

# Chapter 1


## Enhancing Vehicular Communication Through Neutrosophic Queueing Theory and Network Analysis–Based Traffic Signal Optimization

**M. Clement Joe Anand**

 <https://orcid.org/0000-0002-1959-7631>

*Mount Carmel College, Bengaluru,  
India*

**V. A. Anjana**

 <https://orcid.org/0009-0002-7573-2356>


*Mount Carmel College, Bengaluru,  
India*

**Manokamana Agarwal**

 <https://orcid.org/0000-0001-5083-7384>

*Silver Oak College of Engineering and  
Technology, Silver Oak University,  
India*

**Utpal Saikia**

 <https://orcid.org/0000-0003-0235-6871>

*Silapathar College, India*

**B. Ranjitha**

*Mohan Babu University, India*

**Chitra Ramaprakash**

 <https://orcid.org/0000-0002-0421-2479>

*Dayananda Sagar College of  
Engineering, India*

### ABSTRACT

*This chapter explores the integration of Neutrosophic Queueing Theory (NQT) and Neutrosophic Network Analysis (NNA) into the realm of vehicular communication at traffic signals to address the uncertainties and complexities of traffic flow, including*

DOI: 10.4018/979-8-3693-6422-2.ch001

*variable arrival rates, unpredictable service times, and dynamic network conditions. Using real-world traffic data, a neutrosophic queueing model is developed to optimize traffic signal timings specifically for enhancing vehicular communication by determining key traffic parameters such as traffic intensity, the probability of crossing the signal, and various performance measures emphasizing the expected waiting time and queue length. Also proposes a novel framework that integrates NNA into the design and optimization of communication protocols for vehicles at traffic signals with the help of the score function and modified Kruskal's algorithm. The results demonstrate significant improvements in communication reliability, reduced latency, and enhanced system throughput, highlighting the effectiveness of the proposed approach in enhancing vehicular communication efficiency.*

## **1. INTRODUCTION**

Queuing theory is a branch of mathematics and operations research developed by Erlang (1918), that focuses on the study of queues, which are waiting lines or systems where entities such as customers, jobs, or data packets arrive, wait in line for service, and then depart after being served. It's widely used in various fields such as telecommunications, computer networks, transportation, healthcare, and manufacturing to analyze and optimize the performance of systems involving waiting and service. Queuing theory finds extensive application in traffic engineering and transportation systems (Manoj et al., 2019) to analyze and optimize traffic flow, manage congestion, and improve overall system efficiency. In the context of traffic, queuing theory deals with the analysis of queues formed by vehicles at intersections, toll booths, traffic signals, parking lots, and other points where vehicles may wait in line for movement or service. Queuing theory was integrated with fuzzy set theory (Chen & Eur, 2009) in order to handle the uncertainties in the real-world. In fuzzy queuing models, the arrival rates and service times are expressed as fuzzy numbers characterized by membership functions. This approach allowed for a more realistic representation of systems with uncertain parameters. Recently neutrosophic set theory which was introduced by Florentin Smarandache (1999; 2002; 2005) in the 1990s, was also incorporated with queuing theory. This is extremely useful in environments with highly unpredictable and contradictory information. Neutrosophic queuing model (Mohamed, 2020a; 2020b) is a relatively recent development in the field of queuing theory and uncertainty modeling. Now it is a branch of mathematics that deals with the analysis and modeling of queues, particularly in traffic systems, using neutrosophic logic. Neutrosophic logic is an extension of fuzzy logic that allows for the representation of indeterminacy, uncertainty, and imprecise information. In the context of traffic systems, neutrosophic queuing theory helps in understanding

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