting the propagation and reducing the damages generated by fire tragedies in urban settings. On wide paved roads, average travel speed is about 45 km/hr, and is about 25 km/hr on difficult road sections, according to regulatory guidance, and the maximum allowable arrival time for the first unit is commonly 10 minutes. As argued in the literature, particularly in urban settings, large-scale traffic congestion, and specific factors such as the type of vehicle used, time of the day, season of the year, or an administrative decision may disturb the full performance of these standards. This study contributes to bridging the gap between normative knowledge and actual performance of responding decisions using existing operational data of Termez city.

This research conducts a statistical modeling and factor analysis of 36 emergency responses recorded between January and December 2022. Average travel speed (Km/h) was computed with distance and travel time, and call flow was modeled empirically and theoretically with a number of approaches, including testing for Poisson distribution with the Pearson criterion.

The results indicate the mean fire and rescue arrival speed of 51 km/h in the city of Termez, ranging considerably depending on vehicle type and temporal conditions. The results show that cities cannot expect to suddenly get much faster (to 60 km/h or more) and that increasing the number of depots comes with expensive fixed cost.

The study suggests that a purely speed-oriented approach for enhancing the effectiveness of response will likely be ineffective and that attention needs to go to depot placement, operational planning and dispatch management instead.

Keywords: fire and rescue service, response speed, average speed, factor analysis, statistical modeling, urban infrastructure, traffic movement.

Introduction

In urban emergencies, the rapid response of fire and rescue units is among the most decisive factors in reducing the number of victims, limiting the spread of fire, and preventing secondary damage. Fire development has high time dependency, and thus, for the first minutes, flame spread can be initiated and the damage area increased significantly so that international and national regulatory regime have maintained it stringent time definitions for time of arrival of first unit. In practice, factors such as transport infrastructure, traffic conditions, dispatch, depot distribution and characteristics of fire rescue vehicles and related equipment interact in complex ways to determine response performance [1]. Thus, response speed is not only an operational indicator, but also a strategic parameter related to urban risk management and emergency service planning.

It was noted that studies carried out in large cities including Berlin and Moscow observed that fire brigades do not often reach maximal speeds of 50 km/h and performance in most of times of day and days of week differ. These results corroborate a central conceptual link in fire service logistics that the arrival time of a vehicle is a function of not just the ability of that vehicle to reach a point, but is also a system level phenomenon dependent on road network congestion and station coverage [2]. Yet, there is a wider gap for medium sized cities, where no geoinformation systems are available and empirical datasets are not commonly statistically modeled. For cities such as Termez, where regulatory frameworks must be considered in the context of actual operating conditions, and where depot expansion or fleet upgrade costs may be large, this gap is particularly relevant.

This study fills the gap by examining 36 emergency responses from Fire Rescue Station No. 2 in Termez between January and December 2022 with regard to travel speed by calculating it based on distance and travel time and analyzing the call flow by empirical and theoretical distributions including Poisson test with the Pearson criterion. It is expected that response speed will show significant variation by vehicle type, day of week, and time of day, and simply increasing speed will not be enough to meet strict arrival standards. Average system arrival speed was just above 51 km/h but has varying dependence on conditions, suggesting that objectives to optimize system inductance should focus on dispatch planning and depot distribution rather than unattainable speed goals [3]. The findings should be taken as evidence to implement realistic decision making in urban fire rescue management and suggesting alternate, more cost effective strategies to enhance reliability during emergency response.

Methodology

The method of this study is based on integrating regulatory bench-marking, empirical operation data analysis and statistical modelling to assess the actual response time of fire and rescue vehicles in the city of Termez [4]. First, they identified normative requirements to define reference values for

travel speed and acceptable time of the moment of arrival, including guidelines of average speeds on various road categories, and the 85th percentile of maximum time of arrival of the first vehicle, Once these baseline criteria were defined, empirical data were obtained from the call records from Fire Rescue Station No. 2 from January-December 2022, consisting of 36 documented emergency responses. An analytical dataset was created using the travel time to the incident scene and the distance from the station to the fire location, which was extracted for each response. The arrival speed for each instance was computed with the traditional distance over travel time relationship, where $\text{speed} = \text{distance traveled} / \text{travel duration}$ [5]. This was followed by using descriptive statistical procedures to obtain averages, distribution characteristics, and variability of response speed and arrival time. Call flow model was prepared depending on empirical and theoretical approaches (Poisson distribution) to evaluate the frequency pattern of emergency calls, and statistical fit of the model was evaluated according to the Pearson criterion. Also, factor oriented analysis was used to assess whether response speed differs according to vehicle type, day of week, time of day or seasonal or organisational conditions, following the conceptual framework used for similar studies in Berlin and Moscow [6]. The last stage of methodology was the aggregation (synthesis) of the obtained speed indicators and statistical outputs to evaluate the practical applicability of different strategies (for example, increasing traveling speed vs. increasing the number of depots) and the most realistic strategies for improving the emergency response efficiency.

Result and Discussion

According to Clause 9.2 of Table 1.2 of the “Fire Suppression Leader” data collection, the average travel speed of fire rescue vehicles is set at 45 km/h on wide roads with hard pavement and 25 km/h on difficult sections. It is also accepted that the time elapsed from the moment a fire occurs until the fire rescue unit receives notification of the fire (depending on a number of factors) is 8–12 minutes [7]. Table 1.5 of the “Fire Suppression Leader” data collection specifies the linear fire spread rate during a fire at various types of facilities: in administrative buildings it is 1.0–1.5 m/min, in residential (living) houses it is 0.5–0.8 m/min, in museums and exhibition buildings it is 1.0–1.5 m/min, and in theaters and houses of culture (stages) it is 1.0–3.0 m/min.

In accordance with the above regulatory requirements, and in order to prevent the fire from spreading over a large area, the arrival time of the first fire rescue unit at the call location must be $\tau_{\text{max}} = 10$ minutes. This means that in cities the average arrival time should be 3–4 minutes [8]. A practically important question arises: how can these requirements be implemented in practice? What organizational and managerial decisions are necessary to achieve this?

Here, first of all, it is necessary to rationally coordinate two parameters: the speed of fire rescue vehicles along city streets and the number of fire rescue depots. In this case, theoretically, there are two methods for solving the problem of ensuring that fire rescue units arrive at the call location on time.

The first method is to sharply increase the average speed of fire rescue vehicles along city streets (for example, up to 60 km/h and higher). Then, it may be possible to reduce the average arrival time to 3–4 minutes and achieve compliance with the standard.

The second method is a significant increase in the number of fire stations, which will lead to large capital expenditures, since responsibility will arise for the costs of construction, the purchase of fire rescue equipment, and ensuring the operation of personnel [9].

However, the first method is impossible. In November 2013, an article by German specialists on this topic was published. They studied the speed of ordinary vehicles on the streets of Berlin and examined in detail the travel speed of various types of fire rescue vehicles when responding to calls along these streets. It turned out that ordinary vehicles move at an average speed of 24.1 km/h, while fire rescue vehicles, at different hours of the day, week, and month, move at an average speed of 31.8 km/h [10]. The variations were insignificant (for example, in January the speed was 30.8 km/h, and in June it was 32.2 km/h). A similar situation was observed in London, Warsaw, Rome, and Paris. Therefore, it became clear that in cities it is not necessary to increase the speed of fire rescue vehicles to 60 km/h.

Based on geoinformation data, the authors studied the speed of the fire rescue services of the city of Moscow [11]. When studying the speed of fire rescue vehicles in arriving at the call location, the authors took into account various factors: the distance to the call location; the type of fire rescue vehicle; the day of the week; the time of day; and elevation differences. It was determined that for all fire rescue vehicles the average speed of arrival at the call location is 35.13 km/h, and for the main fire engine (AC) it is 33.69 km/h (see Table 1.1).

Table 1.1

Average indicators by types of fire rescue vehicles

Type of fire rescue vehicle	Number of responses	Average distance, km	Average speed, km/h
Fire engine (tanker)	504	5.27	33.69
Communication and lighting vehicle	687	7.46	36.91
Fire rescue vehicle for gas and smoke protection	25	9.23	38.25
Aerial ladder and articulated aerial platform	134	4.57	31.02
Total	1350	6.40	35.13

As can be seen from Table 1.1, the highest arrival speed corresponds to gas and smoke protection fire rescue vehicles (38.25 km/h), while the lowest speed corresponds to aerial ladders and articulated aerial platforms (31.02 km/h) [12]. The influence of the day of the week on the speed of fire rescue vehicles, despite the existing advantages of movement, showed that on working days, due to traffic congestion, the arrival speed is negatively affected (see Figure 1.1).

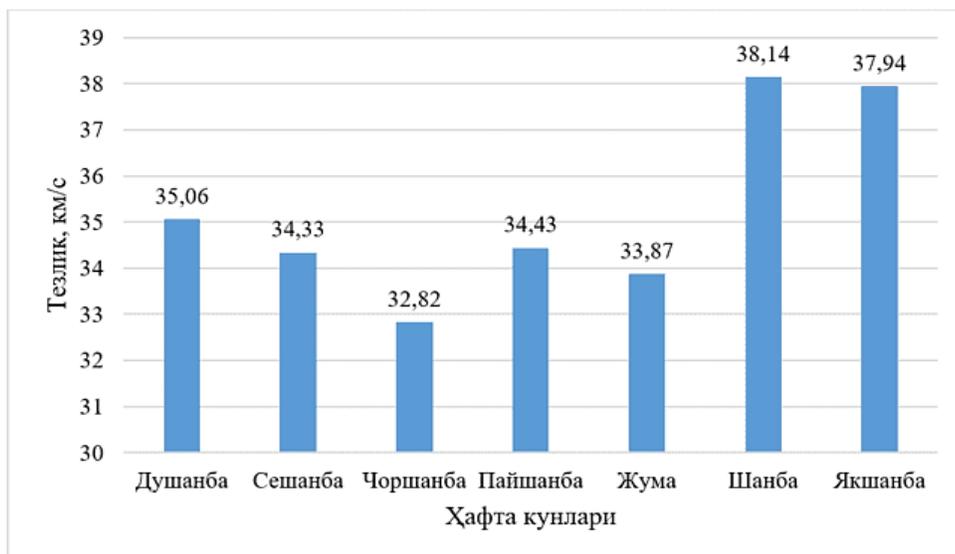


Figure 1.1. Distribution of the average speed of fire rescue vehicles by days of the week

The influence of the time of day on speed is similar to the influence of the day of the week on arrival time. During the most congested hours of the road transport network, the arrival speed of fire rescue vehicles also decreases [13]. In the absence of geoinformation data, the average arrival speed of fire rescue vehicles can be determined using the following formula:

$$\bar{v}_{ave. arrival} = \frac{L}{t},$$

where **L** is the distance from the fire rescue depot to the call location, km; and **t** is the travel time, hours [14]. In order to calculate the arrival speed of fire rescue vehicles to the call location, 36 responses of the units of Fire Rescue Station No. 2 of Termez city were studied during January–December 2022 (see Table 1.2).

Table 1.2

Analysis of the arrival of the units of Fire Rescue Station No. 2 of the Termez City Fire Department during 2025

Fire number	Month name	Arrival time to the fire, min (t)	Distance from the station to the fire, km (L)	$v_{av.arriv.} = \frac{L}{t}$
1.	17 January	8	9	60,0
2.	22 January	6	5	50,0
3.	29 January	9	9	60,0
4.	02 February	10	11	66,0
5.	03 February	5	4	48,0
6.	07 February	3	3	60,0
7.	11 February	15	7	28,0
8.	15 February	6	4	40,0

9.	22 February	5	4	48,0
10.	26 February	13	11	50,8
11.	19 March	6	6	60,0
12.	13 April	7	6	51,4
13.	20 May	4	4	60,0
14.	28 May	5	3	36,0
15.	03 June	7	8	68,6
16.	04 June	9	8	53,3
17.	09 June	16	15	56,3
18.	20 June	6	5	50,0
19.	27 June	3	2,5	50,0
20.	17 July	3	2	40,0
21.	28 July	9	7	46,7
22.	14 August	7	6	51,4
23.	24 August	2	1,5	45,0
24.	28 August	9	7	46,7
25.	29 August	12	12	60,0
26.	03 September	7	4,5	38,6
27.	28 September	5	4	48,0
28.	30 September	5	3,5	42,0
29.	02 November	5	4	48,0
30.	03 November	7	6	51,4
31.	24 November	6	6	60,0
32.	05 December	10	9	54,0
33.	06 December	3	2	40,0
34.	11 December	7	6	51,4
35.	22 December	4	4	60,0
36.	27 December	2	1	30,0
Overall		246	209	51,0

The analysis and calculation results of the arrival speed of fire rescue vehicles are as follows (see Figures 1.2 and 1.3).

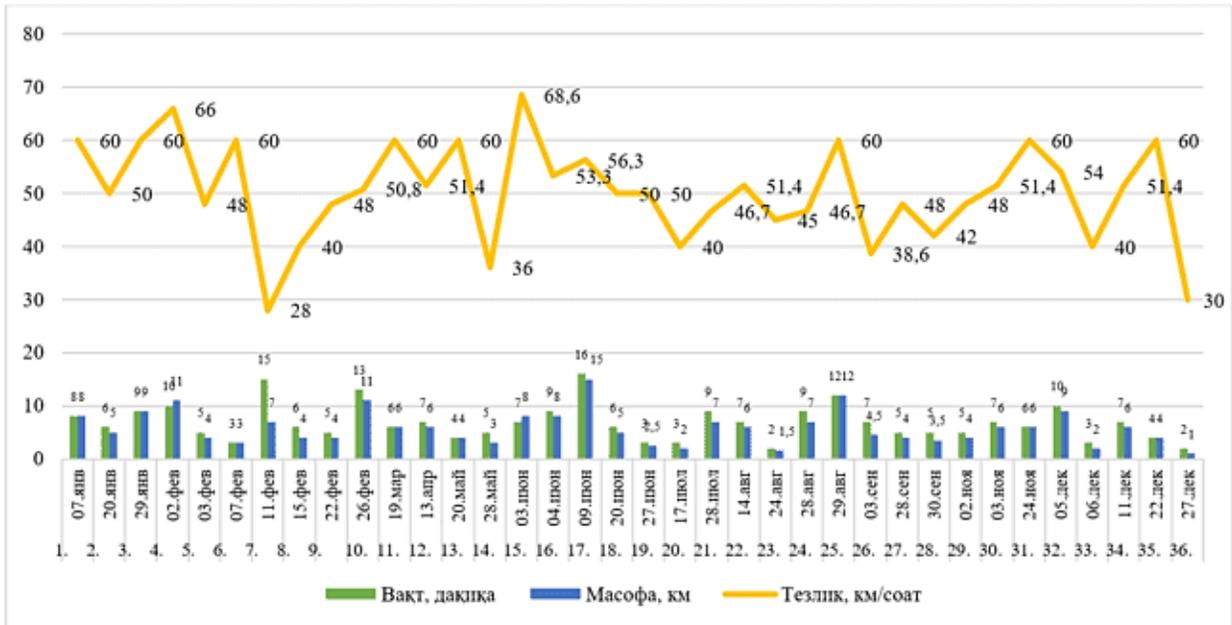


Figure 1.2. Analytical indicators of the arrival time and travel speed of fire rescue vehicles

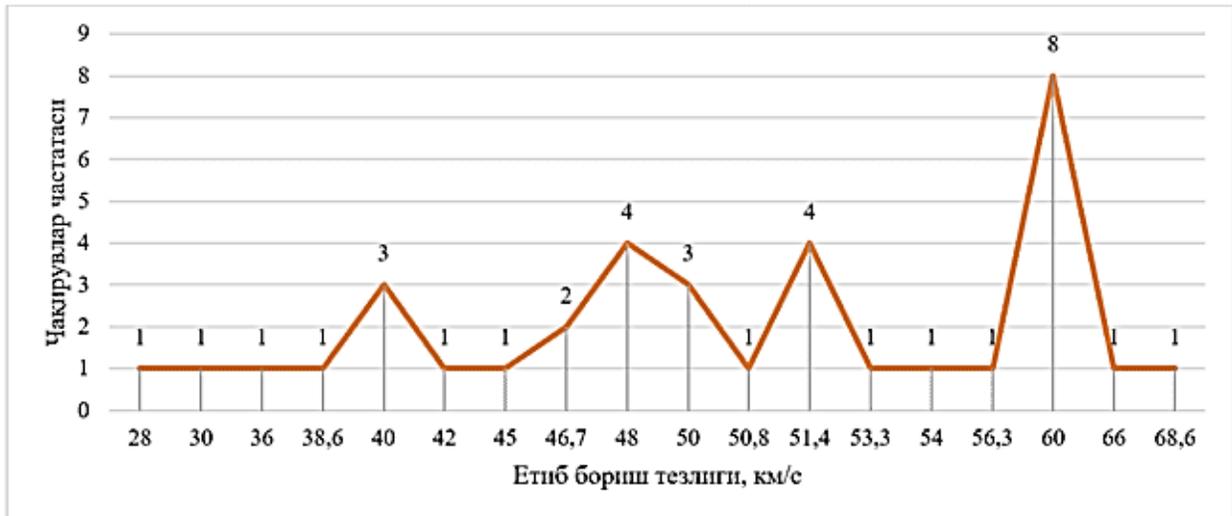


Figure 1.3. Indicators of the travel speed of fire rescue vehicles

As can be seen from Figure 1.3, the largest number of responses corresponds to a speed of 60 km/h. In some individual cases, the speed exceeded 60 km/h. Based on the data in Figure 1.3, calculations of the average arrival time of the Termez city fire rescue services to the call location were carried out. In the city, the average arrival speed was $\bar{v}_{(\text{avg. arrival})} = 57 \text{ km/h} = 0.85 \text{ km/min}$.

The flow of calls received by the fire rescue services in Termez city and the arrival speed of fire rescue vehicles to the call location were analyzed. Based on 2022 data, the call flow was analyzed using empirical and theoretical models, including the Poisson distribution, and its statistical fit was tested using the Pearson criterion. The analyses showed that the average arrival speed in the city is **51 km/h**, and this indicator has variability depending on different vehicle types, the day of the week, and the time of day [15]. Taking into account seasonal and organizational factors, the issues of selecting the optimal speed and the number of depots to ensure the timely arrival of the first fire rescue

unit at the call location were considered. The obtained results can be applied in modeling urban fire rescue services and improving their efficiency.

Conclusion

This study, therefore, confirmed that for realistic urban movement conditions (i.e., conditions close to actual), the response performance of fire and rescue units in Termez strictly depends on field conditions and not by regulatory target values. This study used the empirical analysis of 36 recorded fire emergencies in 2022, which determined that the median speed of fire rescue vehicles on arrival was about 51 km/h, but was found to be clearly influenced by vehicle type, time of day, day of the week, and seasonal/organizational factors. Results showed that operating at high speeds of a few hundred kilometers per hour (e.g., 60 km/h and above) is not a scalable solution in cities, whereas increasing the number of fire depots would incur significant capital and operational costs. Hence, the highest real-world value of the results is that optimizing response effectiveness should occur at the system level, such as depot placement, dispatch boundary management, and route planning, rather than expecting impractical speed improvements. Furthermore, the empirical and theoretical explorations of call flow statistical modeling lend credence to the possible use of probabilistic methods for use in service demand forecasting and readiness planning. Future studies can increase the sample size by including many fire stations, longer time periods, and more explanatory variables such as actual and theoretical traffic density, road geometry, and type of incidents, as well as adopting more sophisticated modelling based on geoinformation to create more precise predictive response maps for urban emergency management.

References:

- [1] S. M. Makhmudov, *Organizing Management in the Activities of the State Fire Safety Service*. Tashkent, Uzbekistan: YOKHOTM, 2010.
- [2] German specialists, "Study of Road Traffic Speed on the Streets of Berlin." Berlin, Germany, 2013.
- [3] Research group, "Observations of Traffic Movement in London, Warsaw, Rome, and Paris." London, UK, 2014.
- [4] Moscow Urban Safety Analysts, "Analysis of Road Traffic Speed in the City of Moscow Based on a Geoinformation System." Moscow, Russia, 2015.
- [5] A. M. M. Awad, "Optimization of New Fire Department Location Using an Optimization Approach to Improve Response Time and Service Coverage," *Int. J. Emerg. Serv.*, vol. 13, no. 1, pp. 80–99, 2024.
- [6] YOKHOTM, *Fire Suppression Leader: Data Collection*. Tashkent, Uzbekistan: YOKHOTM, 2010.
- [7] YOKHOTM, *Organizational and Managerial Decisions: Optimization of Depots and Speed*. Tashkent, Uzbekistan: YOKHOTM, 2012.
- [8] National Fire Protection Association (NFPA), *NFPA 1710: Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, 2020 edition. Quincy, MA, USA, 2020.

- [9] International Organization for Standardization (ISO), *ISO 22320:2018 Security and Resilience: Emergency Management, Guidelines for Incident Management*. Geneva, Switzerland, 2018.
- [10] L. Tao, X. Wang, Y. Li, and J. Zhou, "Location Optimization of Urban Fire Stations Considering Backup Coverage," *Int. J. Environ. Res. Public Health*, vol. 19, no. 24, p. 16815, 2022.
- [11] R. Church and C. ReVelle, "The Maximal Covering Location Problem," *Pap. Reg. Sci.*, vol. 32, no. 1, pp. 101–118, 1974.
- [12] C. ReVelle and K. Hogan, "The Maximum Availability Location Problem," *Transp. Sci.*, vol. 23, no. 3, pp. 192–200, 1989.
- [13] V. Marianov and C. ReVelle, "A Model for the Siting of Emergency Vehicles," *Eur. J. Oper. Res.*, vol. 93, no. 3, pp. 452–458, 1996.
- [14] M. A. Badri, "A Multi-Objective Model for Locating Fire Stations," *Eur. J. Oper. Res.*, vol. 110, no. 2, pp. 243–260, 1998.
- [15] J. Yao, Y. Yang, J. Chen, and F. Liang, "Location Optimization of Urban Fire Stations: Access and Service Coverage," *Comput. Environ. Urban Syst.*, vol. 73, pp. 184–190, 2019.