iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: III Month of publication: March 2026

DOI: https://doi.org/10.22214/ijraset.2026.78978

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

Establishing Real Driving Cycles for Dhaka's Urban Environment: A Methodological Framework for Vehicle Performance Evaluation in Megacity Traffic Conditions

Islam Shaikh Mahinur[1], Ahmed Elsayed Aboud [2]
[1]Department of Transportation Engineering, Huai'an University, Huai'an, Jiangsu 223001, China.

Abstract: The divergence between standardized laboratory driving cycles and actual operating conditions in rapidly urbanizing megacities of developing economies poses a significant challenge for accurate vehicle performance evaluation. This study presents a comprehensive methodology for developing real-world driving cycles (RDCs) that accurately represent the severe urban traffic conditions of Dhaka, Bangladesh one of the world's most congested megacities. Through systematic data collection using high-precision GNSS instrumentation, followed by rigorous signal processing and statistical analysis, six representative driving cycles were synthesized from approximately 33 hours of on-road measurements covering 219.3 km, of which 13 hours and 48 minutes of validated driving data were used. The study reveals that Dhaka's driving environment is characterized by extremely low average speeds (7–12 km/h), high transient intensity (Relative Positive Acceleration: 0.159–0.232 m/s²), substantial idle proportions (8–22%), and predominantly low-speed operation, with 70–94% of time spent below 20 km/h. Comparative analysis with five international standard driving cycles (EPA FTP-75, UDDS, NYCC, Japanese 10-15 Mode, and ARTEMIS Urban) demonstrates that conventional certification cycles substantially underestimate the operational severity of megacity traffic in developing economies, with Dhaka RDCs exhibiting average speeds 60–75% lower than those of standard cycles and RPA values significantly exceeding even the highly congested New York City Cycle. The developed RDCs provide an essential foundation for evaluating hybrid electric vehicle performance under authentic operating conditions and offer critical insights for evidence-based transport electrification strategies in similar rapidly urbanizing contexts.

Keywords: Real driving cycles; Urban traffic driving conditions; Dhaka megacity; Developing countries; Traffic characterization

I. INTRODUCTION

A. Background and Motivation

Vehicle performance is not solely determined by design specifications but is profoundly influenced by the operational environment. In developing megacities like Dhaka, Bangladesh, the divergence between certified laboratory test results and real-world vehicle performance is particularly pronounced due to unique traffic characteristics, infrastructural constraints, and fleet composition. This disparity has critical implications for fuel economy projections, emissions inventories, and the assessment of alternative powertrain technologies, particularly hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) whose efficiency gains are strongly dependent on driving patterns.

Standardized driving cycles developed in industrialized nations such as the EPA FTP-75, NEDC, or WLTP were designed to represent traffic conditions in cities with well-developed infrastructure, lane-disciplined traffic, and relatively homogeneous vehicle fleets. These cycles typically assume average speeds of 20–35 km/h, moderate congestion levels, and limited interaction between motorized and non-motorized transport modes. However, rapidly urbanizing megacities in South Asia and Sub-Saharan Africa operate under fundamentally different conditions: extreme population density, severely constrained road infrastructure, heterogeneous traffic mixing multiple transport modes, weak enforcement mechanisms, and chronic congestion that produces persistently low speeds and high transient intensity.

The mathematical foundation for cycle analysis derives from kinematic relationships where acceleration a(t) is obtained through differentiation of the speed profile v(t), and distance S(t) through integration:

$$[a(t) = \frac{d}{dt} v(t)] \tag{1}$$

$$[S(t) = \int v\,(t)\,dt] \tag{2}$$

From these fundamental relationships, critical performance metrics including average speed, acceleration intensity, and energy demand can be computed:

$$[v_{av} = \frac{1}{T}\int_0^T v\,(t)\,dt = \frac{s}{T}] \tag{3}$$

$$[a_{av} = \frac{1}{T}\int_0^T a\,(t)\,dt] \tag{4}$$

Despite their utility for regulatory harmonization, standardized cycles face persistent criticism regarding real-world representativeness. André et al. [1] demonstrated that European real-world driving emissions substantially exceeded laboratory measurements, prompting development of the Real Driving Emissions (RDE) protocol. Hung et al. [2] developed a practical methodology for constructing region-specific cycles, emphasizing the importance of local traffic conditions. Lin and Niemeier [3] compared stochastic driving cycles with regulatory procedures, revealing significant discrepancies in emission estimates.

Dhaka, the capital of Bangladesh, is one of the world's most densely populated cities. Its driving patterns are dominated by frequent acceleration-deceleration events, prolonged idling, and high power demand variability characteristics that fundamentally affect vehicle energy consumption and emissions and differ substantially from assumptions embedded in international certification procedures [4].

B. Research Objectives

This study addresses the critical need for context-specific driving cycles that accurately represent severe urban congestion in developing megacities. The specific objectives are:

To characterize the unique driving environment of Dhaka through systematic analysis of traffic conditions, fleet composition, and operational constraints;

To develop a rigorous methodology for collecting high-fidelity, real-world driving data under authentic operating conditions;

To synthesize representative Real Driving Cycles (RDCs) that capture the statistical properties of Dhaka's traffic environment;

To validate these cycles through comprehensive kinematic analysis and comparison with international benchmark cycles;

To establish the implications of cycle divergence for vehicle performance assessment and electrification strategy in congested urban environments.

II. LITERATURE REVIEW

A. Driving Cycles and Their Limitations

Driving cycles are standardized speed-time profiles designed to replicate real-world driving behaviour in controlled testing environments [5]. Despite their utility for regulatory harmonization and consistent vehicle certification, standardized cycles face persistent criticism regarding their representativeness of actual on-road conditions.

André et al. [1] demonstrated that real-world European driving emissions substantially exceeded laboratory measurements based on standard cycles, which ultimately contributed to the development of the Real Driving Emissions (RDE) protocol. Hung et al. [2] proposed a practical methodology for constructing region-specific driving cycles, highlighting the critical importance of incorporating local traffic characteristics. Similarly, Lin and Niemeier [3] compared stochastic driving cycles with regulatory procedures and revealed significant discrepancies in resulting emission estimates.

These studies collectively underscore a fundamental limitation: driving cycles developed in industrialized nations (such as the EPA FTP-75, NEDC, or WLTP) were designed for cities with well-developed infrastructure, lane-disciplined traffic, and relatively homogeneous vehicle fleets. They typically assume moderate congestion levels and average speeds between 20–35 km/h. In contrast, rapidly urbanizing megacities in developing economies operate under fundamentally different conditions extreme population density, severely constrained road infrastructure, heterogeneous traffic mixing motorized and non-motorized modes, and chronic congestion that produces persistently low speeds and high transient intensity. As a result, conventional certification cycles often fail to capture the operational severity of traffic in cities like Dhaka, leading to inaccurate predictions of fuel consumption, emissions, and the potential benefits of advanced powertrains such as hybrid electric vehicles.

B. Traffic Characteristics in Developing Megacities

Research on urban traffic in developing economies reveals systematic differences from developed country contexts. Hossain [6] established that standard traffic flow models developed for homogeneous vehicle fleets are inadequate for capturing the complex interactions between motorized and non-motorized vehicles in developing cities. This modal heterogeneity fundamentally reduces effective road capacity and creates continuous stop-and-go flow conditions.

Ahmed et al. quantified "side friction" effects illegal parking, pedestrian activity, and roadside encroachment demonstrating speed reductions up to 36.55% and waiting time increases of 161.3% on critical urban corridors [7]. Mohiuddin et al. [8] identified behavioral factors reinforcing private vehicle dependence despite congestion, while spatio-temporal congestion patterns using emerging data sources [9]. These studies collectively establish that Dhaka's traffic environment generates unique driving patterns requiring dedicated analytical treatment.

C. *Hybrid Vehicle Performance Under Congested Conditions*

Hybrid electric vehicles offer particular advantages under low-speed, high-transient urban conditions through regenerative braking, engine load optimization, and idle elimination [10]. Rojas-Reinoso et al. documented that HEVs achieve fuel economy improvements of 40-45% under favorable conditions, with benefits maximized in stop-and-go driving [11]. However, the magnitude of these benefits depends critically on the specific kinematic characteristics of the driving cycle [12], underscoring the necessity of accurate, context-specific cycle development for reliable performance prediction.

III. DHAKA'S URBAN DRIVING ENVIRONMENT

A. *Traffic Characteristics and Congestion Patterns*

Urban traffic in Dhaka is characterized as heterogeneous, non-lane-disciplined, and demand-saturated. Multiple transport modes including buses, private cars, motorcycles, auto-rickshaws, cycle-rickshaws, freight vehicles, and pedestrians share limited roadway capacity, producing highly stochastic traffic dynamics. Foundational research on Dhaka's traffic composition has demonstrated that standard traffic flow models developed for homogeneous vehicle fleets are inadequate for capturing the complex interactions between motorized and non-motorized vehicles in developing cities [6]. This modal heterogeneity fundamentally reduces effective road capacity and creates continuous stop-and-go flow conditions.

A fundamental structural constraint is the limited extent of transport infrastructure. Roads account for only approximately 7–8% of total urban land area, substantially below the 20–25% typically recommended for major metropolitan regions [13], [14], [15]. Rapid population growth and increasing vehicle ownership have intensified this imbalance, producing persistent congestion across primary corridors and intersections [16].

Empirical studies indicate that traffic speeds in central Dhaka frequently decline to 4–10 km/h during peak periods, reflecting severe operational inefficiency [13], [17]. Without substantial intervention, projections suggest further deterioration in average travel speeds in coming decades [18], [19]. These conditions generate significant time losses for commuters and disrupt urban productivity. A comprehensive analysis of Dhaka's traffic situation identifies unplanned urbanization, poor infrastructure development, and weak enforcement of traffic regulations as primary contributing factors to this chronic congestion [20].

Congestion exhibits strong spatial and temporal variability. Spatio-temporal analyses based on mobility and traffic data identify recurrent bottlenecks concentrated in commercial and administrative districts, with peak congestion typically occurring during weekday commuting hours [21]. Traffic flow disruption propagates rapidly from key intersections, producing network-wide delays.

Infrastructure limitations are compounded by behavioral and institutional factors. Illegal parking, roadside encroachment, weak traffic enforcement, and fragmented transport governance contribute to reduced roadway efficiency and unstable traffic flow [13],. Public transport inefficiencies and increasing reliance on private vehicles further exacerbate congestion pressure on already constrained infrastructure [21]. Qualitative research involving transport stakeholders, including drivers and passengers, confirms that traffic rule violations, illegal occupancy of footpaths, and uncontrolled parking are perceived as primary contributors to Dhaka's congestion [22].

Research examining mode choice behaviour in Dhaka has revealed how individual perceptions of transportation systems influence travel decisions, with implications for understanding why private vehicle usage continues to grow despite severe congestion. Mohiuddin et al. found that for mobility-challenged populations, the inadequacy of public transport options and concerns about safety and accessibility reinforce dependence on private vehicles and para-transit modes, perpetuating the cycle of congestion [23].

Collectively, Dhaka's traffic environment produces an urban driving cycle dominated by:

Frequent acceleration-deceleration events

Prolonged idling periods

Low average speed operation

High power demand variability

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

These characteristics are critical for evaluating hybrid powertrain performance, as they differ substantially from standardized driving cycles used in vehicle certification procedures [24].

B. Economic and Environmental Impact Assessment

Traffic congestion in Dhaka imposes substantial economic costs at both individual and national levels. Studies estimate that congestion results in annual economic losses of several billion US dollars, driven by lost working hours, excess fuel consumption, increased vehicle operating costs, and health-related impacts [22], [5]. These losses represent a measurable constraint on urban productivity and national economic growth.

Fuel inefficiency is a major component of these costs. Vehicles operating under congested stop-and-go conditions experience significantly higher fuel consumption due to repeated transient engine operation and prolonged idling [7]. Excess fuel use also increases dependence on imported petroleum resources and elevates national energy expenditure . Transport workers interviewed in qualitative studies report financial losses due to working hour loss and extra fuel consumption, along with adverse health effects including hypertension, dehydration, and respiratory problems attributed to prolonged congestion exposure [22].

The environmental consequences of Dhaka's transport system are similarly severe. Road transport constitutes a major contributor to urban air pollution, particularly emissions of particulate matter (PM), nitrogen oxides (NO_x), and carbon monoxide (CO) [1]. Field measurements near major traffic corridors consistently report pollutant concentrations exceeding recommended health thresholds [2]. These emissions are amplified by low travel speeds and inefficient combustion conditions associated with congestion.

Air pollution generated by urban traffic has been linked to elevated incidence of respiratory and cardiovascular disease, reduced life expectancy, and broader public health burdens [2], [3]. Hossain [22] notes that prolonged exposure to traffic-related pollution has contributed to rising rates of respiratory illness, stress-related disorders, and reduced quality of life among Dhaka residents. In addition to air quality degradation, traffic congestion contributes to persistent urban noise pollution, which has been associated with psychological stress, sleep disruption, and diminished well-being [6].

Recent infrastructure investments, including the development of Dhaka Metro Rail's MRT Line 6, have demonstrated potential for mitigating some congestion impacts. Roy et al. [25] reported that the introduction of metro rail service has reduced average commute times by up to 66.67% for some routes, with corresponding reductions in fuel consumption and emissions for commuters who shifted from road-based transport. This finding underscores the potential for integrated transport solutions to address congestion-related environmental challenges.

Despite these challenges, Dhaka's traffic conditions also create a favourable operational context for electrified powertrains. PHEVs operating in electric-dominant urban mode can significantly reduce fuel consumption and tailpipe emissions under low-speed, stop-and-go conditions through regenerative braking, engine load optimization, and idle elimination [8]. Consequently, evaluating hybrid vehicle performance under Dhaka-specific driving conditions is essential for accurately assessing their real-world energy and environmental benefits.

C. Representative Vehicle Platform Selection

Understanding the composition, registration trends, and operational characteristics of the urban vehicle fleet is essential for selecting a representative platform for PHEV analysis. Fleet structure influences traffic dynamics, energy demand, modal interactions, and the potential effectiveness of electrified powertrains under congested, low-speed urban conditions.

Dhaka's motor vehicle population has expanded rapidly over recent decades due to urbanization, rising income levels, and increasing demand for personal mobility. Registration statistics from the Bangladesh Road Transport Authority indicate sustained long-term growth in private passenger vehicles and motorcycles, contributing to intensified pressure on limited road infrastructure. Cumulative vehicle numbers in the Dhaka metropolitan area reached approximately 2.24 million registered motor vehicles as of recent estimates, though this figure includes vehicles with expired registrations that may no longer be actively operating [26]. Despite periodic fluctuations in annual registrations with national vehicle registrations declining by 14.7% to approximately 308,000 units in 2024, representing a ten-year low [9] the accumulated fleet reflects substantial motorization within a constrained urban transport network.

Urban transport surveys conducted under the Revised Strategic Transport Plan identify a highly heterogeneous operating fleet composed of both motorized and non-motorized vehicles [27]. Modal distribution analysis reveals that motorcycles constitute approximately 27% of vehicles operating in Dhaka, representing the largest category of motorized transport [16]. This proportion has increased substantially from 11% in 2014, reflecting rapid growth in motorcycle ownership driven by affordability considerations and the expansion of ride-sharing services [16]. Non-motorized vehicles primarily cycle-rickshaws, vans, and pushcarts account for approximately 22% of the fleet, underscoring the continued importance of traditional transport modes despite progressive motorization [16].

Private passenger cars represent approximately 20% of the operating fleet, constituting a substantial vehicle category with significant implications for road space consumption, fuel demand, and emissions [16], [28]. Three-wheelers, including compressed natural gas (CNG) auto-rickshaws and battery-assisted variants, account for 14% of vehicles. Light commercial vehicles such as microbuses and pickups comprise 7%, while trucks represent 6% of the fleet [16]. Notably, formal public transport buses account for only 3% of total vehicles operating in Dhaka [16]. This extreme imbalance between private and public transport modes with private cars, motorcycles, and para-transit vehicles together comprising over 80% of the fleet represents a fundamental structural characteristic of Dhaka's transport system with profound implications for traffic congestion and energy consumption.

A defining characteristic of Dhaka's fleet is the overwhelming dominance of internal combustion engine vehicles. Gasoline-powered passenger cars and diesel freight vehicles represent the primary motorized transport modes, while widespread adoption of compressed natural gas has been promoted for para-transit services to reduce local air pollutant emissions [29]. Electrified vehicles currently constitute only a negligible proportion of the fleet. Fleet age and maintenance conditions further influence energy consumption and emissions patterns. A significant proportion of passenger vehicles consists of reconditioned imports, primarily from Japan, which often incorporate older engine technologies and exhibit higher emission factors compared with modern standards [10].

Within the passenger car segment, Japanese brands overwhelmingly dominate the Bangladeshi market. Toyota holds a commanding market share of approximately 80–86% among passenger vehicles, reflecting strong consumer trust in the brand's reliability, fuel efficiency, and resale value retention [30]. This dominance is particularly pronounced in the reconditioned vehicle market, which accounts for approximately 59–70% of passenger car sales [31], [32]. Honda occupies the second position with approximately 5% market share, followed by Nissan at 3%, while other manufacturers including Mitsubishi and Hyundai each account for approximately 1% of the market [33] Among Toyota models, the Corolla series including the Corolla Axio variant designed for Asian markets consistently ranks as the best-selling passenger car platform, valued for durability, fuel economy, spacious interior configuration, and strong aftermarket support [34], [35].

IV. METHODOLOGY

A. *Experimental Setup and Instrumentation*

Data acquisition was performed using a high-precision Beitian BK-609 GNSS sensor connected via USB to a laptop computer running u-blox u-center software as shown in Fig. 1. The sensor provides real-time position, velocity, and time data with 1 Hz sampling frequency, suitable for vehicular kinematic analysis.

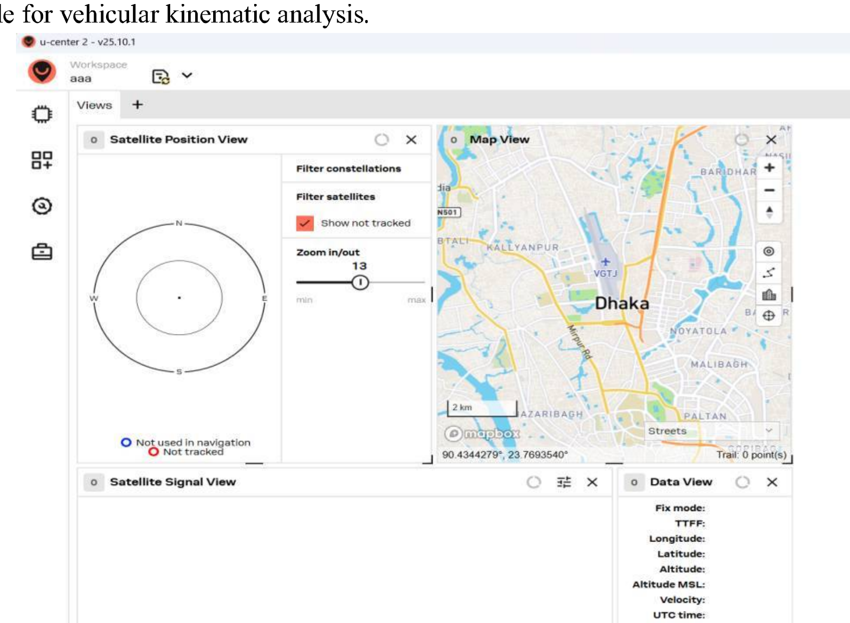


Fig. 1 u-blox u-center software main interface

The technical specifications of the Beitian BK-609 GNSS sensor are presented in Table 1.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

TABLE I
TECHNICAL SPECIFICATIONS OF THE BEITIAN BK-609 GNSS SENSOR

Parameter	Specification
Model	BK-609
Chipset	M9140
Supported constellations	GPS L1 C/A, QZSS L1 C/A/S, GLONASS L1OF, BDS B1I, Galileo E1B/C, SBAS L1 C/A (WAAS, EGNOS, MSAS, GAGAN)
Horizontal accuracy	1.5 m CEP (with SBAS)
Velocity accuracy	0.05 m/s
Dynamic heading accuracy	0.3°
Time accuracy (PPS)	RMS: 30 ns, 99%: 60 ns
Cold start time	24 s
Warm start time	2 s
Hot start sensitivity	–159 dBm
Cold start sensitivity	–148 dBm
Reacquisition time	2 s
Update rate	0.25–25 Hz (configurable; default 1 Hz)
Baud rate	4,800–921,600 bps (default 115,200 bps)
Output level	TTL
Output protocols	NMEA, UBX

Key performance characteristics of the sensor include:
Horizontal positioning accuracy: 1.5 m CEP (Circle of Equal Probability), providing sufficient precision for urban micro-trip reconstruction and speed derivation even in dense city canyons.
Update rate: Nominal 1 Hz, with capability for actuation up to 25 Hz when required for higher temporal resolution (though 1 Hz was consistently used in this study to balance data volume and processing requirements).
Supported constellations: Multi-GNSS support (GPS, GLONASS, BeiDou, Galileo, SBAS, QZSS), enhancing satellite availability and positioning reliability in obstructed urban settings typical of Dhaka.
Output parameters: Time-stamped latitude, longitude, altitude (ellipsoidal height), ground speed (derived from Doppler or position differencing), and additional metadata such as number of satellites in view and HDOP (Horizontal Dilution of Precision) for post-collection quality assessment.
All data were logged at a fixed 1-second interval, ensuring consistent temporal resolution suitable for micro-trip segmentation, acceleration/deceleration profiling, and alignment with standard driving cycle formats. Measured variables included:
Time (in seconds, synchronized to UTC via GPS)
Position (latitude and longitude in decimal degrees)
Altitude (in meters above mean sea level)
Derived instantaneous speed (m/s or km/h, computed from successive position fixes)
No additional on-board diagnostic (OBD-II) interfacing or exhaust measurement equipment was employed at this stage, as the primary objective was kinematic data for driving cycle construction rather than real-time emissions monitoring. This streamlined setup allowed the instrumentation to be non-intrusive, easily transferable between test vehicles, and focused exclusively on the Toyota Corolla Axio (E160) platform to maintain representativeness.
The test vehicle was a Toyota Corolla Axio (E160) equipped with a manual transmission, representing the most common passenger vehicle configuration in Dhaka. The GNSS antenna was mounted on the vehicle roof for optimal satellite visibility, and the sensor was configured to log position and velocity data at 1 Hz to balance temporal resolution with data storage requirements.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

A total of 12 unique real-world driving datasets were collected across diverse road segments, traffic conditions, and times of day in Dhaka. These included:

Morning peak-hour congested arterials and commercial districts

Evening peak queuing at major intersections

Midday off-peak mixed residential-commercial routes

Routes with varying degrees of side friction, non-motorized traffic interaction, and signal density

To account for natural variability in driver behavior a critical factor influencing acceleration profiles, gear usage, and overall energy demand data were gathered using three different drivers. Each driver operated the vehicle in their typical manner without artificial instructions to alter style, thereby capturing realistic heterogeneity in driving aggression, anticipation, and response to traffic events.

An additional crucial aspect of driver behavior captured was gear shift timing and gear shift duration. Since the Toyota Corolla Axio (E160) under study is equipped with a manual transmission, gear-changing patterns significantly affect engine operating points, fuel consumption, and transient emissions under stop-and-go conditions.

Gear shift events were observed and recorded manually during each test drive to capture driver-specific behaviour critical for accurate powertrain simulation in congested conditions:

For each upshift and downshift, the approximate engine speed (RPM) at the initiation of the shift was noted from the vehicle's tachometer and recorded at least 10 times per test drive (minimum 10 observations per drive).

The gear shift transition time (duration from clutch disengagement to full re-engagement in the new gear) was timed using a stopwatch and documented at least 10 times per test drive (minimum 10 observations per drive).

These repeated observations per drive allowed characterization of typical shift RPM ranges and durations, accounting for natural variability among the three drivers and across different traffic states. These manual observations were cross-referenced with logged GPS speed profiles and time stamps to associate gear changes with vehicle speed and acceleration context. This driver-specific gear behavior data is particularly valuable for subsequent powertrain modeling, as it enables realistic simulation of engine load profiles, clutch operation, and torque interruptions during gear shifts factors that are especially pronounced in Dhaka's frequent low-speed transients and prolonged idling periods.

B. Route Selection and Data Collection Protocol

Route selection was strategically designed to fully capture the spectrum of Dhaka's distinctive driving environment as characterized in Section 3.1, including chronic low-speed operation (often 4–10 km/h during peaks), heterogeneous traffic mixing motorized and non-motorized modes, high side-friction effects (illegal parking, pedestrian activity, roadside encroachment), frequent acceleration-deceleration transients, prolonged idling, and stochastic flow disruptions at intersections and bottlenecks. By prioritizing coverage of these real-world conditions, the selected routes ensure that the collected GPS-based kinematic data derived from the Toyota Corolla Axio (E160) test vehicle using the Beitian BK-609 sensor at 1 Hz faithfully represent the operational profiles encountered by typical passenger cars in the city.

Six routes were selected representing Dhaka's road hierarchy including primary arterials, secondary distributors, and local residential-commercial mixed-use streets ensuring comprehensive coverage of the city's diverse operational contexts. This hierarchical approach aligns with established classifications in Dhaka's transport planning documents (e.g., Revised Strategic Transport Plan and related studies), where:

Primary arterials (e.g., major corridors such as Airport Road, Mirpur Road, Panthapath, or arterial segments in commercial/administrative zones like Motijheel and Gulshan) serve high-volume inter-zonal and intra-city movements, often featuring wider carriageways, signalized intersections with heavy queuing, mixed traffic including buses and freight, and recurrent bottlenecks that produce prolonged stop-and-go conditions.

Secondary distributors (e.g., connector or sub-arterial roads linking neighborhoods to main arterials, such as segments in Dhanmondi, Uttara, or Mirpur) provide moderate-capacity distribution, with narrower lanes, increased non-motorized vehicle interactions, frequent side friction, and shorter but still congested trip segments typical of transitional urban zones.

Local residential-commercial mixed-use streets (e.g., narrow inner-city lanes, access roads in residential areas, or bazaar-adjacent streets) emphasize accessibility over mobility, exhibiting the highest density of pedestrians, cycle-rickshaws, motorcycles, auto-rickshaws, illegal parking, and very low average speeds with near-constant transients and idling.

This purposive selection across the hierarchy ensures representation of varying road geometries, traffic compositions, speed regimes, and congestion intensities documented in Section 3.1. Routes were chosen to include:

Recurrent congestion hotspots in central business districts, commercial hubs, and administrative areas.

Diverse road types ranging from wider arterials with partial grade separation or flyovers to narrow, encroachment-prone local streets.

Spatial distribution across key zones (e.g., north-south arterials like Airport Road, east-west corridors like Mirpur Road, and mixed-use areas in older city cores).

Temporal variability through repeated testing during morning peak (7–10 AM), evening peak (5–8 PM), midday off-peak, and occasional weekend conditions to reflect diurnal patterns in traffic demand and flow stability.

Routes were pre-mapped using GIS tools, cross-referenced with spatio-temporal congestion analyses [36], [37], and validated through preliminary scouting drives to confirm they encompass the side-friction-dominated, heterogeneous, non-lane-disciplined dynamics emphasized in Section 3.1. The total network spanned approximately 150–200 km of representative segments, often configured as repeatable loops or origin-destination pairs to enable multiple traversals under different traffic states.

By systematically covering primary arterials, secondary distributors, and local mixed-use streets, the 6 routes collectively capture the full range of Dhaka-specific driving patterns low average speeds, high stop frequency, short trip distances, extended idle-to-motion ratios, and variable modal interactions that are critical for developing realistic driving cycles. This ensures the resulting dataset, collected with multi-driver variability and detailed manual gear-shift logging as described in Section 4.1, provides a robust foundation for constructing representative cycles that reflect authentic operating conditions for the Toyota Corolla Axio (E160) and enable accurate PHEV performance evaluation in subsequent analyses.

C. Data Collection Protocol

The field data collection protocol was carefully designed to ensure high-quality, representative, and reproducible capture of real-world driving data for the Toyota Corolla Axio (E160) under authentic Dhaka traffic conditions, as described in Section 3.2. The protocol emphasized natural driving behavior, coverage of temporal and spatial variability, multi-driver heterogeneity, and detailed behavioral logging to support robust construction of Dhaka-specific driving cycles. The actual data collection was conducted with the assistance of colleagues in Dhaka to ensure geographic accuracy and comprehensive coverage of the city's unique driving conditions.

Data collection was conducted over an extended campaign spanning several months (covering seasonal variations including monsoon impacts on traffic flow and road conditions) to account for day-to-day stochasticity, weekday/weekend differences, and random events that influence congestion patterns in the city. All tests adhered to local traffic regulations where feasible, with priority given to safety and non-disruptive operation.

Key elements of the protocol included:

Driver instructions and natural behavior: Drivers were instructed to operate the vehicle in their typical, everyday manner without artificial acceleration, braking, or idling avoidance strategies. This approach captured realistic driver responses to Dhaka's heterogeneous, non-lane-disciplined traffic, frequent side-friction interruptions, signal queuing, and modal conflicts (e.g., interactions with motorcycles, auto-rickshaws, cycle-rickshaws, pedestrians, and buses). No scripted or chase-car methods were used; instead, drivers navigated freely within the selected routes while following prevailing traffic flow.

Trip duration and repetition: Each individual test run (traversal of a selected route segment or loop) had a minimum duration of 30 minutes to ensure sufficient data for meaningful micro-trip segmentation and to capture complete congestion cycles (including approach to bottlenecks, queuing, clearance, and recovery). Shorter trips were avoided to prevent bias toward outlier conditions. Multiple repetitions were performed on the same route under varying traffic states to build statistical robustness and avoid sensor errors.

Temporal coverage: Testing was scheduled to reflect Dhaka's strong diurnal congestion patterns:

Morning peak (typically 7:00–10:30 AM, with heaviest congestion often 8:30–10:30 AM based on local observations and studies),

Evening peak (typically 5:00–8:00 PM or later, with severe bottlenecks persisting into evening hours),

Midday off-peak (approximately 11:00 AM–3:00 PM, when slight relief occurs but residual congestion remains in commercial zones),

Occasional weekend periods to capture lower but still heterogeneous demand.

This ensured representation of peak-hour stop-and-go dominance, prolonged idling at signals and bottlenecks, and transitional off-peak flow.

Spatial and route execution: The 6 purposively selected routes (covering primary arterials, secondary distributors, and local residential-commercial mixed-use streets) were traversed as repeatable loops or origin-destination pairs. Drivers started from designated points (often residential or commercial origins) and followed the pre-mapped path, allowing natural deviations only when required by traffic (e.g., lane changes or minor rerouting due to blockages). Routes were repeated three times across different conditions to accumulate data under diverse congestion intensities and modal compositions.

Instrumentation and real-time monitoring: The Beitian BK-609 GPS sensor (logged at 1 Hz via u-blox u-center software) was mounted securely with unobstructed sky view. A co-driver or observer monitored equipment in real time, verified satellite lock quality (via HDOP and satellite count), and noted any anomalies (e.g., temporary signal loss in urban canyons, heavy rain affecting visibility, roadworks, or unusual events like protests or accidents). Backup logging ensured continuity.

Manual behavioral logging: During each drive, gear shift events were observed and recorded in detail (as described in Section 4.1).

Safety and ethical considerations: All drives prioritized road safety, with drivers maintaining defensive positioning amid mixed traffic. Instrumentation remained non-intrusive, and no passengers beyond the research team were carried unless necessary for observation. Data collection complied with institutional ethical guidelines for on-road studies.

This protocol produced a comprehensive, high-fidelity dataset tailored to Dhaka's unique low-speed, high-transient, congestion-dominated environment. By incorporating multi-driver variability, repeated route traversals across peak/off-peak periods, hierarchical route coverage, and detailed gear-shift behavior logging, the collected data faithfully reflect the operational realities faced by the Toyota Corolla Axio (E160) and similar passenger vehicles in the city. This foundation enables accurate development of representative driving cycles that better capture real-world energy consumption, regenerative braking potential, and PHEV benefits compared to standardized international cycles.

D. Data Refinement and Signal Processing

Following the extensive field collection protocol outlined in Section 4.3, the raw position-time data acquired from the Beitian BK-609 GNSS sensor underwent rigorous refinement to ensure reliability, consistency, and suitability for driving cycle construction. Dozens of individual test drives were conducted across the six purposively selected routes representing Dhaka's road hierarchy, yielding approximately 33 hours of cumulative driving time, corresponding to nearly 120,000 time-stamped records at 1 Hz resolution. These data captured the extreme variability inherent to Dhaka's traffic environment including prolonged low-speed operation, frequent acceleration–deceleration transients, and high idling proportions as documented in Section 3.2.

Fig. 2, 3, and 4 show examples of the traffic and road conditions while acquiring the real driving cycle data in Dhaka's urban survey, it shows the congested arterials with mixed motorized and non-motorized vehicles, side-friction elements including illegal parking and pedestrian activity, and stop-and-go flow at intersections.

Fig. 2 Example of the Dhaka's urban roads driving environment

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

Fig. 3 Example of the Dhaka's urban roads driving environment

Fig. 4 Example of the Dhaka's urban roads driving environment

The collected data covered the six predefined routes (representing primary arterials, secondary distributors, and local residential-commercial mixed-use streets), with each route traversed approximately three times under varying temporal conditions (morning peak, evening peak, midday off-peak, and occasional weekend periods) to account for stochasticity and diurnal patterns in traffic demand and congestion intensity.

Fig. 5 and 6 show examples of the GPS-derived trajectories of two routes overlaid on a map of Dhaka, illustrating spatial coverage and route characteristics.

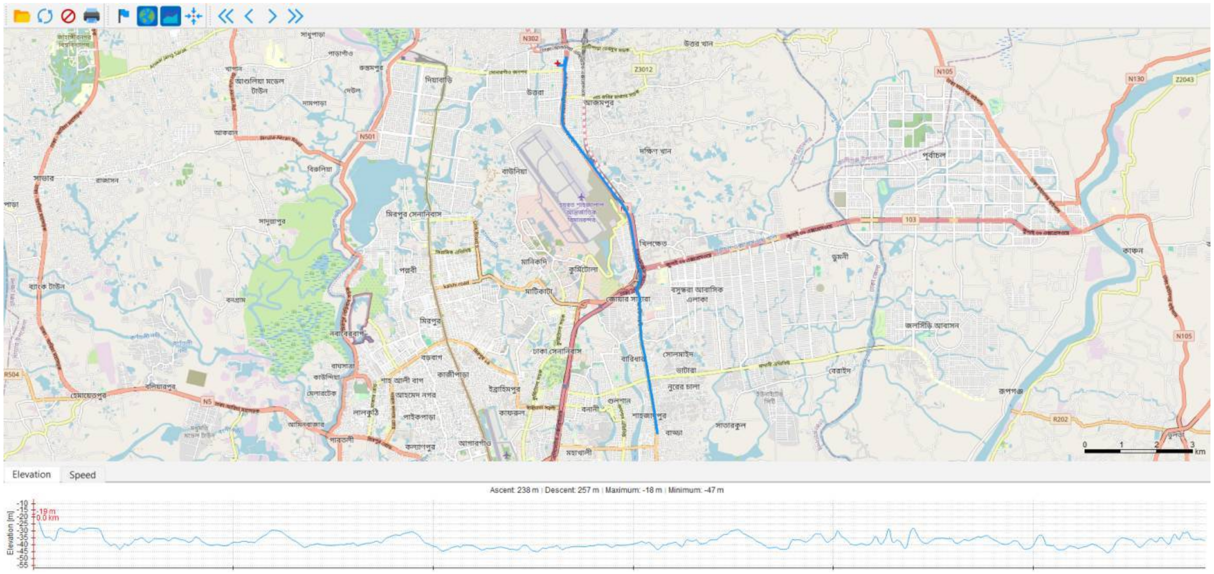


Fig. 5 Example of the Dhaka's urban routes chosen for acquiring the driving cycles data

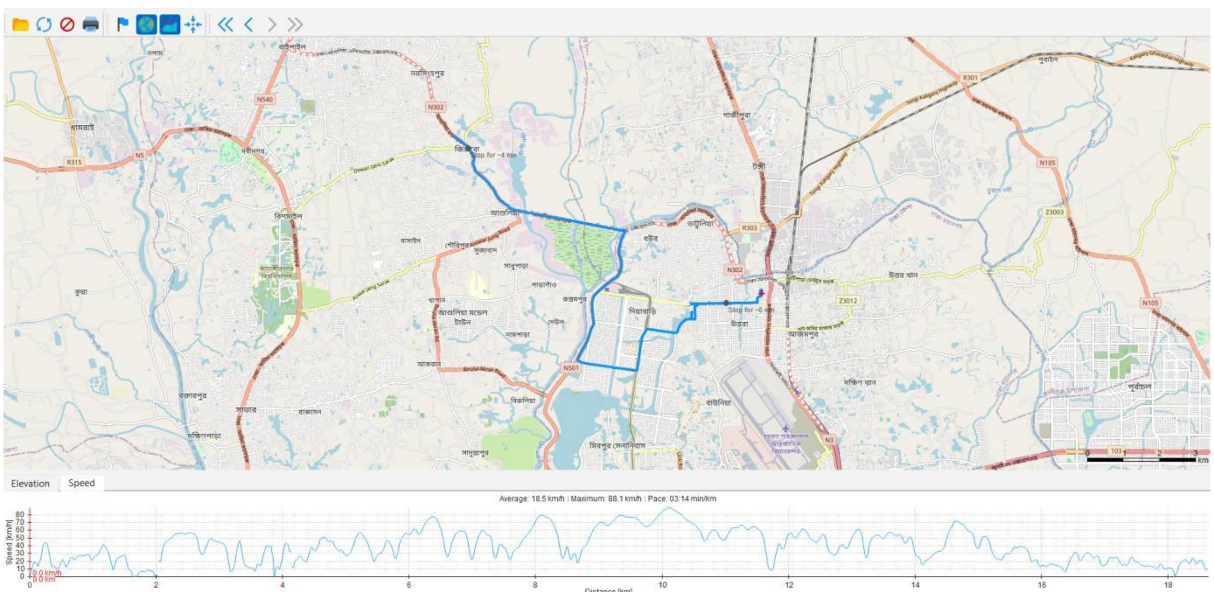


Fig. 6 Example of the Dhaka's urban routes chosen for acquiring the driving cycles data

1) Data Validation Procedures

The initial validation step focused on ensuring data integrity and omitting unreliable segments prior to analytical processing. A conservative filtration approach was implemented to identify datasets affected by significant measurement disturbances that could compromise micro-trip reconstruction or statistical analysis.

Each recorded trajectory was evaluated using multiple quality indicators, including:

continuity of satellite positioning signals

absence of extended GPS signal loss (with threshold exceeding 2 seconds)

consistency between speed, displacement, and elapsed time

stability of sampling frequency

Horizontal Dilution of Precision (HDOP) below 2.5

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

satellite count exceeding 6–8 satellites

absence of abnormal speed spikes inconsistent with vehicle dynamics

Datasets exhibiting major GPS signal dropouts (e.g., prolonged loss of satellite lock in dense urban canyons or under flyovers), logging interruptions, software recording errors, or incomplete timestamp sequences were excluded from further analysis. This conservative validation approach ensured that only physically consistent driving trajectories with high positioning confidence were retained for cycle construction.

Following this initial filtration, twelve high-quality datasets were retained, representing driving cycles through the six predefined routes with a total travelled distance of 219.3 km and a cumulative driving time of 13 hours and 48 minutes. These twelve datasets form the analytical basis for subsequent statistical analysis and cycle synthesis.

Fig. 7 and 8 shows the speed-time graphs using the raw data of two of the twelve acquired driving cycle datasets, illustrating typical low/medium speed, high-transient profiles with frequent stops and prolonged idling, the graphs also show inconsistency in some segments and long stop times.

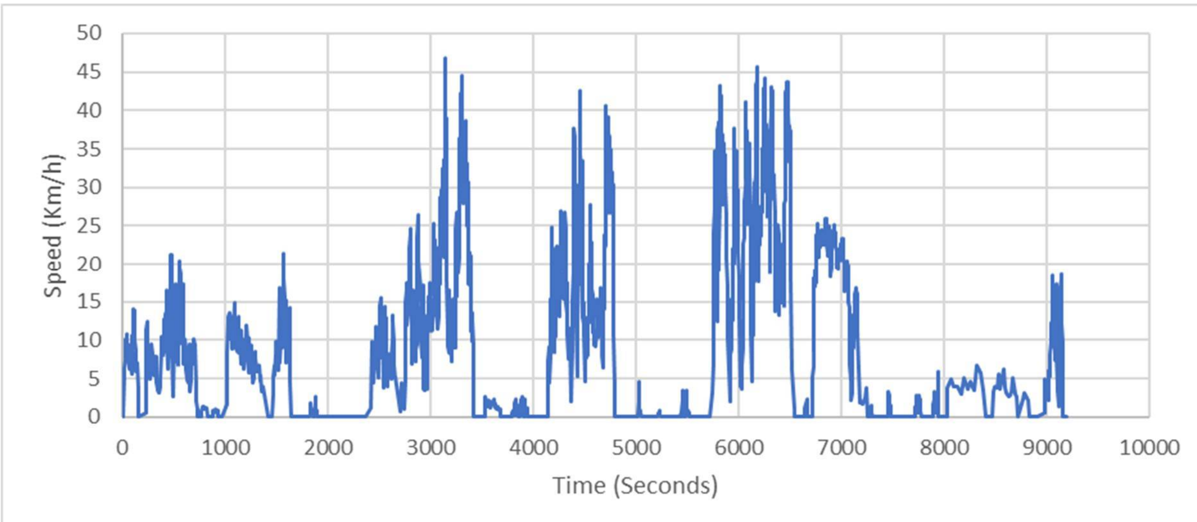


Fig. 7 Example of the speed-time raw data for one of the acquired driving cycles

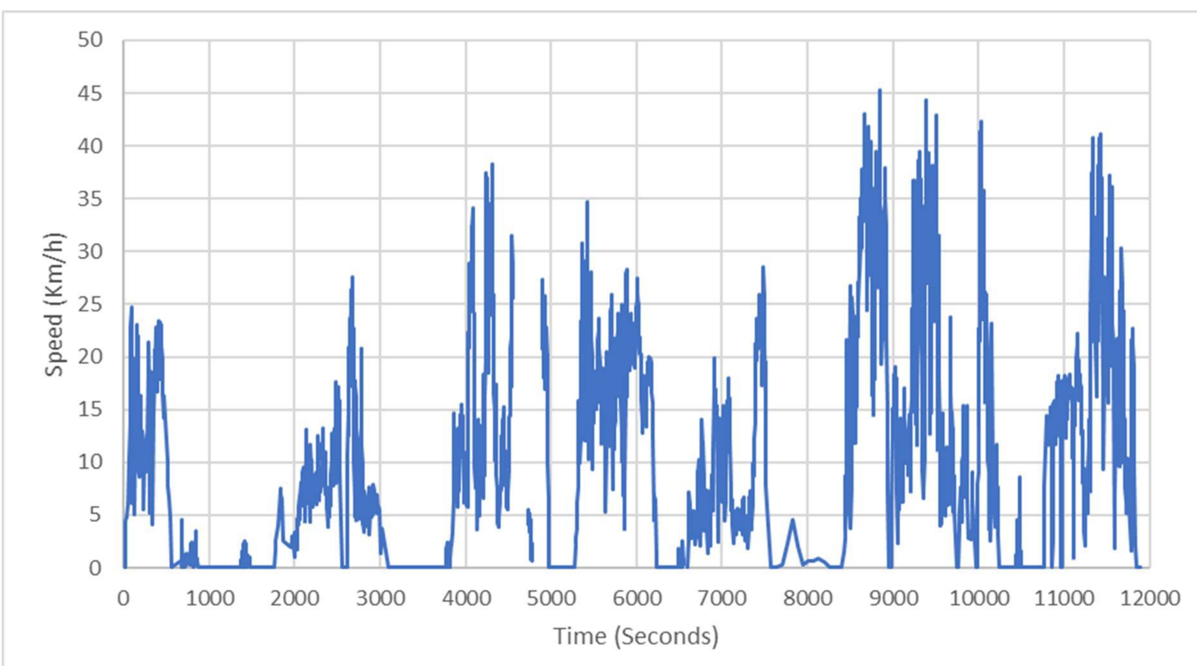


Fig. 8 Example of the speed-time raw data for one of the acquired driving cycles

2) Raw Data Cleaning

A structured multi-stage cleaning procedure was applied to the validated GPS data to remove operational artefacts that do not represent active driving behaviour. The objective was to preserve realistic congestion-induced idling while excluding prolonged engine-off periods that would bias energy demand estimation, regenerative braking potential, and overall cycle representativeness.

The cleaning procedure included the following key elements:

Removal of extended non-operational idling: Idle periods exceeding three minutes were removed from the dataset. This threshold reflects common local practice in Dhaka, where drivers routinely switch off engines during prolonged stoppages at traffic signals, level crossings, or severe bottlenecks. Including such extended engine-off periods would artificially distort energy demand characteristics, idle proportion calculations, and the assessment of start-stop system benefits in hybrid powertrains.

Speed distribution analysis: Average and maximum speeds were evaluated across different traffic conditions to characterize mobility constraints and operational variability. This analysis confirmed the dominance of low-speed operation typical of severe congestion environments, with average speeds frequently below 10 km/h during peak periods and maximum speeds rarely exceeding 40–50 km/h on urban corridors.

Acceleration profile analysis: Instantaneous acceleration and deceleration distributions were examined to characterize transient driving intensity and braking frequency. This analysis revealed the high frequency of stop-go events and the elevated acceleration demand that distinguishes Dhaka's traffic from standard driving cycles.

Relative Positive Acceleration (RPA) calculation: RPA was computed as a normalized measure of positive acceleration energy per unit distance. This metric serves as a key indicator of propulsion energy demand, driving aggressiveness, and the potential benefit of regenerative braking systems. Elevated RPA values in the cleaned dataset confirmed the high transient intensity of Dhaka's driving environment.

All cleaning operations preserved the original statistical structure of driving behaviour while ensuring that the processed dataset accurately represents authentic kinematic patterns without artefacts from measurement errors or non-driving periods.

3) Error Correction Methodologies

Although the Beitian BK-609 GNSS instrumentation provided high positioning accuracy (1.5 m CEP with SBAS), minor signal disturbances remained inevitable in Dhaka's dense urban environment characterized by high-rise structures, flyovers, and tree canopy in some residential areas. A targeted error correction framework was therefore applied to address these artefacts while preserving the physical realism of the driving trajectories.

The correction methodology included:

Filtering of high-frequency noise: Speed signals were examined for high-frequency jitter inconsistent with vehicle dynamic capabilities. Minor noise was smoothed using moving average techniques with small window sizes (typically 2–3 samples) to avoid attenuating genuine transient events critical to Dhaka's stop-and-go patterns.

Correction of short-duration signal dropouts: Minor temporal gaps (<2 seconds) were interpolated using linear or spline methods based on adjacent data points. This interpolation maintained trajectory continuity required for micro-trip segmentation while ensuring no artificial smoothing of genuine acceleration events.

Removal of isolated anomalous points: Individual data points exhibiting speed or acceleration values physically inconsistent with vehicle dynamics (e.g., instantaneous speed changes exceeding achievable acceleration limits) were identified and corrected or removed based on neighboring data context.

Acceleration profile smoothing: Acceleration values derived from successive speed measurements were filtered using physically consistent constraints derived from typical vehicle performance capabilities. This ensured that corrected acceleration profiles remained within realistic bounds while preserving the statistical distribution of transient events.

All corrections were applied conservatively, with the explicit objective of ensuring numerical stability for subsequent kinematic analysis and powertrain simulation rather than idealizing trajectories or removing genuine driving variability. The corrected dataset preserved the defining characteristics of Dhaka's traffic environment including extreme stop-go behaviour, prolonged idling, and low average speeds while eliminating measurement artefacts that could distort cycle construction or simulation results.

4) Data Completeness and Representativeness Assessment

Following validation, cleaning, and error correction, dataset completeness was evaluated to confirm that the retained trajectories adequately represent Dhaka's congestion-dominated driving environment as characterized in Section 3.2. This assessment verified temporal continuity (no gaps exceeding 2 seconds except intentional idling periods), total distance coverage across route categories, and representation across temporal sampling windows.

Assessment criteria included:

representation of morning peak, evening peak, and midday off-peak conditions

coverage of primary arterial, secondary distributor, and local mixed-use street categories

inclusion of diverse traffic densities and congestion intensities

representation of multiple driver behaviours across the three test drivers

consistency with congestion characteristics documented in Section 3.2, including extreme low-speed operation, high stop frequency, and extended idle-to-motion ratios

The refined dataset successfully preserved the defining operational characteristics of Dhaka traffic: extremely low average speeds (frequently 4–10 km/h), high frequency of stop–go transitions, idle proportions exceeding 30–40% in many segments, and elevated transient intensity as measured by acceleration distributions and RPA values. These features provide a robust empirical basis for constructing representative real driving cycles suitable for evaluating hybrid powertrain performance under authentic local conditions.

5) Mathematical Framework for Driving Cycle Analysis

The statistical characterization of driving cycles requires precise mathematical definitions of kinematic parameters. This section documents the equations implemented in the MATLAB analysis script used to quantify the driving patterns of both Dhaka-specific RDCs and international benchmark cycles.

Basic Kinematic Variables

All driving cycles are characterized by discrete time-series data sampled at 1 Hz frequency:

Time vector: $t = [t_1, t_2, ..., t_n]$ where $\Delta t = t_{i+1} - t_i = 1$ s

Speed vector: $v = [v_1, v_2, ..., v_n]$ in km/h or m/s

Acceleration vector: $a = [a_1, a_2, ..., a_{n-1}]$ in m/s²

Speed Metrics

Average Speed:

$\bar{v} = (1/T) \int_0^T v(t)\, dt \approx (1/n) \Sigma^n_{i=1} v_i$

Where T is the total cycle duration and n is the number of data points.

Maximum Speed:

$v_{max} = \max(v_1, v_2, ..., v_n)$

Average Running Speed (excluding idle periods):

$\bar{v}_{run} = (1/T_{run}) \Sigma_{i \in non\neg idle} v_i$

Where T_{run} is the total time excluding idle periods (when $v < 0.7$ km/h).

Acceleration Metrics

Instantaneous Acceleration:

$a_i = (v_{i+1} - v_i) / \Delta t$

For 1 Hz data with speeds in m/s, this simplifies to:

$a_i = v_{i+1} - v_i$ [m/s²]

Average Positive Acceleration:

$\bar{a}_+ = (1/n_-)\ \Sigma\_\{a_i>0\}\ a_i$

Where n_+ is the count of positive acceleration events.

Average Negative Acceleration (Deceleration):

$\bar{a}_- = (1/n_-)\ \Sigma\_\{a_i<0\}\ a_i$

Where n_- is the count of negative acceleration events.

Maximum Acceleration:

$a_{max} = \max(a_1, a_2, ..., a_{n-1})$

Maximum Deceleration:

$a_{min} = \min(a_1, a_2, ..., a_{n-1})$

Relative Positive Acceleration (RPA)

RPA is a key indicator of driving intensity and energy demand, defined as:

$RPA = (1/d) \int_0^T v(t) \cdot a_+(t)\, dt$

Where:

d is the total distance travelled

$a_+(t)$ is the positive acceleration (zero when $a \leq 0$)

For discrete data at 1 Hz:

$RPA = \Sigma^{n-1}_{i=1} (v_i \cdot \max(a_i, 0) \cdot \Delta t) / d$ [m/s²]

Where total distance is:

$d = \Sigma^{n-1}_{i=1} (v_i \cdot \Delta t)$ [m]

RPA represents the average positive acceleration weighted by speed per unit distance, providing a normalized measure of propulsion energy demand that accounts for both acceleration magnitude and the speed at which it occurs.

Idle Characteristics

Idle Threshold: Speeds below 0.7 km/h (approximately 0.2 m/s) are classified as idle (typical range in literature from 0.5 to 1 km/h).

Idle Duration Percentage:

$P_{idle} = (n_{idle} / n) \times 100\%$

Where n_{idle} is the number of time steps with $v < 0.7$ km/h.

Idle Time (absolute):

Tidle = nidle· Δt [seconds]

Number of Stop Events: Count of transitions from $v > 0.7$ km/h to $v < 0.7$ km/h.

Speed Distribution Metrics

Percentage of Time in Speed Range:

$P(vlow \leq v < vhigh) = (n\_range / n) \times 100\%$

Where n_range is the count of points satisfying the speed condition.

Commonly evaluated ranges:

Very low speed: $v < 10$ km/h (heavy congestion)

Low speed: 10 km/h $\leq v <$ 20 km/h (high congestion)

Moderate speed: 20 km/h $\leq v <$ 40 km/h (moderate congestion)

High speed: $v \geq 40$ km/h (normal traffic)

Root Mean Square Acceleration

$a_{rms} = \sqrt{[(1/(n-1)) \Sigma^{n-1}_{i=1} a_i^2]}$ [m/s²]

This metric quantifies overall acceleration intensity regardless of direction.

Distance Calculation

Total Distance:

$d = \Sigma^{n-1}_{i=1} (v_i \cdot \Delta t)$ [m or km]

For speeds in km/h and time in seconds:

$d\,[km] = \Sigma^{n-1}_{i=1} (v_i\,[km/h] / 3600)\,[h/s]$

Data Resampling and Interpolation

Real-world GPS data could have non-uniform sampling intervals due to device or software issues. Linear interpolation is needed to create uniform 1 Hz data:

For irregular time points (t′, v′) → uniform 1 Hz (t, v):

$v_i = v'_j + (v'_{j+1} - v'_j) \cdot (t_i - t'_j) / (t'_{j+1} - t'_j)$

Where $t'_j \leq t_i < t'_{j+1}$

E. Cycle Synthesis Methodology

Representative Real Driving Cycles (RDCs) were synthesized through micro-trip segmentation and clustering:

Micro-trip extraction: Continuous trajectories were divided into segments bounded by idle periods (speed < 0.7 km/h)

Kinematic characterization: Each micro-trip was characterized by average speed, idle proportion, acceleration intensity, and Relative Positive Acceleration (RPA)

Clustering and selection: Micro-trips were clustered based on kinematic similarity; representative segments were selected from each cluster

Cycle concatenation: Selected micro-trips were concatenated to form composite cycles preserving statistical properties of the original dataset

Six finalized RDCs were produced, each representing distinct combinations of congestion intensity, route category, traffic composition, and driver behavior.

F. Comparative Benchmark Cycles

Five international standard cycles were selected for comparative analysis:

EPA FTP-75: US urban certification cycle (avg. speed: 34.1 km/h, duration: 1,874 s)

EPA FTP-72/UDDS: US city driving schedule (avg. speed: 31.5 km/h, duration: 1,369 s)

New York City Cycle (NYCC): Highly congested US urban cycle (avg. speed: 11.4 km/h)

Japanese 10-15 Mode: Former Japanese certification cycle (avg. speed: 22.7 km/h)

ARTEMIS Urban: European real-world urban cycle (avg. speed: 17.3 km/h)

A dedicated MATLAB script implemented the mathematical framework for kinematic analysis, computing all metrics with consistent 1 Hz resampling and validation of interpolation errors (<0.5%).

V. RESULTS AND ANALYSIS

A. Development of Dhaka Real Driving Cycles

From the twelve validated and refined trajectories, six representative Real Driving Cycles (RDCs) were synthesized. The selection process aimed to capture the dominant operational patterns observed across the full dataset while avoiding redundancy and ensuring that the final cycles collectively represent the spectrum of congestion intensities, route categories, and driver behaviours documented during the field campaign.

The synthesis methodology employed micro-trip segmentation, wherein each continuous trajectory was divided into segments bounded by idle periods (zero-speed events). These micro-trips were then clustered based on kinematic characteristics including average speed, idle proportion, acceleration intensity, and RPA. Representative micro-trips were selected from each cluster and concatenated to form composite cycles that preserve the statistical properties of the original dataset.

Each finalized cycle represents a distinct combination of:

congestion intensity (ranging from severe peak-period congestion to moderate off-peak flow)

traffic composition (varying proportions of motorized and non-motorized vehicle interactions)

route category (primary arterial, secondary distributor, or local mixed-use street)

driver behaviour profile (capturing variability across the three test drivers)

The six finalized RDCs exhibit average speeds ranging from approximately 7–12 km/h, maximum speeds rarely exceeding 40–50 km/h, idle times exceeding 35% in most cycles, and elevated Relative Positive Acceleration compared to standard international cycles. These characteristics accurately reflect the extreme stop-and-go nature and characteristic low-speed operation observed in Dhaka's urban corridors.

Fig. 9 to14 show the speed-time profiles for each of the six finalized Dhaka-specific Real Driving Cycles, demonstrating the low/medium speed, frequent-stop, high-transient characteristics typical of congested Dhaka traffic.

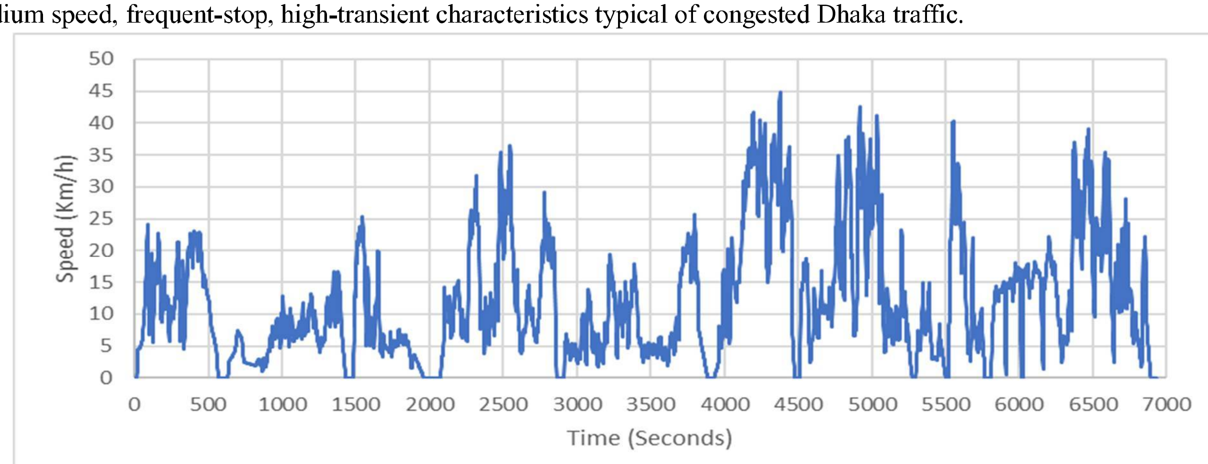
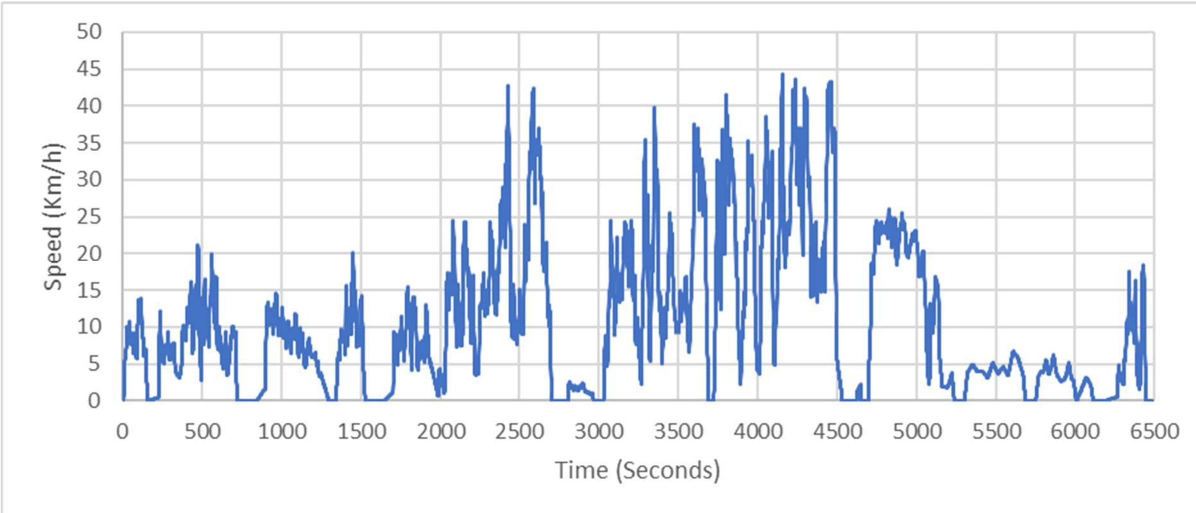
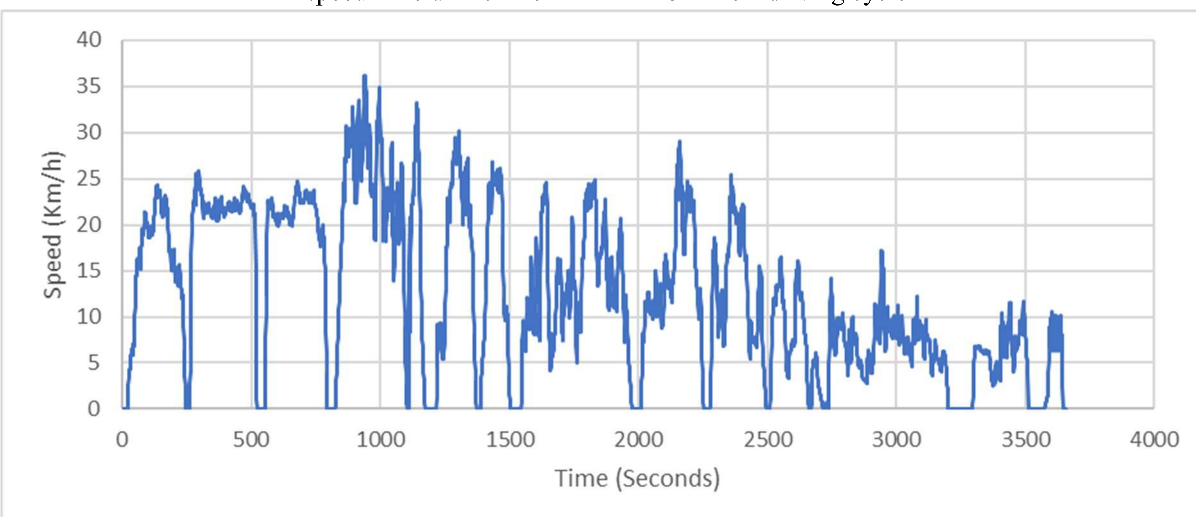


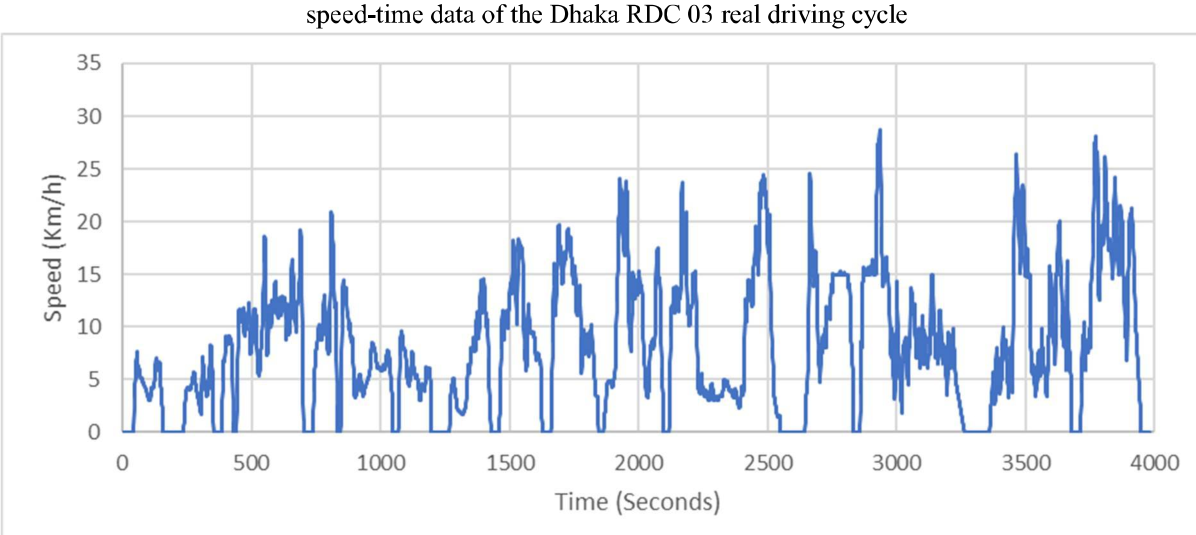
Fig. 9 speed-time data of the Dhaka RDC 01 real driving cycle



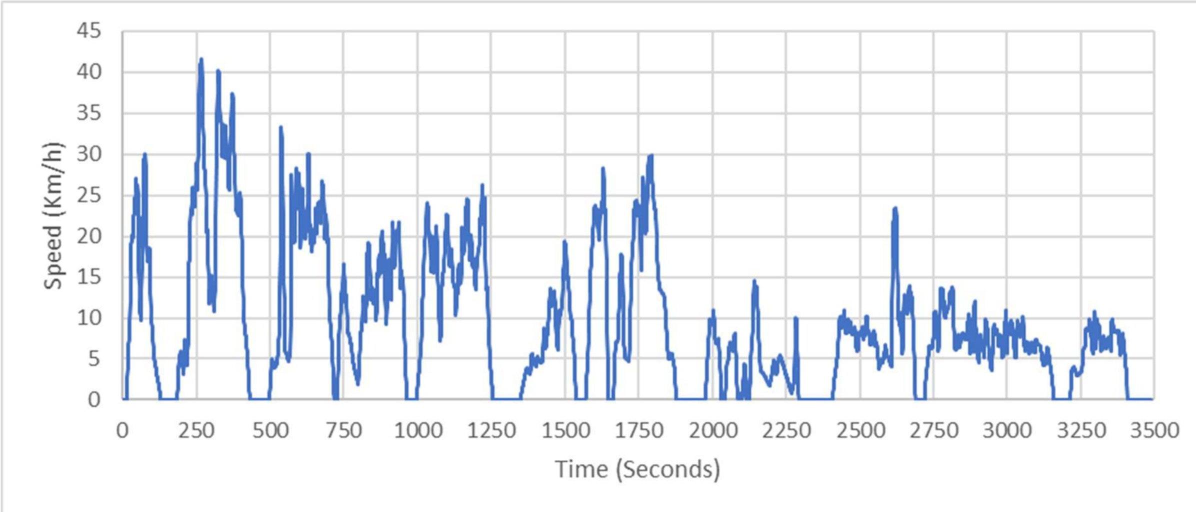
speed-time data of the Dhaka RDC 02 real driving cycle



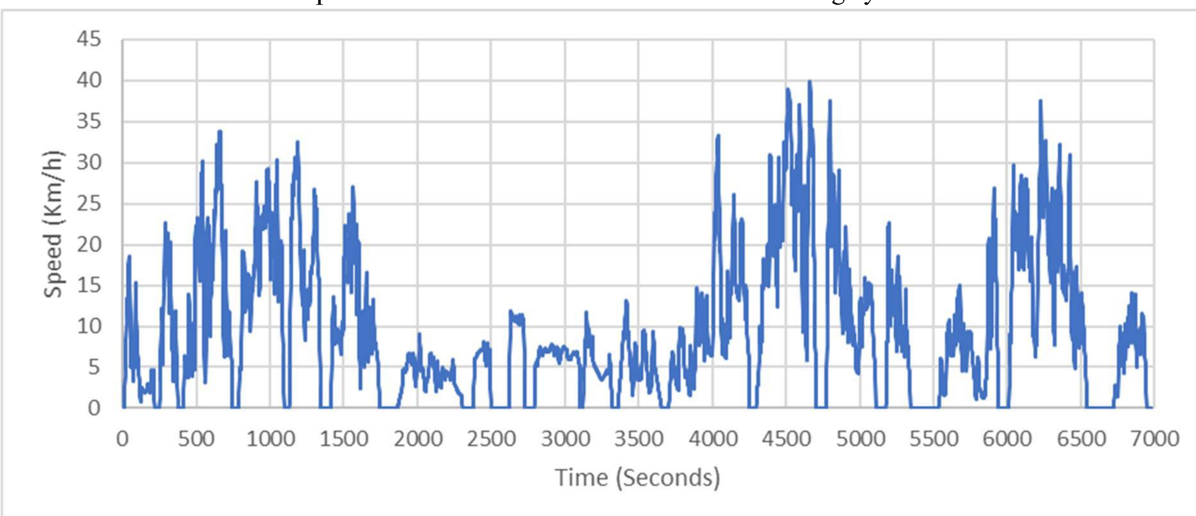
speed-time data of the Dhaka RDC 03 real driving cycle



speed-time data of the Dhaka RDC 04 real driving cycle



speed-time data of the Dhaka RDC 05 real driving cycle



speed-time data of the Dhaka RDC 06 real driving cycle

These finalized cycles constitute the primary "test group" for the dynamic powertrain model developed in subsequent chapters, enabling realistic assessment of fuel consumption, tailpipe emissions, and hybrid system benefits under authentic Dhaka operating conditions.

B. Selection of Supporting Standard Driving Cycles

To position the Dhaka driving cycles within a global analytical context and establish a benchmark for comparative evaluation, a comprehensive survey of existing international standard driving cycles was conducted. Five widely used cycles were selected to represent diverse urban driving conditions developed under standardized testing frameworks across different regions.

The selected benchmark cycles include:

EPA FTP-75 (United States): The Federal Test Procedure 75 is the primary certification cycle for light-duty vehicle emissions testing in the United States. It represents urban driving conditions with an average speed of approximately 34 km/h, a maximum speed of 91 km/h, and a total duration of 1,874 seconds. The cycle includes cold-start and hot-start phases to capture the effects of engine temperature on emissions.

EPA FTP-72 / UDDS (United States): Also known as the Urban Dynamometer Driving Schedule, this cycle represents city driving conditions with frequent stops and starts. It has an average speed of 31.5 km/h, a maximum speed of 91 km/h, and a duration of 1,369 seconds. The UDDS is often used for fuel economy certification and serves as the basis for the EPA's city fuel economy estimates.

New York City Cycle (NYCC): The NYCC was developed to represent highly congested urban driving conditions with extremely low average speed (approximately 11.4 km/h), frequent stops, and high transient intensity. It provides a useful benchmark for comparing Dhaka's congestion severity against an extreme US urban driving scenario.

Japanese 10–15 Mode: This cycle was the primary certification cycle for light-duty vehicles in Japan until 2005 and represents urban and suburban driving conditions with moderate congestion. It has an average speed of approximately 22.7 km/h and a maximum speed of 70 km/h.

ARTEMIS Urban (European Union): The ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems) urban cycle was developed under European research programs to represent real-world urban driving conditions. It captures low-speed, stop-and-start driving typical of congested European cities with an average speed of approximately 17.3 km/h.

These benchmarks serve as a control set against which the Dhaka-specific cycles can be compared, enabling direct quantitative assessment of the extent to which conventional certification cycles represent or fail to represent the operational severity of megacity traffic environments in developing economies.

Fig. 15 to19 shows the speed-time profiles for each selected standard driving cycle (EPA FTP-75, EPA FTP-72/UDDS, NYCC, Japanese 10–15 Mode, and ARTEMIS Urban), illustrating their characteristics relative to Dhaka's profiles.

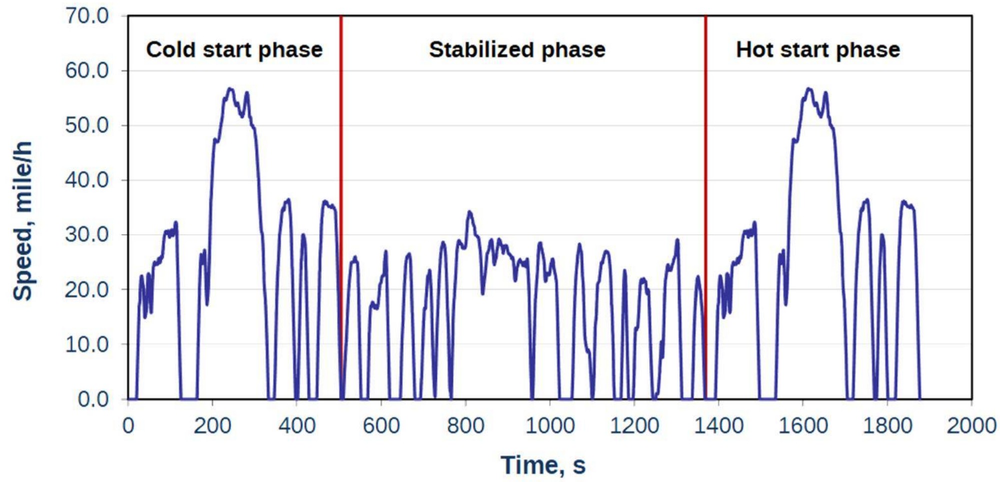


Fig. 10 Speed-time data of the EPA FTP-75 standard driving cycle

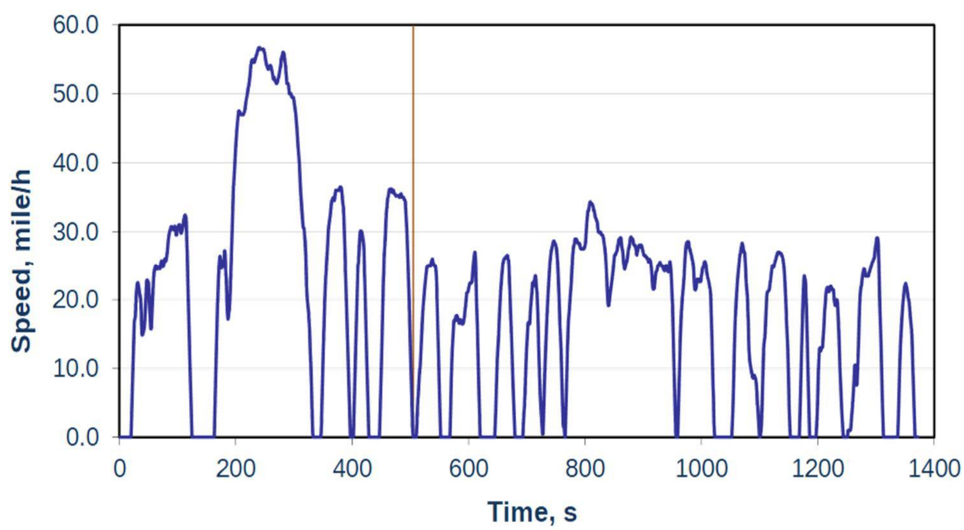


Fig. 11 Speed-time data of the EPA FTP-72 'UDDS' standard driving cycle

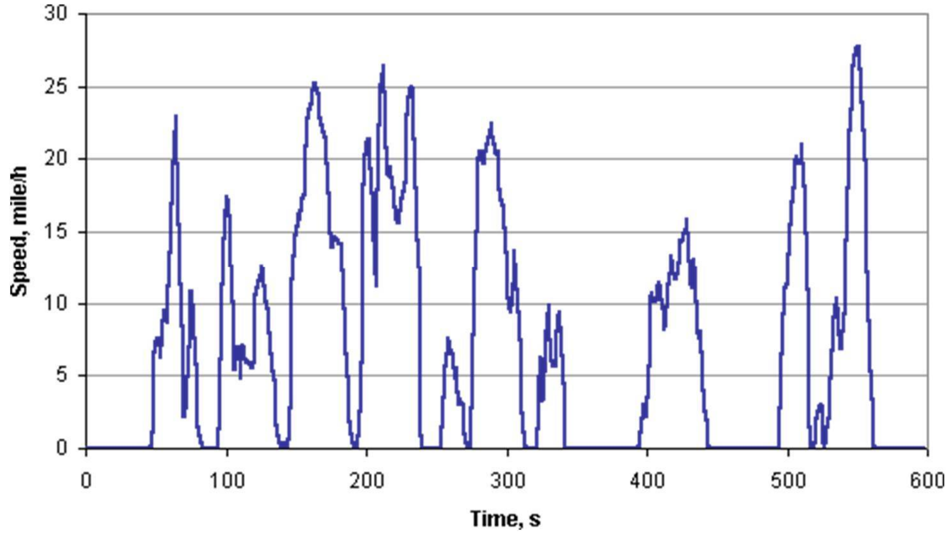


Fig. 12 Speed-time data of the EPA NYCC standard driving cycle

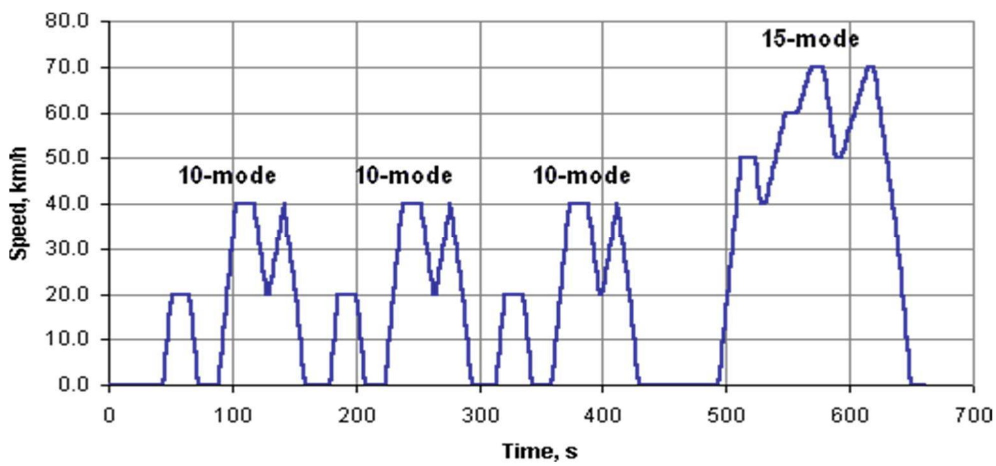


Fig. 13 Speed-time data of the Japanese 10-15 Mode standard driving cycle

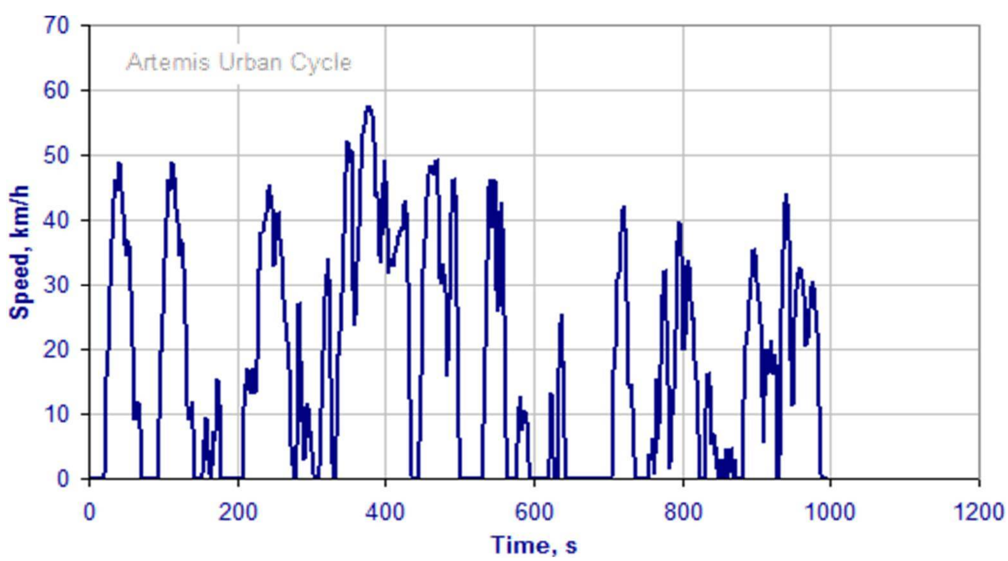


Fig. 14 Speed-time data of the ARTEMIS Urban standard driving cycle

C. Comparative Statistical Analysis

The six finalized Dhaka RDCs and the five selected international benchmark cycles were subjected to comprehensive kinematic analysis to quantify driving intensity, energy demand characteristics, and transient behaviour. This statistical characterization provides the empirical basis for understanding how Dhaka's unique traffic environment influences vehicle energy consumption and emissions, and for evaluating the relative benefits of hybrid powertrains under different operating conditions.

To ensure consistent, accurate, and reproducible calculation of all kinematic metrics, a dedicated MATLAB script was developed using the equations explained in section 4.4.5 as shown in Fig. 20 and 21. The MATLAB script reads raw CSV files containing time–speed data (with potentially non-uniform sampling intervals), resamples the data to a uniform 1 Hz frequency using linear interpolation, and computes a comprehensive suite of statistical indicators. Key calculations implemented in the code include:

- Average and maximum speeds via numerical integration
- Acceleration profiles derived from speed differences, with separation of positive and negative events
- Relative Positive Acceleration (RPA) computed as the integral of (velocity × positive acceleration) divided by total distance
- Idle duration and frequency using a threshold of 0.7 km/h
- Speed distribution characteristics, including percentage of time spent below 10 km/h and within the 10–20 km/h range
- Additional metrics such as root mean square acceleration and stop frequency

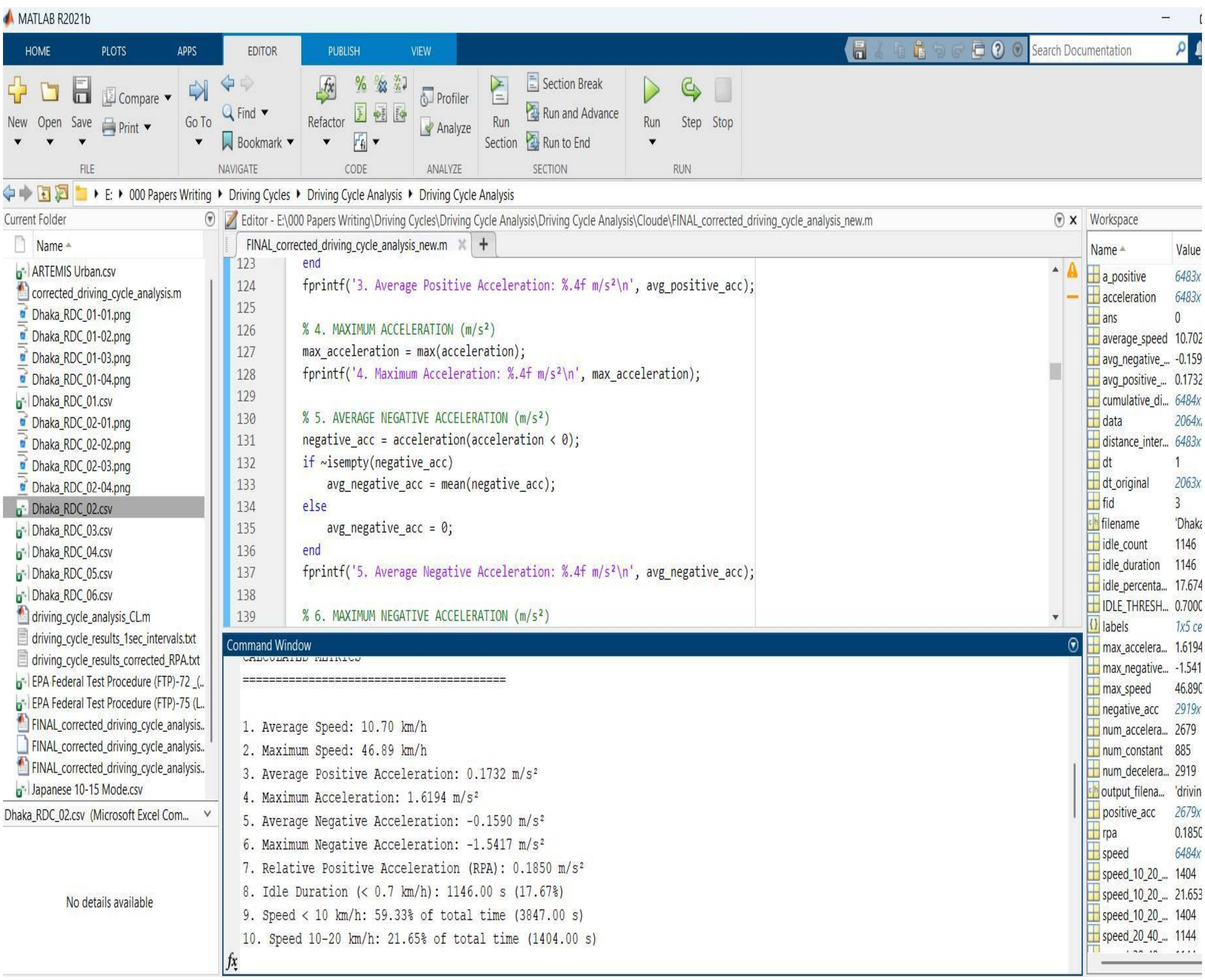


Fig. 15 Screen from the MATLAB script developed for the driving cycles analysis

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

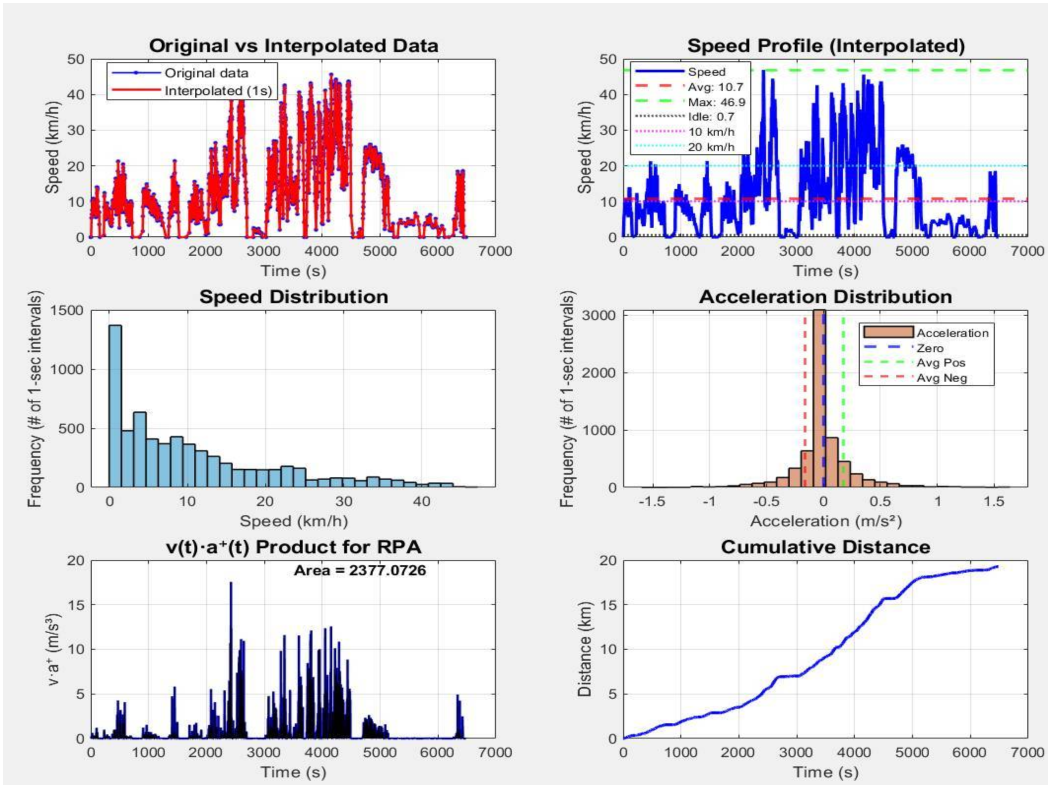


Fig. 16 The MATLAB script driving cycles analysis graphs

The code handles variable time intervals inherent in real-world GPS data by first resampling to a consistent 1 Hz grid, ensuring that all cycles are analyzed on a comparable temporal basis. Validation routines compare distances derived from raw and resampled data to quantify interpolation errors, which remained below 0.5% for all cycles analyzed.

1) Dhaka RDCs Statistical Analysis

Application of this MATLAB routine to the six Dhaka RDCs cycles produced the statistical summary presented in Table 2.

TABLE II

COMPARATIVE STATISTICAL ANALYSIS OF DHAKA RDCS

Metrics	RDC 01	RDC 02	RDC 03	RDC 04	RDC 05	RDC 06
Average Speed (km/h)	12.22	10.7	12.83	8.28	9.25	9.63
Maximum Speed (km/h)	45.29	46.89	37.46	31.22	42.54	41.07
Average Positive Acceleration (m/s²)	0.2084	0.1732	0.208	0.1746	0.1976	0.2131
Maximum Acceleration (m/s²)	2.2028	1.62	2.335	1.358	2.098	2.5889
Average Negative Acceleration (m/s²)	-0.1687	-0.159	-0.18	-0.155	-0.1705	-0.1790
Maximum Negative Acceleration (m/s²)	-1.736	-1.542	-3.74	-1.336	-2.344	-4.3361
Relative Positive Acceleration (m/s²)	0.1751	0.1850	0.1592	0.1937	0.217	0.232
Idle Duration (%) *	8.22 %	17.67 %	14.07 %	18.29 %	21.99 %	20.36 %
Speed < 10 km/h (%) *	51.19 %	59.33 %	44.52 %	63.65 %	64.54 %	61.45 %
Speed 10-20 km/h (%)	28.69 %	21.65 %	25.48 %	30.49 %	20.76 %	23.38 %

* Dhaka RDC idle percentages reflect removal of extended non-operational idling (>3 min) per local practice

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

2) Standard Driving Cycles Statistical Analysis

Application of this MATLAB routine to the five international benchmark cycles produced the statistical summary presented in Table 3.

TABLE III
STATISTICAL ANALYSIS OF THE INTERNATIONAL BENCHMARK STANDARD DRIVING CYCLES

Metrics	EPA FTP75	UDDS	NYCC	Japanese 10-15 Mode	ARTEMIS Urban
Average Speed (km/h)	34.06	31.44	11.4	22.69	17.64
Maximum Speed (km/h)	91.24	91.24	44.58	70	57.7
Average Positive Acceleration (m/s²)	0.511	0.505	0.66	0.5689	0.7324
Maximum Acceleration (m/s²)	1.475	1.475	2.682	0.7937	2.8611
Average Negative Acceleration (m/s²)	-0.576	-0.578	-0.636	-0.647	-0.7824
Maximum Negative Acceleration (m/s²)	-1.475	-1.475	-2.638	-0.833	-3.1389
Relative Positive Acceleration (m/s²)	0.1340	0.1346	0.2224	0.1274	0.2841
Idle Duration (%) *	19.44	19.37	40.4	32.53	28.97
Speed < 10 km/h (%) *	24.92	25.56	56.43	38.88	44.57
Speed 10-20 km/h (%)	6.02	6.85	18.36	6.51	14.59

3) Comparative Statistical Analysis of the RDCs and the Standard Benchmark Cycles:

a) Average and Maximum Speeds: Mean velocities were calculated for each cycle to characterize mobility constraints and operational variability across traffic conditions. For Dhaka RDCs, average speeds ranged from 8.28 to 12.83 km/h, reflecting severe congestion constraints. Maximum speeds ranged from 31.22 to 46.89 km/h, indicating that even under the most favorable conditions, vehicles rarely achieve speeds typical of international urban cycles. In contrast, standard cycles exhibited substantially higher average speeds (FTP-75: 34.1 km/h; ARTEMIS Urban: 17.3 km/h; NYCC: 11.4 km/h), with only the NYCC approaching the lower bound of Dhaka's speed range.

b) Speed Distribution Characteristics: Frequency distributions of instantaneous speeds were analyzed to quantify the dominance of low-speed operation. Dhaka RDCs showed that 70–94% of operating time was spent at speeds below 20 km/h, with 8–22% of total time spent at idle (after removal of extended non-operational idling >3 minutes). This contrasts sharply with standard cycles, where idle proportions typically range from 15–25% (with the exception of NYCC at 40.4%) and a greater proportion of time is spent at moderate speeds.

c) Acceleration and Deceleration Profiles: Instantaneous acceleration distributions were examined to characterize transient driving intensity and braking frequency. Dhaka RDCs exhibited high frequencies of acceleration events in the range ±0.5–1.5 m/s², reflecting the frequent stop-go transitions documented in Section 3.2. The magnitude and frequency of deceleration events—critical for assessing regenerative braking potential—were substantially elevated compared to standard cycles.

d) Relative Positive Acceleration (RPA): RPA was calculated as a key indicator of propulsion energy demand and driving aggressiveness. For Dhaka RDCs, RPA values ranged from 0.159 to 0.232 m/s², exceeding values for most standard urban cycles (FTP-75: 0.134 m/s²; UDDS: 0.135 m/s²; Japanese 10-15 Mode: 0.127 m/s²), and comparable to the highly congested NYCC (0.222 m/s²), despite their much lower maximum and average speeds. It only remains below the ARTEMIS Urban cycle (0.284 m/s²) due to the lower speed range. These RPA values confirm the high transient intensity of Dhaka's driving environment and underscore the substantial energy dissipation in braking events—energy that could potentially be recovered through regenerative braking in hybrid configurations.

e) Idle Characteristics: Idle duration and frequency were analyzed. Raw idle proportions in the collected data ranged from 35–42%, reflecting the severe congestion conditions. Following the removal of extended engine-off periods (>3 minutes) in accordance with local driving practice, the finalized Dhaka RDCs exhibit idle proportions of 8–22%, with individual idle events ranging from a few seconds to several minutes. This high idle intensity in the raw data represents a substantial source of fuel waste and emissions in conventional vehicles, but an opportunity for efficiency improvement in hybrid powertrains capable of engine shutdown during standstill periods.

The statistical analysis confirmed that Dhaka's driving environment is characterized by:

- extremely low average speeds (approximately one-third to one-half those of standard urban cycles)
- exceptionally high raw idle proportions (35–42% before data cleaning, reduced to 8–22% in finalized cycles)
- elevated transient intensity as measured by acceleration distributions and RPA
- frequent deceleration events offering substantial regenerative braking potential
- operating conditions that diverge fundamentally from the assumptions underlying standard certification cycles

These findings validate the necessity of developing Dhaka-specific driving cycles for accurate vehicle performance evaluation and establish a robust quantitative foundation for the powertrain modelling and simulation studies presented in subsequent chapters. The six finalized RDCs, with their demonstrated statistical representativeness, provide a realistic and rigorous basis for assessing fuel consumption, tailpipe emissions, and hybrid system benefits under authentic Dhaka operating conditions.

D. *Key Findings*

Extremely Low Average Speeds:

Dhaka RDCs exhibited average speeds ranging from 8.28 to 12.83 km/h, representing approximately one-third to one-half of standard urban cycles. For comparison, FTP-75 averages 34 km/h, ARTEMIS Urban 17.3 km/h, and even the highly congested NYCC 11.4 km/h. This persistent low-speed operation fundamentally alters vehicle operating points, reducing internal combustion engine efficiency while creating favorable conditions for hybrid electric operation.

Elevated Transient Intensity:

Relative Positive Acceleration (RPA) values for Dhaka RDCs ranged from 0.159 to 0.232 m/s^2, significantly exceeding most standard cycles (FTP-75: 0.134 m/s^2; UDDS: 0.135 m/s^2; Japanese 10-15 Mode: 0.127 m/s^2), comparable to the NYCC (0.222 m/s^2), though remaining below ARTEMIS Urban (0.284 m/s^2). High RPA indicates substantial propulsion energy demand and aggressive transient behavior, implying significant energy dissipation in braking events—energy potentially recoverable through regenerative braking in hybrid configurations.

Significant Idle Periods:

Raw idle percentages of the collected RDC data ranged from 35–42%. Following the removal of extended engine-off periods (>3 minutes) in accordance with local driving practice, the finalized RDCs exhibit idle proportions of 8–22%. This high idle intensity represents substantial fuel waste and emissions in conventional vehicles, yet presents an opportunity for efficiency improvement through engine shutdown strategies in hybrid powertrains.

Predominantly Low-Speed Operation:

The percentage of time spent below 20 km/h ranged from70–94% across the six RDCs, with the most congested cycles (RDC 04, 05, 06) exceeding 84%. This distribution confirms that vehicles operating in Dhaka spend the overwhelming majority of time in low-efficiency operating regimes for conventional internal combustion engines, but within the optimal efficiency envelope for electric motor operation.

VI. DISCUSSION

A. *Implications for Vehicle Performance Evaluation*

The marked divergence between Dhaka's real-world operating conditions and international certification cycles has profound implications for vehicle performance evaluation. Published fuel economy and emissions figures based on FTP-75, NEDC, or WLTP testing substantially overestimate on-road performance and underestimate actual environmental impacts for vehicles operating in megacity environments. This mismatch affects consumer expectations, national environmental accounting, and evidence-based policy formulation. For conventional internal combustion engine vehicles, the persistent low-speed operation documented in Dhaka RDCs implies operation at suboptimal engine loads, elevated specific fuel consumption, and increased emissions per kilometer traveled. The high transient intensity and frequent acceleration-deceleration events further exacerbate these inefficiencies through repeated movement away from steady-state operating points.

B. *Opportunities for New Energy Vehicles (Electric Vehicles and Hybrid Electric Vehicles)*

Paradoxically, the specific characteristics of Dhaka's driving environment persistently low speeds, high transient intensity, frequent deceleration events, and significant idle periods create uniquely favorable conditions for new energy vehicles, including both Battery Electric Vehicles (BEVs) and Hybrid Electric Vehicles (HEVs/PHEVs).

These powertrain technologies offer distinct but complementary advantages under severe congestion, capitalizing on operating conditions that conventional internal combustion engines find least efficient.

For Battery Electric Vehicles (BEVs), the extreme stop-and-go dynamics documented in the RDCs present optimal operating conditions. Electric motors exhibit peak efficiency at low speeds and high torque demands, precisely matching the 0–20 km/h speed regime that dominates 65–94% of driving time in Dhaka. The elevated Relative Positive Acceleration (RPA: 0.159–0.232 m/s²) indicates substantial regenerative braking potential, allowing BEVs to recover kinetic energy otherwise dissipated as heat during frequent deceleration events. Furthermore, BEVs eliminate idle fuel consumption entirely during the extended standstill periods (8–22% of cycle time), as electric motors consume negligible energy when stationary. The absence of tailpipe emissions during zero-speed idling and low-speed crawling also offers immediate localized air quality benefits in densely populated corridors.

For Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs), three mechanisms underlie their enhanced performance potential:

Regenerative braking can recover substantial kinetic energy during the frequent braking events characteristic of stop-and-go traffic, as evidenced by elevated RPA values (0.159–0.232 m/s²), thereby reducing overall fuel consumption and brake wear

Electric-only operation (particularly for PHEVs) can eliminate idle fuel consumption and emissions during the extended standstill periods documented in the RDCs (idle proportions of 8–22%), while HEVs can shut down the internal combustion engine during these periods

Optimized engine load management can improve efficiency under the highly variable power demand characteristic of congested urban driving, with the electric motor providing torque fill during high-demand transients and allowing the engine to operate within its optimal efficiency envelope when engaged

Both vehicle categories benefit from the decoupling of vehicle speed from engine speed (in series configurations) or the elimination of engine operation entirely (in electric mode), avoiding the low-load inefficiencies that plague conventional powertrains in severe congestion. The high frequency of deceleration events (indicated by RPA values significantly exceeding international cycles) maximizes energy recuperation opportunities, while the predominantly low-speed operation (average speeds 7–12 km/h) minimizes aerodynamic losses and extends electric range for PHEVs.

These factors suggest that new energy vehicles are likely to deliver disproportionately larger efficiency and emission-reduction benefits in Dhaka compared with operation under standard certification cycles or in less congested urban settings.

C. Methodological Contributions and Transferability

The methodology developed in this research integrating detailed contextual characterization, representative vehicle selection, high-fidelity on-road data collection using accessible GNSS technology, and systematic cycle synthesis offers a transferable framework for driving cycle development in other rapidly motorizing megacities facing similar challenges of constrained infrastructure, heterogeneous traffic, and extreme congestion.

The approach balances methodological rigor with practical feasibility, employing commercially available instrumentation, open-source software tools, and transparent signal processing algorithms. This accessibility facilitates replication in resource-constrained contexts where specialized chassis dynamometer facilities or high-cost instrumentation may not be available.

VII. CONCLUSIONS

This research has established a comprehensive methodological framework for developing real-world driving cycles representative of severe urban traffic conditions in developing megacities. Through systematic data collection, rigorous signal processing, and statistical analysis, six Dhaka-specific driving cycles were synthesized that authentically capture the operational severity of congested urban transport in a rapidly urbanizing context.

The key conclusions are:

Dhaka's driving environment is kinematically distinct from conditions represented by international certification cycles, with average speeds 50–75% lower than most standards (8.28–12.83 km/h versus 17–34 km/h, except NYCC: 11.4 km/h), severe congestion reflected in 35–42% raw idle proportions (reduced to 8–22% in finalized cycles after accounting for local engine-off practices), and Relative Positive Acceleration (0.159–0.232 m/s²) exceeding most standard cycles including the congested NYCC (0.222 m/s²), though remaining below ARTEMIS Urban (0.284 m/s²).

International standard driving cycles substantially underestimate the operational severity of megacity traffic in developing economies. The FTP-75, ARTEMIS Urban, and even the NYCC fail to capture the extreme low-speed dominance, high transient intensity, and elevated RPA characteristic of Dhaka's environment.

Severe congestion creates favorable conditions for hybrid electrification, where the high transient intensity and frequent deceleration events maximize regenerative braking potential (as indicated by RPA values), and electric-only operation can eliminate substantial idle fuel consumption and emissions.

The developed RDCs provide an essential empirical foundation for evaluating vehicle performance under authentic operating conditions and inform evidence-based transport electrification strategies for Bangladesh and similar rapidly urbanizing contexts.

Future research should employ these cycles in dynamic powertrain simulation to quantify fuel consumption, tailpipe emissions, and hybrid system benefits under realistic Dhaka operating conditions, enabling evidence-based assessment of alternative powertrain technologies for sustainable urban transport in developing megacities.

REFERENCES

[1] M. André, R. Joumard, R. Vidon, P. Tassel, and P. Perret, 'Real-world European driving cycles, for measuring pollutant emissions from high- and low-powered cars', Atmos. Environ., vol. 40, no. 31, pp. 5944–5953, Oct. 2006, doi: 10.1016/j.atmosenv.2005.12.057.

[2] W. T. Hung, H. Y. Tong, C. P. Lee, K. Ha, and L. Y. Pao, 'Development of a practical driving cycle construction methodology: A case study in Hong Kong', Transp. Res. Part Transp. Environ., vol. 12, no. 2, pp. 115–128, Mar. 2007, doi: 10.1016/j.trd.2007.01.002.

[3] J. Lin and D. A. Niemeier, 'An exploratory analysis comparing a stochastic driving cycle to California's regulatory cycle', Atmos. Environ., vol. 36, no. 38, pp. 5759–5770, Dec. 2002, doi: 10.1016/S1352-2310(02)00695-7.

[4] N. Sharmeen and D. Houston, 'Spatial Characteristics and Activity Space Pattern Analysis of Dhaka City, Bangladesh', Urban Sci., vol. 3, no. 1, p. 36, Mar. 2019, doi: 10.3390/urbansci3010036.

[5] K. Ahn, H. Rakha, A. Trani, and M. Van Aerde, 'Estimating Vehicle Fuel Consumption and Emissions based on Instantaneous Speed and Acceleration Levels', J. Transp. Eng., vol. 128, no. 2, pp. 182–190, Mar. 2002, doi: 10.1061/(ASCE)0733-947X(2002)128:2(182).

[6] M. Hossain, 'Estimation of saturation flow at signalised intersections of developing cities: a micro-simulation modelling approach', Transp. Res. Part Policy Pract., vol. 35, no. 2, pp. 123–141, Feb. 2001, doi: 10.1016/S0965-8564(99)00050-6.

[7] A. M. S. Rumi et al., 'A Tale of Side Friction Elements in Dhaka City: From Modeling Real Cases to Revealing Impacts Through Event-Based Simulation', IEEE Access, vol. 13, pp. 37344–37360, 2025, doi: 10.1109/ACCESS.2025.3544511.

[8] M. Ehsani, Y. Gao, S. Longo, and K. Ebrahimi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, 3rd ed. Boca Raton: CRC Press, 2018. doi: 10.1201/9780429504884.

[9] M. U. Babu, 'Vehicle registration drops 15% to a decade low in 2024', The Business Standard. Accessed: Mar. 27, 2026. [Online]. Available: https://www.tbsnews.net/bangladesh/vehicle-registration-drops-15-decade-low-2024-1033676

[10] A. Iqbal, S. Afroze, and M. M. Rahman, 'Vehicular PM Emissions and Urban Public Health Sustainability: A Probabilistic Analysis for Dhaka City', Sustainability, vol. 12, no. 15, Aug. 2020, doi: 10.3390/su12156284.

[11] E. V. Rojas-Reinoso, M. Anacleto-Fernández, J. Utreras-Alomoto, C. Carranco-Quiñonez, and C. Mata, 'Comparative Study of Fuel and Greenhouse Gas Consumption of a Hybrid Vehicle Compared to Spark Ignition Vehicles', World Electr. Veh. J., vol. 16, no. 1, p. 4, Dec. 2024, doi: 10.3390/wevj16010004.

[12] A. Hasnat, 'Toyota Cars Price in Bangladesh 2026', Carbarn Bangladesh. Accessed: Mar. 27, 2026. [Online]. Available: https://www.carbarn.com.bd/blog/toyota-cars-price-in-bangladesh

[13] R. Ahasan, Md. N. Hoda, Md. S. Alam, Y. R. Nirzhar, and A. Kabir, 'Changing institutional landscape and transportation development in Dhaka, Bangladesh', Heliyon, vol. 9, no. 7, p. e17887, Jul. 2023, doi: 10.1016/j.heliyon.2023.e17887.

[14] Md. Z. Uddin and T. Mizunoya, 'An economic analysis of the proposed Dhaka–Chittagong Expressway in Bangladesh with the viewpoint of GHG emission reduction', Asia-Pac. J. Reg. Sci., vol. 4, no. 2, pp. 285–314, Jun. 2020, doi: 10.1007/s41685-019-00136-5.

[15] A. Iqbal, S. Afroze, and Md. M. Rahman, 'Probabilistic Health Risk Assessment of Vehicular Emissions as an Urban Health Indicator in Dhaka City', Sustainability, vol. 11, no. 22, p. 6427, Nov. 2019, doi: 10.3390/su11226427.

[16] 'Updating the Revised Strategic Transport Plan for Dhaka', Early Warning System. Accessed: Mar. 27, 2026. [Online]. Available: https://ews.rightsindevelopment.org/projects/54451-001-updating-the-revised-strategic-transport-plan-for/

[17] P. Akbar, V. Couture, G. Duranton, and A. Storeygard, 'The Fast, the Slow, and the Congested: Urban Transportation in Rich and Poor Countries', National Bureau of Economic Research, Cambridge, MA, w31642, Aug. 2023. doi: 10.3386/w31642.

[18] K. Mahmud, K. Gope, and S. M. R. Chowdhury, 'Possible Causes & Solutions of Traffic Jam and Their Impact on the Economy of Dhaka City', J. Manag. Sustain., vol. 2, no. 2, p. p112, May 2012, doi: 10.5539/jms.v2n2p112.

[19] M. A. Rahaman, A. Kalam, and Md. Al-Mamun, 'Unplanned urbanization and health risks of Dhaka City in Bangladesh: uncovering the associations between urban environment and public health', Front. Public Health, vol. 11, p. 1269362, Oct. 2023, doi: 10.3389/fpubh.2023.1269362.

[20] F. T. K. Saqui, 'Regional Analysis of Urban Sprawl in Bangladesh', J. Bangladesh Inst. Plan., pp. 15–23, Dec. 2017, doi: 10.3329/jbip.v10i1.76759.

[21] M. Sarker, K. Sakib, and N. Nower, 'Identification of Traffic Bottlenecks in Central Dhaka Through Spreading Graph-Based Congestion Analysis':, in Proceedings of the 11th International Conference on Vehicle Technology and Intelligent Transport Systems, Porto, Portugal: SCITEPRESS - Science and Technology Publications, 2025, pp. 125–135. doi: 10.5220/0013296200003941.

[22] M. Hossain, 'Dhaka traffic: causes, effects and solution'. Accessed: Mar. 27, 2026. [Online]. Available: https://www.newagebd.net/post/opinion/258763/dhaka-traffic-causes-effects-and-solution

[23] H. Mohiuddin, M. M. R. Bhuiya, M. M. U. Hasan, and H.-T. Jamme, 'How individual perceptions of transportation systems influence mode choice for mobility-challenged people: A case study in Dhaka using an integrated choice and latent variable model', Transp. Policy, vol. 147, pp. 259–270, Mar. 2024, doi: 10.1016/j.tranpol.2023.12.017.

[24] H. Ward, S. Robertson, K. Townley, and A. Pedler, Reporting of road traffic accidents in London: Matching Police STATS19 with hospital accident and emergency data: supplementary report for St. Thomas' Hospital Central London, Version: phase 3 final. in Published project report / TRL Limited PPR, no. 242. Wokingham, Berks, UK: TRL Limited, 16.

[25] P. Roy, J. F. Ayshe, Md. I. A. S. Arnob, and Md. I. H. Bappy, 'IMPACT OF MRT LINE 6 (DHAKA METRO RAIL) ON COMMUTER MODAL SHIFT, TRAVEL TIME REDUCTION, AND FUTURE EXPANSION PROSPECTS'. Accessed: Mar. 27, 2026. [Online]. Available: https://www.aiub.edu

[26] M. L. H. Mollah, 'Reducing traffic congestion through ride sharing in Bangladesh: a case study of Dhaka City', Thesis, Brac University, 2020. Accessed: Mar. 27, 2026. [Online]. Available: https://dspace.bracu.ac.bd:8443/xmlui/handle/10361/14816

[27] L. Ferretto, M. Carra, and B. Barabino, 'Enlarging the concept of quality of service: from a sectoral to a multimodal perspective', Transp. Lett., pp. 1–16, Feb. 2026, doi: 10.1080/19427867.2026.2636006.

[28] Updating the Revised Strategic Transport Plan for Dhaka - DRAFT FINAL REPORT. DTCA, 2025. Accessed: Mar. 27, 2026. [Online]. Available: //library.dtcabd.com%2Findex.php%3Fp%3Dshow_detail%26id%3D59

[29] N. Tabassum, A. F. S. A. Rahman Khan, and A. Arefin, 'Impact of Various Transportation Modes on the Air Quality of Dhaka City: A Case Study at Motijheel', J. Eng. Sci., vol. 13, no. 2, pp. 83–89, Jan. 2023, doi: 10.3329/jes.v13i2.63728.

[30] 'Car market in BD showing signs of recovery in 2025'. Accessed: Mar. 27, 2026. [Online]. Available: https://observerbd.com/news/535768

[31] D. R. Keith, S. Naumov, H. E. Rakoff, L. M. Sanches, and A. Singh, 'The effect of increasing vehicle utilization on the automotive industry', Eur. J. Oper. Res., vol. 317, no. 3, pp. 776–792, Sep. 2024, doi: 10.1016/j.ejor.2022.10.030.

[32] M. A. Majid, C. R. K. J, and A. Ahmed, 'Advances in electric vehicles for a self-reliant energy ecosystem and powering a sustainable future in India', E-Prime - Adv. Electr. Eng. Electron. Energy, vol. 10, p. 100753, Dec. 2024, doi: 10.1016/j.prime.2024.100753.

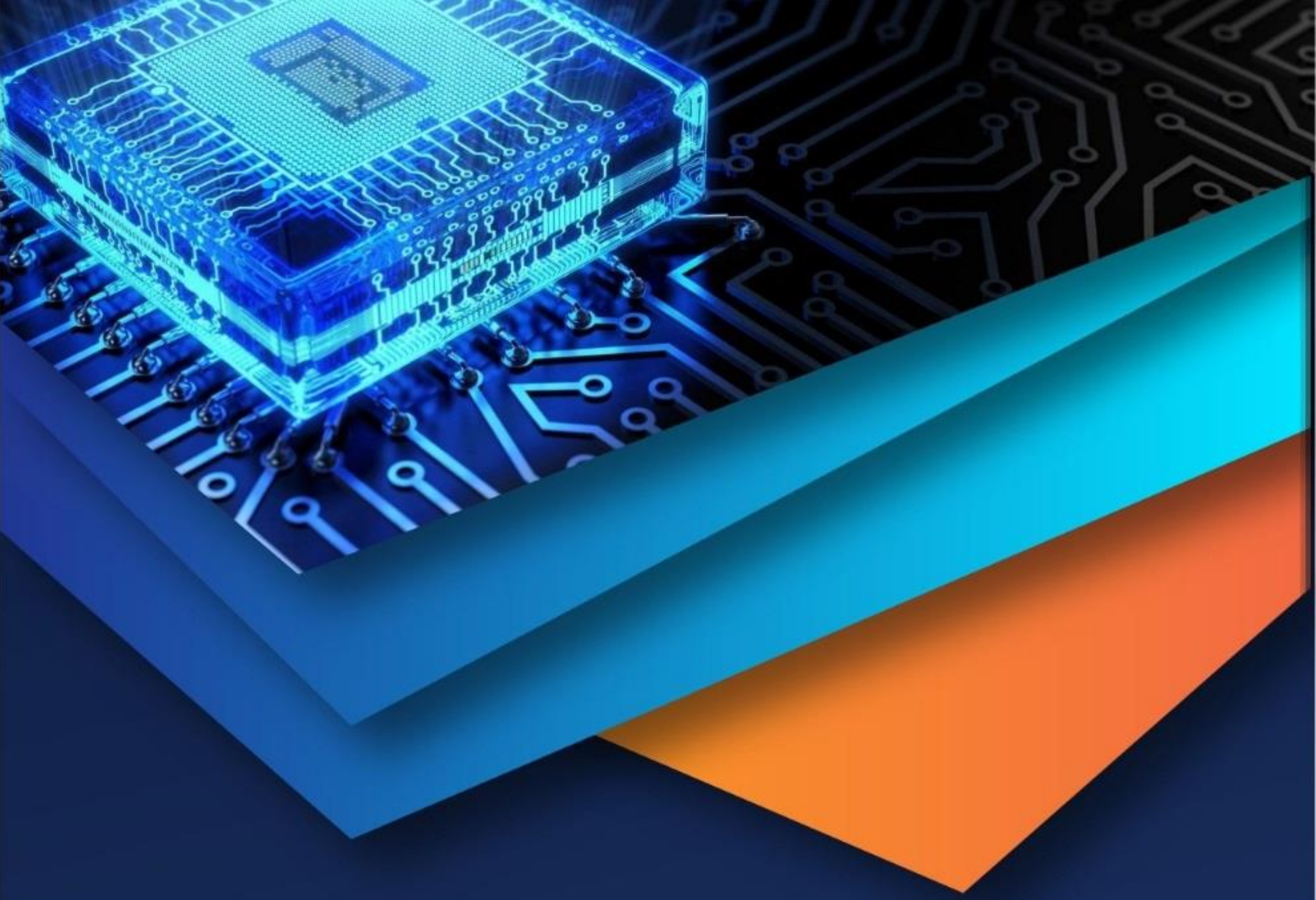
[33] 'Exploring The Top 5 Popular Car Brands In Bangladesh'. Accessed: Mar. 27, 2026. [Online]. Available: https://www.garirbazar.com/en/blog/exploring-the-top-5-popular-car-brands-in-bangladesh

[34] Garirbazar, 'Analyzing the Top 5 Best-Selling Cars in Bangladesh'. Accessed: Mar. 27, 2026. [Online]. Available: https://www.garirbazar.com/en/blog/analyzing-the-top-5-best-selling-cars-in-bangladesh

[35] J. M. Miller, 'Hybrid electric vehicle propulsion system architectures of the e-CVT type', IEEE Trans. Power Electron., vol. 21, no. 3, pp. 756–767, May 2006, doi: 10.1109/TPEL.2006.872372.

[36] M. Majidi Nezhad, S. Moradian, M. Guezgouz, X. Shi, A. Avelin, and F. Wallin, 'A GIS-portal platform from the data perspective to energy hub digitalization solutions- A review and a case study', Renew. Sustain. Energy Rev., vol. 223, p. 116019, Nov. 2025, doi: 10.1016/j.rser.2025.116019.

[37] H. Yuan and G. Li, 'A Survey of Traffic Prediction: from Spatio-Temporal Data to Intelligent Transportation', Data Sci. Eng., vol. 6, no. 1, pp. 63–85, Mar. 2021, doi: 10.1007/s41019-020-00151-z.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY