https://doi.org/10.22306/al.v12i4.699 *Received: 29 Mar. 2025; Revised: 21 Oct. 2025; Accepted: 06 Nov. 2025*

NetLogo for transport and logistics: agent-based modeling of flows, control, and operations

Duy-Thoi Do
Faculty of Civil Engineering, Ho Chi Minh City University of Technology and Education, Vo Van Ngan Street, Thu Duc Ward, Ho Chi Minh City, Vietnam, dthoidd.ncs@hcmute.edu.vn
Vu-Tu Tran
Faculty of Civil Engineering, Ho Chi Minh City University of Technology and Education, Vo Van Ngan Street, Thu Duc Ward, Ho Chi Minh City, Vietnam, tutv@hcmute.edu.vn (corresponding author)

Keywords: NetLogo simulation, agent-based modelling (ABM), transport and logistics systems, traffic-flow optimisation, multi-scale and behavioural modelling.

Abstract: NetLogo is widely used for agent-based simulation of transport and logistics because it is open, flexible, and fast to prototype. This review synthesizes peer-reviewed studies on NetLogo across four application streams: (a) Intelligent Transport Systems (ITS) and flow optimisation; (b) Public-transport operations and evacuation management; (c) Traffic-control, energy use, emissions analysis; and (d) Driver/vehicle behaviors and connected/autonomous vehicle modelling. We map how agent rules, interaction topologies, and calibration choices shape material, information, and human flows across networks and terminals, and how they inform transport operations, distribution logistics, and supply chain decisions. A thematic synthesis highlights five recurring gaps: (1) Oversimplified agent size/geometry; (2) Limited behavioral realism for drivers, passengers, and controllers; (3) Weak mesoscopic linking between macro demand and micro operations; (4) Short time horizons for dynamics of congestion and energy; and (5) Incomplete calibration-verification-validation. We propose a logistics-oriented research agenda: multi-scale coupling (macro–meso–micro), behavior learning with ML, real-time digital-twin use cases, standardized CV&V protocols, and energy-emissions co-metrics. The review clarifies where NetLogo adds value to transport logistics - rapid what-if testing of control policies, routing, and terminal operations - while outlining steps needed for rigorous, decision-grade models.

1 Introduction

Transportation is the lifeblood of a country's economy. Viewed through a logistics lens, transport systems organise material, information, and human flows across networks and terminals, shaping throughput, dwell times, reliability, and energy/emissions. Along with advances in computing, multi-agent modelling (ABM) has been used widely in sociology, medicine, finance, agriculture, and transportation to encode agent interactions and reproduce real-world phenomena with transparent rules.

In traffic and transport engineering, common simulators include PARAMICS, VISSIM, VISUM, and NetLogo. While each tool has distinct strengths, NetLogo is open, simple, and flexible, enabling rapid prototyping of transport operations and control policies with practical applications across diverse problems. This review examines recent NetLogo-based studies in transport, highlights their features and advantages, diagnoses gaps, and proposes directions that better connect traffic modelling to logistics and supply-chain decision-making. This article aims at:

- Providing an overview of NetLogo as a multi-agent platform for transport.
- Classifying the main research directions applying the multi-agent model on the Netlogo platform to the field of transportation.
- Proposing future directions for Netlogo-based multi-agent model research and application for transportation.

The article is organised as follows: Section 2 details the review scope and protocol; Section 3 presents a thematic synthesis of NetLogo applications; Section 4 discusses implications for transportation, logistics and limitations; Section 5 concludes with future research directions.

2 Literature review and review protocol

This section first outlines the scope and protocol of the review and then introduces the fundamentals of multi-agent modelling on the NetLogo platform. Peer-reviewed papers were collected from Web of Science, Scopus, and Google Scholar using the combined keywords “NetLogo”, “agent-based model”, and “transportation”. Publications from 2010 onward were screened by title and abstract, excluding purely technical or non-transport studies. The final corpus was coded according to application domain, model type, and evaluation focus, forming the basis for the thematic synthesis presented in the next section.

Agent-based models are used to simulate the behavior and interactions of autonomous agents to evaluate the overall impact on the system as well as to investigate the emergent and collective effects on the system[1]. Multi-agent modeling platforms use communication ways and customisable characteristics to interact and coordinate many independent agents in the simulation environment.

Each agent can adapt and has unique traits that demonstrate independence and flexibility.
The process of building a multi-agent model in NetLogo is illustrated in Figure 1

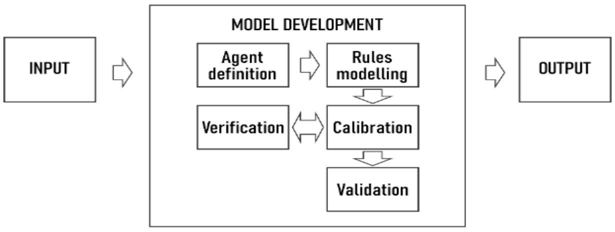

Figure 1 The process of building a multi-agent model in NetLogo

It includes three steps: input, model development, and output. The input and output steps define objectives and report results, while model development begins with defining agents and their behaviours. Rule modelling captures agent interactions based on real-world data to meet the research goals [2]. In microscopic models applying multi-agent platforms, many research studies focused on simulating rules related to motion behaviour, motion efficiency, acceleration, deceleration or lane changing behaviour of agents. The calibration and verification steps are done simultaneously to validate the validity and accuracy with real-world behaviours.

Process-based multi-agent platforms simulate complex real-world events to address large-scale problems. Common simulators include StarLogo, SUMO, Matlab, AgentSheets, Swarm, Repast, TNG Lab, Asape, AnyLogic, and GAMA. Among these, NetLogo is widely used because it supports both simple and complex models with a flexible language and diverse built-in tools. A brief summary of the NetLogo toolkit is provided in Table 1.

Table 1 Agent-based NetLogo software toolset

Programming language	Scalability	Scope of application	Website	Main features and advantages
Netlogo	Desktop Computing	Social and natural science	https://ccl.northwestern.edu/netlogo/	- Multiple built-in agent types - Extensive model libraries - Exploration of interface elements - Flexible model building and modification

Source: [3]

3 Main findings and thematic synthesis

This section synthesises the main findings from the reviewed literature on NetLogo-based transport simulations, focusing on goals, functions, strengths, and gaps identified across studies. Based on the review protocol described in Section 2, four dominant research themes were observed in Figure 2.

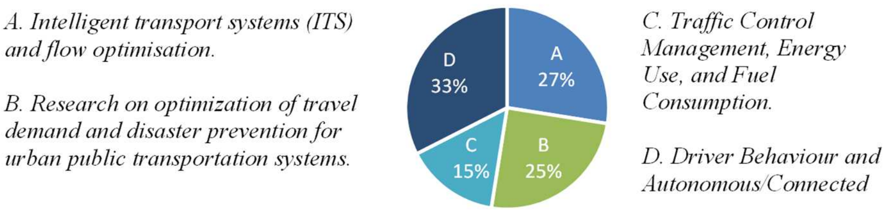

Figure 2 Classification chart for Netlogo based research in the field of transportation

As shown in Figure 2, studies focusing on driver behavior and connected/autonomous vehicles account for the largest proportion - approximately 33% of the analyzed publications. This finding is reasonable, as NetLogo is an easy-to-use programming language that offers high flexibility in simulating interactions, making it particularly suitable for modeling vehicle behavior. The second major research direction involves the application of artificial intelligence (AI) technologies in Intelligent Transportation Systems (ITS), representing 27% of the analyzed publications. The remaining research topics account for 25% and 15%, corresponding to studies on travel demand optimization and disaster prevention, and those examining the impacts of traffic control management and fuel consumption, respectively. These themes represent the principal directions in which NetLogo has been applied to model material and human flows, operational control, and system performance within transportation and logistics contexts.

3.1 Intelligent transport systems (ITS) and flow optimisation

The research on Intelligent Transportation Systems (ITS) and flow optimisation has been analyzed. Table 2 presents several representative studies, including their research objectives, agent types, strengths, and limitations.

Typically, Jerry and his research team [4] were inspired by Ant Colony Optimisation (ACO) to model the traffic control problem as a Multi-Agent Multi-Purpose (MAMP) system, in which traffic flow information is collected and shared through a Distributed Intelligent Traffic System (DITS). The model was examined under two scenarios: one employing ACO and the other without ACO (Figure 3). Through this framework, the study compared the influence of ACO on the effectiveness of traffic management solutions.

Table 2 Typical studies using ITS to optimize traffic flow

Articles	Research objectives	Agent types/Attributes	Strengths of the study	Shortcomings
[4]	Control and optimize traffic flow	Vehicle agents Intersection agent Decentralized	The ACO algorithm. The distributed intelligent traffic system.	Single type of vehicle agents Not considering variables like trace volatility rate.
[5]	Urban Traffic Simulation and control the traffic signal	Vehicle Agent, Intersection agent/Knowledge, autonomy, interaction and communication	Dynamic multi-agent traffic simulation system Interaction-based dynamic signal control analyzes real-time and forecast traffic flow from road agents.	The association from different. Intersections are ignored to predict road agent traffic flow. Single type of vehicle agents.
[6]	Traffic control	Autonomous agents Traffic Signal Control agents	ATSC system development. Q-Learning Algorithm.	Need real data for validation.
[7]	Simulate and optimize urban traffic network	Car agents, Traveler agents, Intersection agent	IPSO approach method. Applying linear stability with nonlinear theories.	Simple network Many issues, like traffic laws, are overlooked.
[8, 9]	Multiple-intersection traffic control by ITS	Vehicle agents, Road agents Controller agents	IoT technology. Cooperative game theoretic algorithms.	More research is needed on driver psychology. Multi-intersection traffic light algorithm
[10]	Cooperating vehicles minimize traffic congestion.	Nodes agent, Directed links HGV agents, Traffic behavior properties	V2V Smart and V2I protocols. Routing algorithms Case study on real network in Spanish	Behavioral studies for each vehicle agent are necessary expanded.

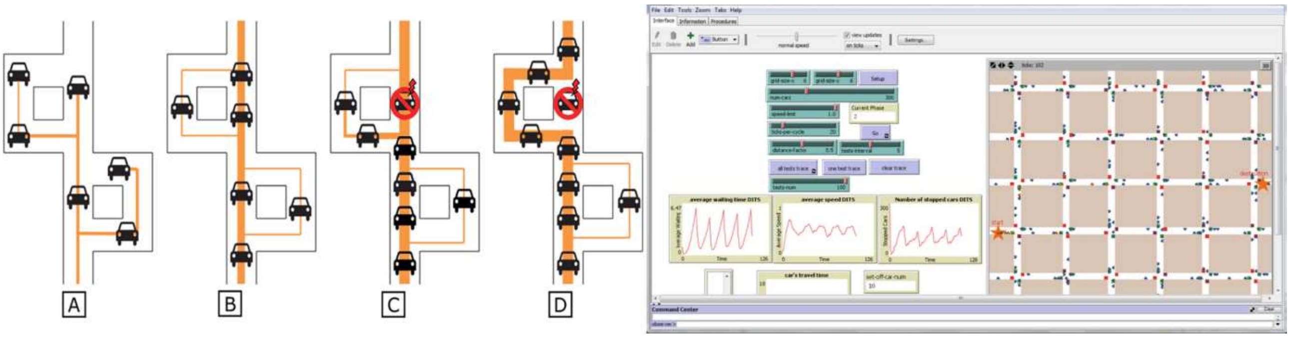

Figure 3 Ant Colony Optimisation (ACO) schematic and NetLogo DITS-ACO model interface, (Source: [4])

Figure 4 illustrates the simulation flow diagram of the NetLogo DITS–ACO model. The diagram illustrates the main operational sequence of the model, in which road topology and traffic density are dynamically varied to evaluate system performance. At each simulation interval, the average vehicle speed, waiting time, and queue length are recorded and plotted against time to assess the effectiveness of the Ant Colony Optimisation (ACO) algorithm in improving traffic flow efficiency.

Another ACO-based study [8] examined dynamic traffic routing for connected vehicles with different origins and destinations. Based on NetLogo simulations, the proposed strategy significantly reduced the average journey time compared with the conventional shortest-path routing method. By applying Intelligent Transportation Systems (ITS) technology, a research group [5] modelled a road section with signalised intersections, integrating traffic analysis functions into intersection agents to calculate optimal signal timings in real time and evaluate their effectiveness. Similarly, Santos and his team [10] demonstrated that model-driven development for multi-agent-based adaptive traffic signal control (ATSC) reduces the workload involved in developing NetLogo simulations for traffic flow optimisation.

In another study, some authors [7] employed Intelligent Particle Swarm Optimisation (IPSO) to enhance traffic flow and developed a single-lane NetLogo traffic grid model to predict traffic performance. Likewise, other researchers [11] constructed a NetLogo model with 25 intersections to assess the system's effectiveness in reducing vehicle waiting times. Building on cooperative game theory, Nam Bui and Jung [9] utilised NetLogo to simulate a road network aimed at minimising junction waiting times and proposed integrating the Internet of Things (IoT) into the system.

Figure 5 illustrates how the cooperative game-based model introduces an algorithm to interconnect urban transportation network intersections.

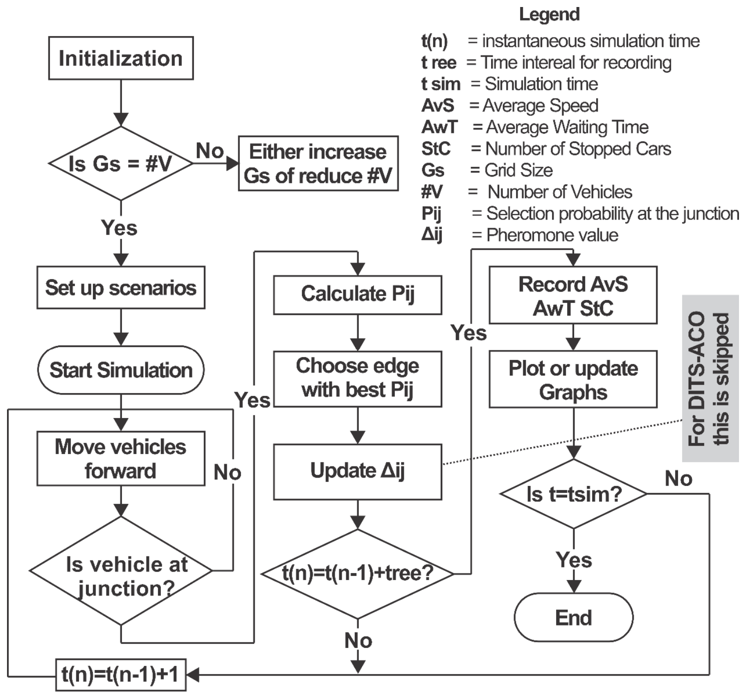

Figure 4 Flowchart of the NetLogo DITS–ACO simulation process showing initialisation, vehicle movement, pheromone updating, and performance recording, (Source: [7])

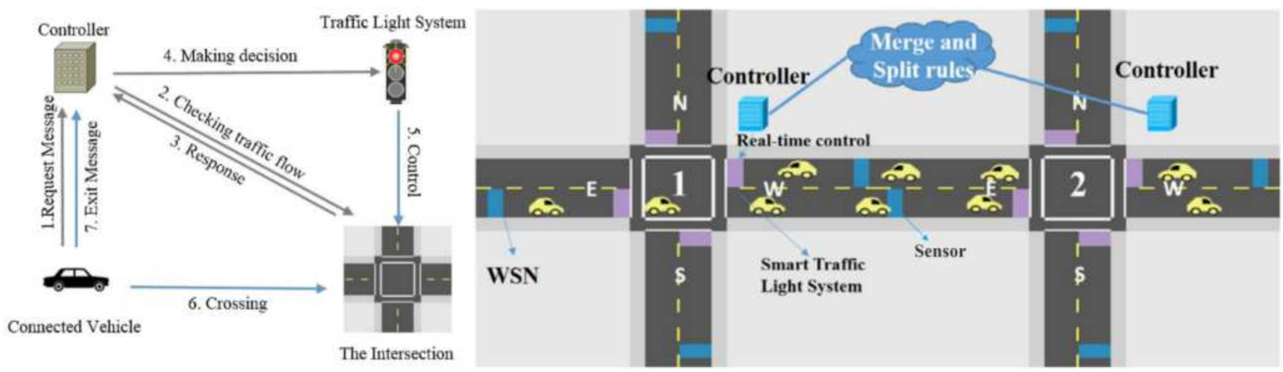

Figure 5 Cooperative game–based model for urban traffic control using the Internet of Things (IoT), (Source: [13])

A study [10] employed NetLogo's multi-agent modelling framework to evaluate the Vehicle-to-Everything (V2X) communication traffic system, which integrates Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications to estimate trip performance and alleviate traffic congestion (Figure 6). Using real-time traffic data, Zhu Chaolei and his research team [12] proposed a merging-zone congestion mitigation approach that ensures driving safety and provides lane-entry guidance based on dynamic traffic conditions.

In addition, Wang developed the Cell Transmission Model (CTM) and Dynamic Graph Hybrid Automata (DGHA) models to estimate traffic density and construct a real-time dynamic traffic state within an urban transport network using NetLogo [13].

Taken together, these ITS studies show that NetLogo enables rapid prototyping of control and routing strategies that measurably reduce delay, queue length, and journey time - key indicators of operational performance in transport-logistics systems. However, many models rely on simplified network geometries and limited behavioural calibration, which constrains transferability to decision-grade applications and to energy/emissions co-metrics. These insights motivate the next subsections on public-transport operations, energy use, and driver behaviour, where the logistics relevance and validation needs become more pronounced.

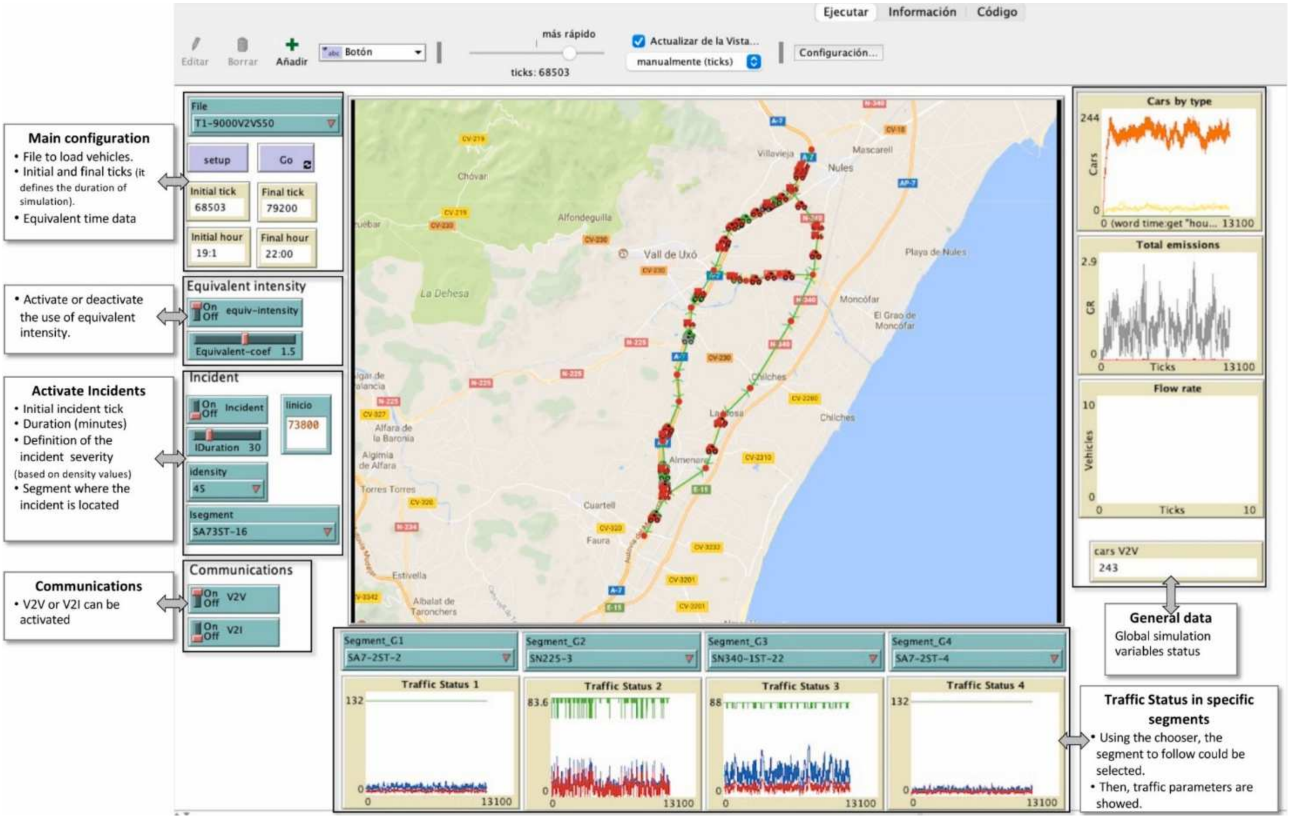

Figure 6 Multi-agent V2X communication model in NetLogo integrating V2V and V2I systems for traffic flow optimisation and congestion reduction, (Source: [9])

3.2 Research on the optimisation of travel demand and disaster prevention in urban public transport systems

Public transport carries large numbers of passengers efficiently and safely, reducing congestion and improving urban living conditions. Within transport logistics systems, it plays a crucial role in organising and maintaining continuous human flows across networks and stations. Several representative studies employing NetLogo to optimise travel demand and support disaster prevention are summarised in Table 3.

Table 3 Some typical studies on optimisation of travel demand and disaster prevention

Articles	Research purposes	Agent types/Attributes	Strengths of the study	Shortcomings
[14]	Optimising passenger demand and service in URT	Network agents Train agent Station agent Passenger agents Route agents	Modelling URT network Modeling dynamic passenger traffic demand/service supply of train with agents.	Requires large-scale real data for validation; Passenger-agent behaviour needs to be more complex
[15]	Optimisation of Bus Transit Lines	Bus agent. Station agent. Traveler agent. Bus operating/ pausing.	Updating operating parameters and cost statistics. Change departure and stopping distances to improve operations.	Needs consideration of other vehicle agents; single-vehicle behaviour
[16]	Subway station evacuation simulation	Train agents, Passenger agents Agents' behavior Passenger choice	Case study on real station (L'Enfant Metro Station- Washington, DC)	Requires event-specific studies for customised analysis
[17]	Simulating metro station evacuation. route choice	Autonomous agents Passenger agents Agents' behavior	Shortest-path exit choice algorithm. Multinomial / Modified multinomial logit model	Need big real data for calculating MNL value
[18]	Highway tunnel emergency rescue simulation	Environmental agents, rescued waiting agents, and rescuer agents	Support emergency evacuation planning. Showing realistic agents' moving behaviors during emergency situations.	Need further study of psychological characteristics affecting rescued persons' behaviors.

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Urban public transport systems are designed to meet travel demand. However, determining the appropriate number of stops, their spacing, and the optimal bus schedule remains a challenge. Several studies have employed NetLogo to simulate and propose stop-location strategies aimed at enhancing network efficiency, or to apply overall system cost criteria in evaluating the effectiveness of bus operations [15]. The agent-based simulation framework is illustrated in Figure 7.

Figure 7 Netlogo's bus transit line agent-based simulation and visual user interface, (Source: [15])

Some scholars used NetLogo to model and provide solutions for metropolitan public-transport disasters. For tunnel-collapse rescues, Yu and colleagues simulated tunnel-collapse scenarios using tunnel, rescued, and rescue agents [18]. Regarding subway stations, Zou et al. developed an agent-based model (ABM) to study evacuation scenarios in a typical underground station [16], considering critical parameters such as the number of trains, passengers, stairs, ticket gates, exits, and destination choices. Other research teams [19] simulated station evacuations incorporating psychological and behavioural features, while Liu Xiaoding used NetLogo to simulate pedestrian flows at intermittent stations [20], aiming to optimise crowd management. Additional research on urban railway networks focused on customer behaviour at transfer stations and on optimising operational management [14], both exploiting NetLogo's adaptability for complex multi-agent scenarios.

These studies demonstrate that NetLogo provides a practical and flexible platform for analysing passenger-flow logistics, evacuation strategies, and public-transport operations. Its capability to represent heterogeneous agents and simulate dynamic responses enables researchers to link behavioural processes with operational performance indicators such as throughput, dwell time, and evacuation efficiency - establishing an important bridge between transport modelling and urban logistics management.

3.3 *Traffic control management, energy use, and fuel consumption*

Transport systems consume substantial amounts of energy and contribute to congestion and pollution. Studying traffic-control mechanisms that reduce fuel consumption and emissions is therefore essential for sustainable development and efficient transport logistics operations [21]. Typical related studies employing NetLogo are summarised in Table 4.

Table 4 Typical studies related to traffic control management and fuel consumption

Articles	Research purposes	Agent types/Attributes	Strengths of the study	Shortcomings
[22]	Optimized cost and fuel with dynamic carpooling	Driver agent Passenger agent The carpooling Decentralized optimization	The matching algorithm Optimization algorithms.	Need implement the model in a real road network region to confirm its efficacy.
[23]	Analyzed traffic density, speed, and fuel usage.	Vehicle agent Road agents/ Agents rule and behavior Coordination of signals.	Case study on real network (Lilongwe city) Update traffic, cost, and fuel statistics. Studying double lanes to evaluate its efficacy. Cellular automata model	Car length set at 7.5 m in CA model, whereas actual average is 4.5 m
[24]	Traffic management to save cargo transit energy	Government agent Transportation enterprise agent Cargo owner agent	Q-learning algorithm. Develop a simulation model to adjust transportation costs	The energy consumption system of freight transportation is complex. However, this article solely uses transportation cost as an indicator coefficient.

Several studies have proposed carpooling strategies to optimise traffic efficiency and reduce fuel consumption within multi-agent simulations [22], or have developed traffic–fuel interaction models using NetLogo [23]. Other research applied mathematical approaches to junction control and model selection, combining NetLogo, Aimsun, and MATLAB environments [25]. To investigate transport energy systems, some authors created NetLogo-based models for traffic-management optimisation, aiming to minimise total energy use and transport costs [24], while others designed commodity supply-chain models with port clusters to optimise transportation costs and profit [26]. The simulation interface of a representative study is illustrated in Figure 8.

Figure 8 Multi-agent Transport Cost Adjustment System for transportation enterprises, (Source:[30])

The reviewed studies confirm that NetLogo offers an adaptable platform for linking traffic control, energy efficiency, and logistics cost management. By representing vehicles, enterprises, and government authorities as interactive agents, researchers can explore the dynamic feedbacks among fuel consumption, transport costs, and supply-chain performance. However, most existing models remain conceptual and rely on simplified indicators such as cost coefficients or idealised agent behaviours. Future work should integrate empirical fuel–flow data and cross-scale coupling to evaluate both environmental impacts and logistics operational performance more accurately.

3.4 Driver behaviour and autonomous/connected vehicle modelling

Understanding vehicle and driver behaviour in traffic systems is crucial for improving flow efficiency, safety, and overall transport-logistics performance [27]. Studies adopting NetLogo to model vehicle interactions, decision-making, and communication systems are summarised in Table 5.

Table 5 Some typical studies using the Netlogo platform for vehicle behavior

Articles	Research purposes	Agent types/Attributes	Strengths of the study	Shortcomings
[28]	Assessing the impact of heterogeneous traffic.	Vehicles agent. Stationaly agents. Vehicle behavior.	Car-following model IDM. Lane-changing model MOBIL. Human Driver Model.	All vehicles have same size, patience and error characteristics. All vehicles accelerate similarly.
[29]	Autonomous vehicle intersection traffic control.	Autonomous vehicle agents Intersection, Vehicle agents rule	Vehicle platoon optimization algorithm. Rolling Window Time Control Strategy Based on Greedy Algorithm.	Conducted at an isolated intersection; requires extension to larger networks
[30]	Traffic management - driver and vehicle behavior in VANET.	Vehicle agent/ Road network includes intersections, and vehicle behavior rules.	P-AOC modeling method.	Requires inclusion of more parameters and communication protocols in vehicular ad hoc networks
[31]	Cooperative lane-changing model at intersections.	Driving agents / Cooperation lane-changing behavior for vehicles.	Intersection cooperative lane-changing reinforcement-learning algorithm; QuickBundles algorithm	Need consider the vehicle's lane changing behavior at consecutive traffic intersections.
[32]	Effects of different driver types on traffic	Vehicle–driver agents (law-abiding, deviant, non-myopic, aggressive)	Development of traffic models with different types of driving behavior Case study on a real highway (Ontario)	Does not incorporate accident-incidence analysis

As shown in Table 5, driving behaviour has been modelled and compared across different countries using NetLogo [28]. The impact of autonomous-vehicle behaviour on overall flow operations has also been examined [29]. Some studies analysed the distribution of travel time for each autonomous vehicle in NetLogo to control and improve intersection flow based on behavioural attributes. In addition, several researchers modelled vehicular ad hoc networks (VANETs) to investigate communication dynamics and to promote safe driving and early-warning mechanisms [30]. Other scholars [33] used NetLogo to build heterogeneous traffic-flow models to study driver behaviour using indicators such as vehicle-speed index, lane-allocation ratio, lane-change patience, accident rate, and driver-distraction index.

Related to mixed-traffic conditions, NetLogo has been used to simulate motorcycles, cars, and buses operating simultaneously in Vietnamese cities [34], highlighting the complexity of behavioural heterogeneity in developing countries. Such simulations have supported efforts to improve traffic efficiency under diverse driver habits and infrastructure constraints. A representative NetLogo interface is presented in Figure 9.

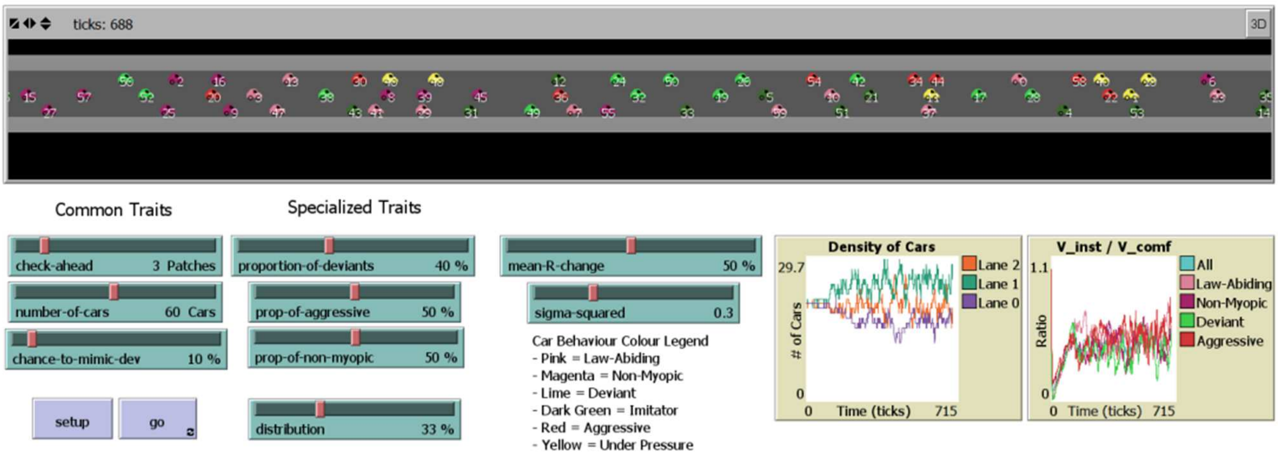

Figure 9 General interface of the NetLogo model, (Source: [32])

The outcomes of these multi-agent simulations demonstrate that traffic performance is shaped not only by vehicle types but also by the interactions and adaptive learning of drivers. For example, Yao and colleagues [31] applied game theory to develop a cooperative lane-changing model in NetLogo, investigating how collaboration among drivers can enhance traffic efficiency. The logic flow and interface of this model are shown in Figure 10.

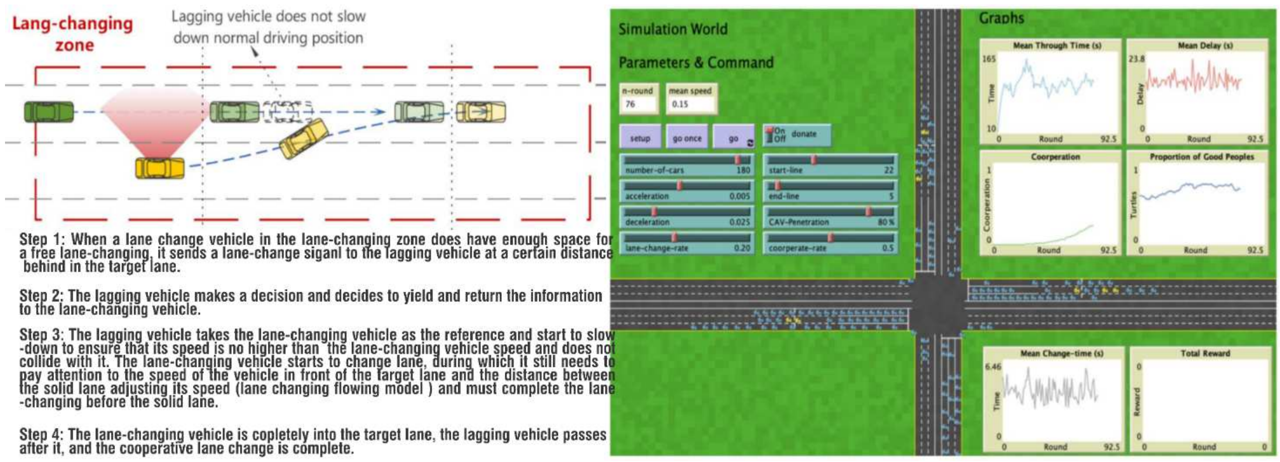

Figure 10 Cooperative lane-changing model logic flow and NetLogo interface, (Source: [31])

Additional experiments further refined heterogeneous-traffic models by varying driver patience and interaction mechanisms, while others incorporated behavioural rules for acceleration, deceleration, and lane-changing to explore spatio-temporal dynamics in traffic flow. To evaluate the influence of autonomous vehicles in mixed manual–autonomous traffic conditions, Chen et al. (2023) developed a simulation model for mixed traffic flow in diverging off-ramp areas, analysing how different penetration rates of connected autonomous vehicles (CAVs) affect traffic safety and efficiency[35].

Overall, these studies confirm that NetLogo is a flexible and transparent platform for analysing driver–vehicle interactions in both conventional and connected environments. By modelling behavioural diversity and adaptive cooperation, it offers valuable insights for traffic-control strategies, fleet operations, and transport-logistics optimisation. However, most studies still employ simplified physical assumptions and lack integration with empirical driver data, limiting direct application in real-world logistics planning - a challenge that will be further discussed in the next section.

4 Discussion and implications for transportation and logistics

This section discusses the limitations and lessons drawn from previous NetLogo-based transport studies and highlights their implications for both transportation planning and logistics operations. The discussion synthesises methodological shortcomings, modelling constraints, and future research opportunities identified across the reviewed literature. Figure 11 illustrates the five main categories of limitations identified from the reviewed studies, which are discussed in detail below.

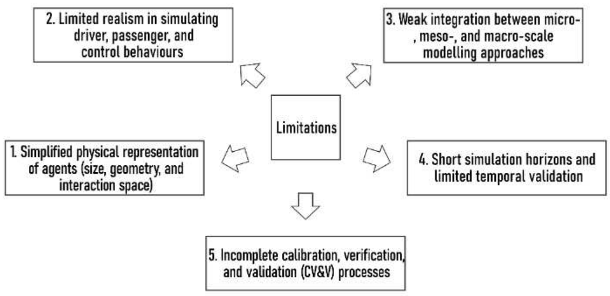

Figure 11 Key limitations of NetLogo-based transportation modelling

Although NetLogo offers transparency, simplicity, and flexibility in agent-based traffic modelling, several limitations are apparent when applied to complex, real-world transport systems.

4.1 Limitations related to the physical dimension modelling of agents

The physical size and shape of mobile agents in transportation systems directly affect their movement and interactions. For simplicity, most NetLogo-based models assume that all mobile agents are identical in size and occupy a single patch or point. However, the effects of agent dimensions on simulation accuracy have rarely been examined.

In some previous simulations of heterogeneous traffic flows, trucks and cars were often modeled as agents of equal size for simplicity. In practice, however, trucks are considerably larger than cars, and the safe distances for acceleration, deceleration, and lane-changing should be determined based on the full vehicle length rather than a single central point. Such dimensional differences were frequently overlooked due to programming constraints and model simplifications.

Such simplification, while computationally convenient, reduces the model's ability to represent realistic spatial interactions and traffic-density effects. It also weakens the applicability of simulation results to transport-logistics operations, where vehicle size, cargo load, and clearance distances critically determine throughput and safety. Future studies should therefore develop more refined representations of agent dimensions and evaluate their influence on model accuracy and flow efficiency.

4.2 Limitations in simulating the actions and reactions of driver, passenger, and control agents

The accuracy of multi-agent traffic simulations depends largely on how effectively the behaviours, decisions, and reactions of individual agents are represented. In most NetLogo-based studies, driver, passenger, and control agents are modelled using simplified rule sets with limited behavioural diversity. These rules usually assume homogeneous reactions to stimuli such as congestion, signals, or other vehicles, thereby underestimating the variability of human decision-making in real transport environments.

Although such simplification reduces computational cost and improves visual clarity, it restricts the capacity of the model to reproduce interactive dynamics between different categories of agents. For instance, the interactions between passengers and control agents during boarding or evacuation, or between human-driven and autonomous vehicles in mixed traffic, are rarely calibrated using empirical data. Most models lack a feedback mechanism to simulate delayed or adaptive responses, resulting in deterministic and overly stable flow patterns.

These limitations diminish the model's usefulness for analysing behaviour-sensitive logistics and transport operations, where driver response time, passenger boarding patterns, and signal-control adaptation significantly affect throughput and reliability. Future research should incorporate richer behavioural datasets - derived from field observations, sensors, or trajectory data - to refine agent-response functions. Integrating machine-learning or reinforcement-learning algorithms could further enhance behavioural realism, enabling more accurate assessment of operational performance and decision-making in transport-logistics systems.

4.3 Limitations in the scale approach for traffic modeling

NetLogo can simulate transport systems at either the microscopic or macroscopic level. However, a macro-level simulation that simultaneously accounts for detailed agent behaviours and dynamic interactions becomes computationally intensive and may significantly slow down the model, especially when large numbers of agents and dense traffic networks are involved. Consequently, most previous researchers have tended to adopt one of the two scales - micro or macro - rather than attempting to integrate them. The majority of existing NetLogo-based traffic studies employ microscopic modelling, which focuses on the behaviour and interactions of individual agents. While this approach captures local dynamics effectively, it restricts the capacity to evaluate system-wide performance such as network throughput, congestion propagation, and service reliability. Conversely, macro-level models describe aggregate flow patterns but fail to represent driver heterogeneity or lane-level dynamics. As a result, the macro-to-micro evaluation of the overall transportation system remains limited.

To bridge the gap between these two scales, some researchers have explored an intermediate mesoscopic (meso) modelling approach, combining the aggregated efficiency of macro models with the behavioural detail of micro models. Nevertheless, experiments using NetLogo at this level remain scarce due to the lack of standardised interfaces and the computational cost of cross-scale data transfer. Conceptually, macro-, meso-, and micro-models form a continuum, linking large-scale system efficiency with individual behavioural dynamics through intermediate mesoscopic representations.

NetLogo's increasing connectivity with other analytical toolkits - such as GIS, optimisation solvers, and machine-learning platforms - offers opportunities to develop multi-scale hybrid models. These integrations will enable future research to analyse transportation and logistics systems more comprehensively, linking micro-level agent decisions with macro-level flow, cost, and energy performance indicators. Such coupling is essential for supporting strategic transport-logistics planning and sustainable system design.

4.4 Limitations in the time-based approach to traffic modelling

Temporal resolution is a crucial element in simulating transport systems, as the timing of events determines the accuracy of flow evolution and system performance. In most NetLogo-based studies, time is represented through discrete ticks rather than continuous processes. While this discrete-time structure simplifies computation and visualisation, it constrains the ability to represent dynamic variations in traffic demand, driver reactions, and control adjustments over extended periods.

Many models employ short simulation horizons, typically focusing on seconds or minutes of system activity. As a result, long-term variations in travel demand, congestion accumulation, or vehicle emissions are rarely captured. Simplified time steps also prevent the models from representing feedback loops between network performance and behavioural adaptation - such as changes in departure time, route choice, or vehicle utilisation. These simplifications reduce the realism of simulations, particularly when analysing logistics operations that depend on scheduling accuracy, delivery reliability, and cumulative fuel consumption.

The absence of consistent temporal calibration and validation further limits the generalisability of results. Few studies compare simulated and observed flow patterns across different times of day or traffic conditions. For logistics and transport planning, this shortcoming weakens the potential of NetLogo models to support timetable optimisation, shift scheduling, or demand forecasting. Future research should therefore develop multi-temporal modelling frameworks that integrate real-time or longitudinal datasets, enabling a better understanding of transport dynamics, congestion cycles, and time-dependent logistics efficiency.

4.5 The calibration, verification and validation (CV&V) procedures are limited and incomplete

Calibration, verification, and validation (CV&V) are essential for ensuring the credibility and applicability of simulation outcomes. However, due to the large scale of models, limited funding, licensing constraints, and deployment time, most NetLogo-based traffic studies rely primarily on computational outputs without systematic testing against real-world data. As a result, many models remain unverified and uncalibrated, reducing their relevance to actual traffic conditions. Only 17.5% of the studies reviewed in this article reported explicit CV&V procedures. A comparison between calibrated–validated and non-calibrated–validated studies is presented in Figure 12.

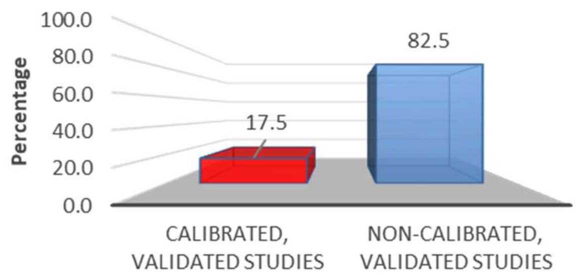

Figure 12 Comparison histogram of calibrated, validated and non-calibrated studies

Although a few studies conducted partial validation, their influence on model accuracy and interpretation of results was rarely discussed. To ensure feasibility and correctness, future research should prioritise systematic calibration, verification, and validation, and compare simulated outputs with empirical observations to strengthen the reliability of transport and logistics simulations. In summary, this limitations expose key methodological gaps in NetLogo-based transport studies and their logistics applicability. The next section distils our conclusions and outlines concise, data-driven, multi-scale directions for logistics-oriented simulation research.

5 Conclusions and future research

This review confirms that NetLogo is a powerful and accessible platform for simulating transport systems through an agent-based modelling approach. Its open architecture, ease of customisation, and rich model libraries enable researchers to prototype traffic and logistics scenarios rapidly and cost-effectively. Across the reviewed studies, NetLogo has been applied to a broad range of topics, including: (a) Intelligent-transport systems

(ITS), (b) Public-transport operations and evacuation, (c) Traffic control and energy efficiency, and driver and (d) Vehicle behaviour. Collectively, these applications demonstrate the platform's capacity to represent material, information, and human flows, supporting both transportation analysis and logistics decision-making.

At the same time, five recurring methodological limitations were identified: simplified agent dimensions, limited behavioural realism, weak integration between micro–meso–macro scales, short simulation horizons, and incomplete calibration–verification–validation (CV&V). Addressing these gaps will enhance the reliability and policy relevance of future agent-based studies. Accordingly, future research should focus on five key directions:

- *Agent representation:* Develop more realistic simulations of agent size, geometry, and spacing to improve the accuracy of flow and safety assessments.
- *Behavioural realism:* Integrate machine-learning or data-driven approaches to refine driver, passenger, and controller behaviours.
- *Multi-scale modelling:* Combine micro-, meso-, and macro-levels into hybrid frameworks for comprehensive transport-logistics analysis.
- *Temporal modelling:* Extend simulation horizons and incorporate real-time or longitudinal data to capture time-dependent dynamics.
- *Model validation:* Establish standardised CV&V protocols and empirical benchmarking to verify simulation reliability.

This article has shortcomings that should be conducted in further research. The process of building a multi-agent model using NetLogo was described in a simplified way, not describing agent functions and simulation environment interactions. The article has not yet delved into the examination of the algorithms employed in the research models. The evaluation of research models from a time and space perspective has not yet been analyzed in detail, etc. This presents a challenge for scholars seeking to comprehend the application of the Netlogo model in the transportation field. This goal also requires further research in the future. With the development of many other agent-based platforms, Netlogo is a powerful, intuitive tool that incorporates various add-ons and a diversified model library system to help researchers learn and improve the proposed models for sustainable and resilient transport-logistics management.

Acknowledgement
The authors gratefully acknowledge the support of Ho Chi Minh City University of Technology and Education (HCMUTE) for providing the facilities and favourable conditions that enabled the completion of this study.

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