

IoT-Based Connected Fleet Management for Smart and Sustainable Mobility in Saudi Arabia

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Abstract: Fleet management based on connectivity is now evolving from simple location tracking towards becoming a cyber-physical mobility capability in which vehicles, roadside infrastructure, cloud platforms and operational teams constantly share data. This article looks at how Internet of Things technologies can help to achieve smart and sustainable fleet management in Saudi Arabia, with a focus on real-time visibility, predictive maintenance, route and energy optimisation, safety, interoperability, cybersecurity and environmental performance. A structured review of 30 peer-reviewed studies verified by DOI was carried out between 2020 and 2025. The evidence was organised using thematic synthesis rather than statistical aggregation since the body of literature includes a wide variety of fleet types, communication technologies, optimisation models and evaluation scenarios. The synthesis indicates that efficient fleet platforms rely on five interacting layers: reliable vehicle sensing, low-latency connectivity, edge-cloud data processing, decision intelligence, and governance that leads to measurable sustainability outcomes. The greatest operational benefits occur when these layers function as a closed loop so that telemetry data can be turned into actions such as changing routes, scheduling maintenance, giving driver feedback and making decisions about charging. Yet having good technical connectivity by itself does not ensure sustainable mobility; the benefits depend on the quality of the data, cybersecurity, interoperability, the electrification of the fleet, the readiness of the infrastructure and co-ordination at an institutional level. For Saudi Arabia, the literature recommends a step-by-step architecture that combines current telematics with 5G and vehicle-to-everything services, scalable edge-cloud analytics, common data models and performance governance. The review also suggests an implementation framework tailored to Saudi conditions and a number of indicators relating to operational performance, the environment, safety and digital resilience which are appropriate for fleet operators and mobility authorities.

Keywords: Internet of Things (IoT); Smart Fleet Management; Sustainable Mobility; Saudi Arabia; Real-Time Vehicle Tracking; Predictive Maintenance; Route Optimisation.

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1. INTRODUCTION

Road fleets are at the point where logistics, public transport, municipal services, corporate mobility and emerging automated transport come

together. The way these fleets perform has a simultaneous impact on congestion, service reliability, energy consumption, road safety and urban emissions. Traditional fleet systems have

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mostly been set up to provide information on position, distance travelled and simple vehicle conditions. By contrast, modern Internet of Things (IoT) systems combine data from onboard sensors, navigation information, controller-area-network signals, wireless connectivity and processing power at the edge or in the cloud to produce a continuous view of operations. Research into the Internet of Vehicles takes this approach further by considering vehicles as mobile data nodes that communicate with the infrastructure, with platforms and with other vehicles [3, 4]. The practical change is a shift from merely reporting things after the fact to continuous sensing, prediction and coordinated action.

The situation is especially pertinent to Saudi Arabia, since the development of smart mobility in the country is linked to large-scale transport investments, the expansion of digital infrastructure, the introduction of intelligent transport services and the aim of making urban mobility more efficient and sustainable. A national benchmarking study revealed that the Saudi initiatives already include a number of intelligent transport elements, although it also pointed out the need for better integration, standardisation, cybersecurity and performance monitoring [1]. Recent evidence from Saudi cities also connects smart-mobility solutions with improved transport efficiency, demonstrating that the results depend on infrastructure and institutional coordination, not on technology alone [2].

Fleet management is likewise becoming more technically demanding. A connected fleet can produce a large amount of data relating to its position, engine performance, battery, tyres, temperature, driver behaviour, cargo and diagnostics. If all of these data streams are processed centrally, this can lead to problems in terms of bandwidth, latency and scalability. That is why vehicular edge computing spreads the computing tasks between the vehicles, the roadside or local edge resources and the central platforms [15-18]. Moreover, digital-twin methods involve creating virtual representations of both vehicles and transport environments so that the operational states can be monitored, simulated and optimised before any actions are taken with respect to the physical assets [10-12]. As a result, the capabilities of fleet management extend well beyond simple dispatching and become part of a dynamic decision system.

Sustainability introduces yet another aspect: connected mobility has the potential to cut down on unnecessary idling, enhance traffic flow and enable more efficient routing, but this does not mean that environmental benefits will automatically follow. Studies of connected and automated vehicles indicate that the energy and emissions results are influenced

by the way the vehicles are used, the level of travel demand, routing behaviour, the technology of the vehicles and the existing transport system [24-26]. Electrified fleets also involve certain constraints relating to the availability of charging stations, the state of the batteries, energy consumption and routing that varies with time [28, 29]. Sustainable fleet management thus requires the simultaneous optimisation of service performance and resource use.

The literature is still scattered throughout the areas of IoT architecture, intelligent transportation, fleet control, edge computing, routing, cybersecurity, digital twins and sustainable mobility. Although fleet studies usually show technical prototypes they fail to link these with city-wide governance, and while smart-city studies may talk about strategy they do not explain how fleet data should be turned into operational decisions. This lack of integration is important in Saudi Arabia, since there heterogeneous public, commercial and industrial fleets operate in dense cities, along intercity corridors and in high-temperature environments whilst the digital infrastructure is still developing.

The review looks at how IoT-driven connected fleet management can contribute to achieving smart and sustainable mobility in Saudi Arabia. Instead of proposing a new hardware platform, it seeks to establish an architecture and a method of implementation based on evidence. The analysis is guided by four objectives: identifying the technical layers needed to ensure reliable connected operations; evaluating the aspects of routing, analytics, predictive maintenance and digital twins; looking at the sustainability, cybersecurity and governance requirements; and converting the evidence into a step-by-step framework for Saudi Arabia that includes measurable performance indicators.

2. REVIEW METHODOLOGY

A structured review approach was used since the topic in question is multidisciplinary and relates to technology. Fleet management involving connectivity covers areas such as transportation engineering, computer networks, IoT, operations research, cybersecurity and sustainability, which is why a single quantitative measure of effect is not suitable. The period for the review was limited to 2020 to 2025 in order to include the most recent developments in connected vehicles, edge computing, digital twins and smart mobility.

The identification of the source involved the use of a range of terms including "Internet of Things", "Internet of Vehicles", "connected vehicle", "fleet

management", "fleet optimisation", "intelligent transportation system", "smart mobility", "vehicular edge computing", "digital twin", "vehicle-to-everything", "predictive maintenance", "electric vehicle routing", "cybersecurity", "sustainable mobility" and "Saudi Arabia". The source selection focused on peer-reviewed material listed in major engineering and multidisciplinary scholarly databases. The two papers provided were employed to adjust the thematic scope, incorporate the Saudi contextual perspective and determine the structure of the manuscript; the more recently dated paper was not included as evidence since the review period concludes in 2025.

To be eligible, a study had to have a publication date between 2020 and 2025, include a verifiable DOI, and make a direct contribution to at least one of the following six areas: connected-fleet architecture, vehicular communication and edge computing, routing or operational optimisation, digital-twin or predictive analytics, cybersecurity and trust, or sustainability and smart-mobility implementation. Those studies which were concerned solely with a component and had no relevance to mobility were excluded. Non-peer-reviewed reports, duplicates, items lacking DOI verification, and sources outside the date range were also excluded. The final evidence base consisted of 30 publications with verified DOIs and intentionally included reviews, architecture studies, optimisation research and applied prototypes.

All the sources were evaluated using a standard framework which included the physical and

digital architecture, the decision functions such as routing, dispatching, maintenance and charging, the performance results such as latency, reliability, utilisation, safety and energy consumption, the enabling factors such as interoperability, privacy and cybersecurity, and any evidence relating to smart cities or to the implementation in Saudi Arabia. Additionally, the limitations of the study were noted in order to differentiate between claims based on simulation and those that were actually demonstrated in real operations.

The process took place in three stages. First, the evidence was examined within each theme in order to spot repeated requirements and areas of disagreement. Next, the relationships between the themes were mapped out to find where operational value arises from the combination of different technologies. Lastly, the evidence was converted into a framework tailored to the Saudi context, with a focus on deployable functions and measurable results. Like this, it is not assumed that all technologies are equally mature; vehicle telemetry is well established, while fleet-scale digital twins and fully integrated vehicle-to-everything services still remain more dependent on infrastructure [10-12].

The validity of the references was verified by means of DOI resolution or by consulting the publisher's or index's metadata. Rather than trying to estimate a pooled treatment effect, this review is a concentrated, reproducible synthesis thematically based on a well-defined set of current evidence.

Table 1: Thematic synthesis of the reviewed evidence and relevance to connected fleet deployment

Theme	Representative evidence	Primary implication	Saudi deployment relevance
Fleet IoT and data architecture	[3-8]	Vehicle telemetry requires gateway normalisation, scalable streaming and integration with decisions.	Prioritise canonical vehicle data and modular integration across heterogeneous fleets.
Edge, cloud and communications	[14-18]	Latency-sensitive services benefit from edge processing, while cloud resources support history and enterprise analytics.	Use workload-based placement rather than a single connectivity or computing model.
Routing and operational optimisation	[9-29]	Dynamic routing must incorporate traffic, service constraints, battery state and charging availability.	Calibrate optimisation to local travel patterns, heat and charging infrastructure.
Digital twins and predictive intelligence	[10-12]	Synchronised virtual state can support simulation, maintenance and adaptive resource decisions.	Introduce twin fidelity progressively where it improves operational decisions.
Cybersecurity and trust	[19-22]	Connected vehicles increase attack surfaces and make telemetry integrity safety-relevant.	Apply identity, segmentation, continuous verification, logging and controlled interfaces.
Sustainability and smart mobility	[1-30]	Environmental outcomes depend on operational policy, electrification, infrastructure and governance.	Link smart-fleet programmes to measurable energy, service and safety outcomes.

3. Connected Fleet Architecture and Data Flow

The literature always presents connected fleet management as a system made up of several layers and not as a single application. At the vehicle level, sensing starts with information on location and movement but gradually also involves engine parameters, fault codes, the energy state, environmental conditions and driver inputs. The IoV architectures define the way in which vehicles, users, infrastructure and service platforms interact [3]. Research based on big data indicates that connected vehicles generate heterogeneous data streams whose value relies on timely processing, data quality and context [4]. Studies carried out on fleets also show that sensor data only become useful when they are linked to diagnostics, maintenance, utilisation and decision-making processes [6-8].

There is also an onboard gateway which collects the signals, records the time at which they occur, carries out the first stage of validation and handles communication with external systems. It would be neither efficient nor reliable to send all the raw sensor data directly to a remote cloud. Research into industrial fleets has shown the advantages of having open interfaces, supporting multiple protocols and carrying out local processing in cases where the fleets include machines from different manufacturers and of different types [8]. Given that this kind of diversity is probably present among the fleets used by Saudi operators in the areas of logistics, construction, municipal services and industry, normalising the data before it is transmitted helps to reduce reliance on vendors and makes integration easier.

The third layer is connectivity. As demonstrated by the various fleet-management prototypes, in situations where cost and coverage are the main concerns, lower-bandwidth networks are appropriate for periodic monitoring, while cooperative or safety applications demand lower latency and higher capacity [5]. Because of this, research into the Internet of Vehicles (IoV) regards connectivity as a portfolio comprising cellular networks, vehicle-to-everything links and dedicated low-power technologies [3-14]. Data must be categorised according to its urgency since safety messages and dynamic routing events require priority, whereas maintenance history can afford to have its synchronisation delayed.

The fourth layer involves edge and cloud computing; vehicular edge computing brings about processing being nearer to the vehicles so that latency-sensitive functions do not have to rely

completely on remote data centres [15, 16]. Although federated and distributed methods can reduce the centralisation of raw data they also give rise to problems concerning orchestration and security [15]. Research into serverless edge computing shows how elastic execution can assist with dynamic roadside workloads [17], and offloading studies point out that mobility, privacy, resource allocation and communication variability are ongoing constraints [18]. It follows that a Saudi fleet platform should carry out immediate anomaly detection at the vehicle level and leave the historical analytics or enterprise integration for the cloud.

The fifth layer is the fleet-intelligence platform, on which telemetry is transformed into fleet state together with alerts, predictions and actions. The scalable Logistics 4.0 architectures explain the importance of a stream-processing design when thousands of devices are publishing continuously [7]. Research into digital twins contributes synchronised virtual representations that allow scenarios to be tested and enable adaptive control [10]. Smart-mobility twins combine real-time communication, the virtual state and navigation logic [11], and studies involving digital-twin-assisted IoV demonstrate that the virtual state can also be used to support computing decisions [12].

Figure 1 presents a five-layer architecture based on these findings. Its key feature is bidirectionality; data should not be allowed to flow only upwards to the dashboards, since decisions have to be sent back to the vehicles, to the dispatchers, to the maintenance teams or to the charging systems. The presence of this closed loop means that there is a need for command validation, for identity management, for audit trails and for fail-safe behaviour. If communication is interrupted, the local components must have sufficient intelligence to operate safely and to resynchronise later.

Interoperability applies to all levels, since proprietary interfaces and inconsistent data structures are still obstacles to scalability [5-8]. In order to be practical, an architecture must include a standard model for vehicle identity, trip state, energy state, fault status, location, driver assignment and maintenance events. Versioned application interfaces should then be used to make these objects available to dispatch, enterprise, maintenance, charging and authority systems without the need to hard-code each integration. It is thus possible for the digitalisation of the Saudi fleet to take place gradually while at the same time retaining the earlier telematics investments.

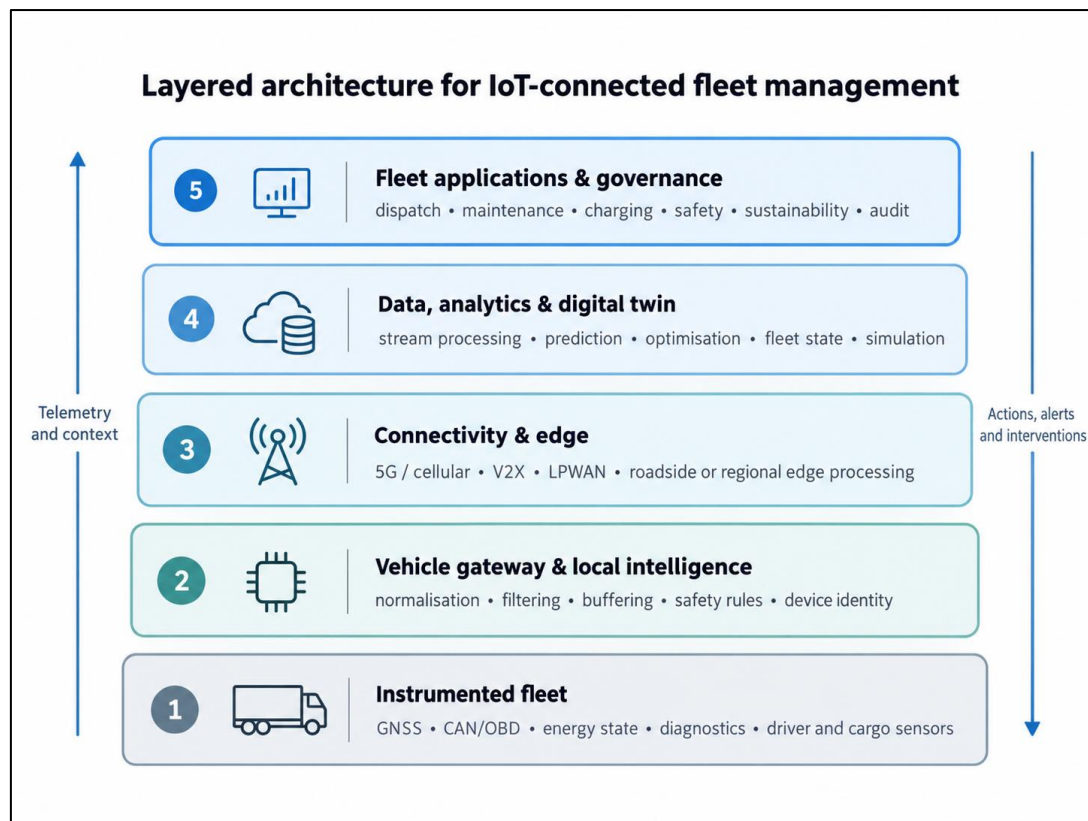


Figure 1: Layered architecture for IoT-connected fleet management, showing bidirectional telemetry and intervention flow

4. Operational Intelligence: Routing, Maintenance and Digital Twins

The value of a connected fleet is achieved when telemetry leads to changes in operational decisions. Route and dispatch optimisation provide the most obvious examples. Research into IoV routing indicates that dynamic networks need algorithms which adapt to changes in topology, congestion and communication conditions rather than depending entirely on fixed paths [13]. Network-optimisation studies do the same by viewing intelligent transport as a combined issue of connectivity, computing resources and mobility management [14]. At fleet level, research into the optimisation of connected and autonomous vehicles is now increasingly combining traffic conditions with assignment, capacity and service constraints [9].

The impact of route quality goes beyond just travel time; it also influences fuel or electricity consumption, the number of hours drivers have to work, punctuality, and the productivity of the vehicles. For electric fleets, battery state, charging location, charging duration, and uncertainty regarding energy consumption must be taken into account. Studies on routing for electric vehicles have found that traditional routing assumptions are no longer adequate when range and the need for charging become binding constraints [28, 29]. An IoT platform can reduce this uncertainty by providing up-

to-date information on the state of charge, temperature, traffic conditions, and the status of the chargers, enabling plans to be modified as the journey is being carried out. This is particularly important in hot climates since auxiliary loads and thermal management can affect energy demand.

Predictive maintenance represents a second value approach. Instead of treating vehicles that have travelled similar distances as if they are subjected to the same level of stress, connected diagnostics enable maintenance to react according to the actual operating conditions [6]. The IoT fleet prototypes show that sensor and diagnostic data can be continuously collected in order to identify anomalies and allow for earlier intervention [8]. The industrial fleet architecture combines multipurpose telemetry with analytics and decision support, so that fleet health becomes an integral part of daily operations [7]. Scalable stream-processing designs prove that the same logic can be applied across large numbers of devices.

An effective maintenance pipeline should include rule-based thresholds, trend detection and predictive models. The thresholds offer understandable protection for important parameters; trends show a slow decline; and predictive models are used for estimating risk when there is enough training data. Moreover, maintenance

feedback needs to be fed back into the asset's history. In the case of a component being replaced, the event should either reset or provide context for any further analysis in order that the behaviour after repair is not incorrectly classified.

Digital twins include simulation and a representation of state. It is not acceptable in the field of transport to regard a twin simply as a three-dimensional model; rather, its value is in keeping the physical and virtual states in sync so that different options can be assessed before taking action [10]. Research into smart mobility shows the linking of the virtual and physical states of vehicles for the purpose of navigation [11], and digital-twin-assisted optimisation of the Internet of Vehicles makes use of the virtual state to predict communication and computing demand [12]. Possible applications for fleets could be what-if analysis regarding maintenance, coordination of charging, testing routes for stress, and recovery from disruptions.

Even though twin maturity should correspond with business needs, it is not necessary to have a high-fidelity mechanical twin before connected operations can generate value. A step-by-step method is more defensible in this case: first establish a digital operational profile which includes

information on identity, configuration, trips, maintenance and energy state; then add predictive models for high-value assets; and finally introduce scenario simulation when the consequences make the extra complexity worthwhile.

Figure 2 shows the final closed loop consisting of sense, integrate, predict, optimise, act and audit. Audit is essential since the decisions regarding the fleet have an impact on safety, cost and service. The automated recommendations must be traceable to the particular version of the data and model that produced them, and operators should still have the authority to override the decisions. When overrides occur, they can act as learning signals rather than simply disappearing from the system.

The evidence points to the existence of an operational hierarchy in which real-time rules handle immediate exceptions, optimisation engines look after routes and assignments, predictive models deal with emerging risk, and digital twins assess complex scenarios. All of these functions should be based on a single data foundation; and when the system is integrated, the fleet platform will be able to balance punctuality, utilisation, maintenance risk, energy use and safety rather than focusing on one objective at the expense of the others.

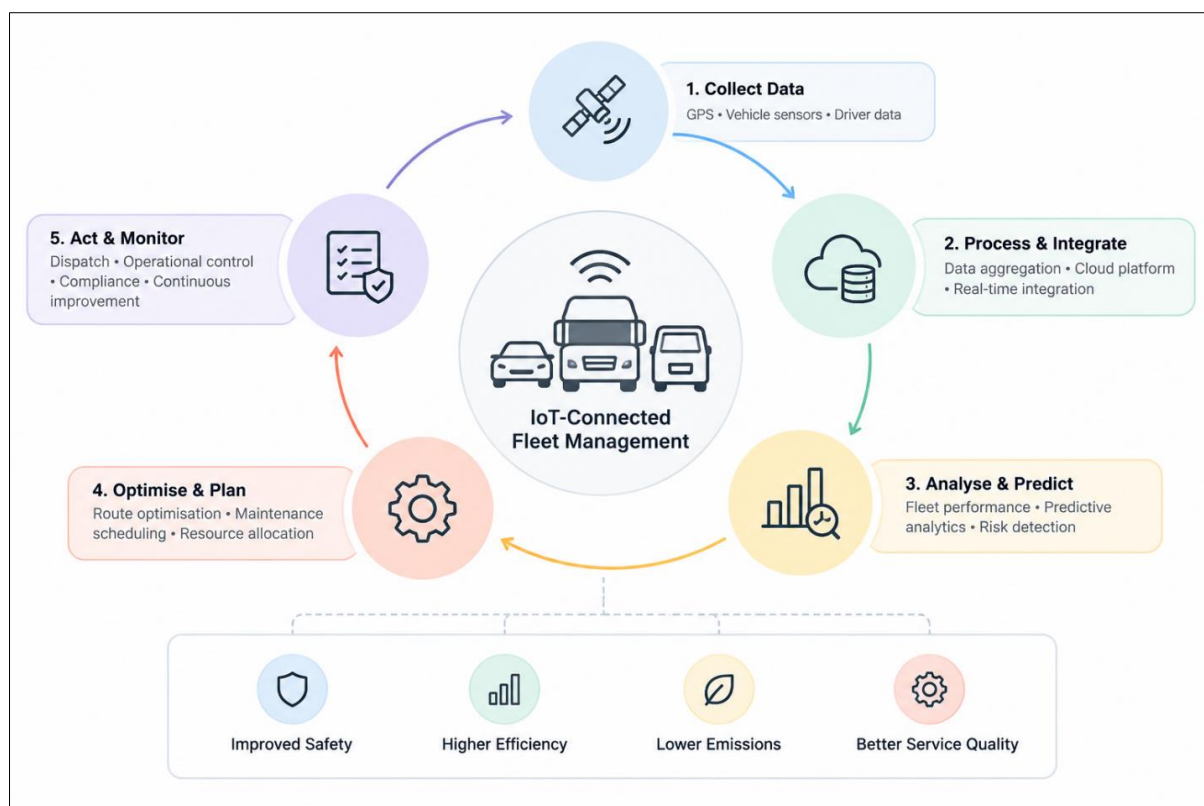


Figure 2: Closed-loop operating model linking fleet telemetry to prediction, optimisation, intervention and auditable learning

5. Sustainability and Saudi Smart-Mobility Implications

The sustainability assertions relating to connected fleets must be interpreted with care. Although connectivity can lead to less waste by means of better routing, reduced idling, improved use of vehicles and earlier maintenance, rebound effects may cancel out these benefits if the ease of using the vehicles results in a higher total level of travel. When environmental assessments are carried out on connected and automated mobility, a systems approach is stressed: the energy and emission results are influenced by vehicle technology, network performance, user behaviour and induced travel altogether [24-26]. Sustainability should thus be assessed at the level of the operational system rather than being deduced from the presence of IoT devices.

The most significant short-term benefits lie in the elimination of inefficiency. Real-time routing can lessen detours and queues; health monitoring can stop energy-wasting faults; driver feedback can reduce aggressive acceleration and idling; and having visibility into capacity can cut down on empty journeys. The impact of these measures can be measured using current telematics systems, since operators can monitor energy per kilometre, energy per completed service unit, idle time, empty kilometres and route deviation both before and after the interventions have been made. Just as these indicators do, the technology can be more reliably linked to actual results than by simply using the general term "smart fleet".

The fact is that electrification enhances the relationship between the IoT and sustainability. Research into vehicle-to-everything systems shows that connected energy systems are able to coordinate vehicles with charging infrastructure and, in certain configurations, with broader energy networks [23]. When it comes to fleets, the main concern at the moment is charging orchestration—that is, knowing which vehicles require energy, when they will return, how long they can stay connected and what tasks will come next. As has been shown in the literature on electric-vehicle routing, decisions regarding charging and routing are interdependent [28, 29]. It therefore follows that a connected platform can reduce range risk and alleviate charger congestion by treating energy as an operational resource.

Saudi Arabia has introduced specific conditions. The nature of its urban development, the need for long-distance travel, the rapid expansion of its infrastructure and the high summer temperatures result in patterns that are different from those found in compact temperate cities. The smart-mobility studies carried out in Saudi Arabia place emphasis on advances in intelligent transport as well as on the

importance of integrated planning, standardisation and monitoring [1, 2]. This encourages the development of architectures which are resilient under varying network conditions and that can function even when the infrastructure is only partially developed. Thus, a municipal fleet in Riyadh, an industrial fleet at a remote location and an intercity logistics fleet could use the same data model while employing different levels of connectivity and edge configurations.

Smart mobility is also an issue within an ecosystem. Studies into sustainable smart mobility stress the importance of coordination between infrastructure, service providers, technology, users, and governance rather than focusing on individual applications [27-30]. Connected fleets can act as mobile sensing assets as part of that ecosystem. Data that has been aggregated and made privacy-protected can show recurring congestion, unsafe spots, charging demand, abnormalities in road conditions, or gaps in services, generating value for the public once the data-sharing rules are clearly defined.

Fleets also offer controlled environments in which progressive deployment can take place. It is simpler to fit equipment with monitoring devices and to manage public buses, delivery vehicles, municipal fleets, airport fleets, industrial fleets and large corporate fleets than it is to do so with the entire population of private vehicles. Since these fleets have clear owners, established procedures and defined service outcomes, pilot schemes are able to test connected infrastructure, charging coordination, edge services and safety analytics while at the same time producing evidence for broader policy decisions.

Sustainability governance must stop metric substitution. For example, a route algorithm might decrease the number of kilometres travelled but at the same time lead to more late deliveries; a charging strategy could reduce electricity costs but at the cost of reduced availability; a utilisation target might increase productivity even though it makes fatigue worse. That is why Table 2 includes measures relating to operational performance, the environment, safety, service and digital resilience. Organizations can set minimum thresholds for safety and service and then optimise their cost and energy performance within those limits.

The literature also allows the distinction to be made between direct and enabling outcomes; direct outcomes are things such as less idling, fewer breakdowns, lower energy consumption and better on-time performance, while enabling outcomes include improved data quality, faster incident detection, interoperability and planning accuracy. It

is possible that early deployments will first lead to an improvement in visibility before resulting in optimised behaviour. This kind of distinction enables decision-makers to assess progress without overestimating the environmental benefits.

IoT-based fleet management can be linked to sustainable mobility only if it alters the way

resources are allocated rather than merely digitising current practices. The most plausible route for Saudi Arabia is to link its digital investments to specific baselines, targets and mechanisms for accountability. Before any technology is expanded, the programmes should specify the operational problem, the data needed, the expected change in decision-making and the performance indicators.

Table 2: Proposed performance indicator framework for Saudi connected fleets.

Dimension	Example indicators	Decision use	Primary data source
Operational performance	Vehicle utilisation; on-time completion; route deviation; empty kilometres; mean downtime	Dispatch, capacity planning, service recovery	GNSS, trip events, work orders, schedule data
Energy and environment	Fuel/energy per km; energy per service unit; idle energy; charging efficiency; estimated CO ₂ e intensity	Routing, electrification, charging and driver interventions	Fuel/energy telemetry, charger data, distance and load
Safety	Harsh events; speeding exposure; incidents per distance; safety-critical alerts; fatigue-related exceptions	Driver coaching, risk controls, route and schedule design	Vehicle sensors, driver events, incident records
Digital resilience	Connectivity availability; packet/data loss; stale-data rate; authentication failures; cyber incidents	Network design, edge placement, security and continuity planning	Gateway logs, network telemetry, identity and security logs
Service quality	Completion reliability; response time; cancelled trips; customer/service exceptions; recovery time	Service planning and stakeholder accountability	Dispatch system, customer/service records, operational logs

6. Cybersecurity, Interoperability and Governance

The use of connected fleets increases the number of potential points of attack in transport operations since vehicles, gateways, wireless links, edge nodes, cloud services, interfaces and user accounts all become possible means of entry. Surveys have recorded threats ranging from compromise of the vehicle itself and the use of malicious software to message manipulation and attacks on external communications [20]. More up-to-date reviews of IoV security indicate that the level of risk rises as vehicles place greater reliance on cloud, edge and data-sharing services [21]. Cybersecurity should therefore be considered an architectural property.

Identity must come first; all vehicles, gateways, users, and services should have a managed identity and commands must be authenticated before they are carried out. As zero-trust research contends, it is not acceptable to regard a device as trustworthy just because it is part of a fleet network [19]. It is particularly important to implement continuous verification, apply the principle of least privilege and ensure segmentation in cases where maintenance systems, charging operators or logistics partners connect to the platform. Threat and risk assessments should be carried out again whenever software or dependencies change [22].

Data integrity should be given just as much attention since optimisation relies on reliable telemetry; even if the application is still available, false location data, manipulated state-of-charge figures or altered diagnostics can lead to unsafe or expensive decisions. Monitoring must therefore involve plausibility checks for impossible movements, inconsistent sensor relationships, abnormal frequencies of messages and unexpected changes to the configuration. While edge processing is able to detect anomalies close to where they occur, distributed computing also results in more components that have to be patched and monitored [16-18].

Interoperability is in part a matter of governance. Although open interfaces offer flexibility, unregulated interfaces increase the number of possible attacks. In order to achieve controlled openness it is necessary to have documented data models, versioned interfaces, certificate-based access and auditable agreements for data sharing. Operators must specify who is responsible and for how long raw telemetry, derived analytics, driver-related information and maintenance records should be kept. At the city level sharing should include the use of aggregation and anonymisation where appropriate.

Governance should also define who has the right to make decisions. Certain actions can be safely automated, for example by generating a maintenance ticket after a fault has been verified, while others have to be confirmed by a human, especially those which involve changing routes, immobilising vehicles or impacting safety-critical operations. A tiered automation policy can categorise actions according to their consequences and reversibility while still retaining the speed benefits of analytics.

When deploying in Saudi Arabia, the operator's controls must be in line with the country's cybersecurity, data-management and transport requirements. The framework proves to be the most effective when compliance evidence is automatically generated on the basis of asset inventories, software versions, access logs, incident records, model versions and retention status. This enables connected fleet management to address both operational performance and tangible digital accountability.

7. Proposed Implementation Framework for Saudi Arabia

The evidence indicates that implementation should be carried out in phases not with a single technological jump. In the first phase trustworthy visibility of the whole fleet should be established by registering the vehicles in a common asset model, linking the essential telematics, applying data-quality rules and measuring the baseline indicators. The priority data should be location, trip status, mileage, fuel or energy use, the critical diagnostic codes, idling and maintenance events. The aim is not to achieve the highest possible sensor density but rather reliable operational truth.

In the second phase, decision intelligence will be introduced for specific use cases; for different types of fleet the following can be given priority: routing, adherence to schedule, maintenance alerts, driver-risk indicators and energy management. Edge processing should be included in those situations where latency, coverage or bandwidth make it worthwhile. The platform must provide versioned interfaces to the maintenance, enterprise and charging systems, and the benefits should be assessed in comparison with the phase-one baseline.

Phase three involves combining fleet operations with the broader smart-mobility infrastructure, offering services such as vehicle-to-infrastructure messages, dynamic traffic information, cooperative incident alerts, details on charging availability and certain city data. Since decisions are becoming more dependent on external sources, greater interoperability and governance are needed; it is also the right time for cross-fleet data sharing where there is clear public value.

In the fourth phase, advanced digital twins and multi-objective optimisation are introduced for high-value or complex operations. These twins are capable of representing vehicle health, route conditions, charging constraints and service commitments, which allows scenarios to be evaluated before they are carried out [10-12]. The optimisation process should take into account service, safety, energy and asset-health objectives rather than focus simply on minimising distance [9-29]. Human supervision is still necessary throughout the period when the models are being calibrated to Saudi conditions.

In all the different phases, Table 2 offers a standard way of describing performance. The operational measures reflect utilisation and punctuality; the environmental measures relate to energy intensity; the safety measures relate to incidents and risky behaviour; the digital-resilience measures relate to connectivity, data quality and cyber events; and the service measures relate to completion reliability.

The framework also suggests the use of modular procurement. Since vehicle hardware, connectivity features, data platforms and analytical applications develop at different speeds, purchasing them as a single, integrated set of proprietary products could result in long-term lock-in. By defining clear interfaces, it is possible to upgrade the various components separately and leave room for local software, analytics and integration capabilities.

The implementation should revolve around the principle of learning. In each phase it is necessary to record what has changed, whether the expected result was achieved, which data were missing and how the users reacted. Successful functions can then be extended to other fleets or areas. By using this iterative method, connected fleet management is treated as an operational capability that is continually developing and is aligned with smart and sustainable mobility rather than being seen as a single-time installation.

8. INTEGRATED DISCUSSION

The report shows that connected fleet management should be viewed as a capability stack, not as a telematics product; the various layers depend on one another. If high-frequency sensing is present but reliable connectivity is not achieved, there will be data gaps; if connectivity exists but common semantics are not established, the result will be fragmented databases; if analytics are carried out without operational integration, dashboards will be produced rather than actual decisions; and if optimisation takes place in the absence of governance, it may improve one metric at the

expense of safety, fairness or service quality. The appropriate unit for achieving transformation is therefore the decision loop, not the single device.

The way this interpretation is presented makes it clear as to why certain fleet projects end up delivering only limited value even though their pilot phases have been technically successful. It is possible for a project to demonstrate that data can be transmitted without, however, specifying who is to take action when an alert is received, how quickly action is expected, or how the results are to be recorded. In order to overcome this shortcoming, the suggested framework links each data stream to a decision owner, an intervention, and an outcome indicator; thus making the system's performance auditable and providing the necessary evidence for scaling.

Saudi Arabia is well placed to adopt this method since large fleets can offer structured testing environments for wider mobility services. Yet, whether the approach can be expanded nationally will depend on preventing the introduction of separate and proprietary systems. By agreeing on common data definitions, providing secure interfaces and setting shared minimum performance standards, competition among technology suppliers can be maintained while at the same time allowing information to pass between organisations when authorised. This kind of standardisation need not have every operator working with the same platform; it only requires that the platforms consistently describe the key states of the fleet.

The review also states that sustainability should be regarded as an optimisation constraint and as a governance objective, not as a marketing feature. Connected operations can reduce energy consumption and enhance asset utilisation, but only if routing, maintenance, charging and service policies are designed with measurable resource outcomes in mind. Similarly, digital twins and advanced artificial intelligence should be adopted in cases where they lead to better decisions than simpler forms of analytics. Complexity should be accepted whenever it serves to reduce uncertainty, increases resilience or allows for coordination in a way that simpler methods cannot.

When assessing Saudi Arabia's fleet programmes, it is important to differentiate between availability and operational adoption. A platform might attain connectivity without providing much real benefit if alerts are ignored, if the maintenance procedures stay manual, or if the charging plans are not connected to dispatching. On the other hand, even limited telemetry can be of value if it is trusted, incorporated into decision-making processes, and

compared against a baseline. This distinction is important in the context of procurement since the specifications should outline the desired outcomes, the interfaces, the security controls, and the requirements for evidence, rather than specifying a single technology stack. Pilot contracts should require interoperable data export, cybersecurity controls, baseline and post-deployment indicators, and clear responsibilities regarding model monitoring. Including such provisions would make it easier to compare different deployments, reduce vendor lock-in, and promote cumulative learning within the various mobility programmes [1-29].

Hence, the best approach to implementation is one that is incremental and at the same time follows a clear architectural plan. In the early phases, trustworthy data and simple interventions should be put in place, while at the same time keeping the interfaces open for future vehicle-to-everything, edge intelligence and digital-twin functions. This achieves a balance between the immediate operational value and long-term technological preparedness and also makes sure that more advanced features do not end up being costly alternatives to basic discipline and sound data management practices.

9. Research Gaps and Future Agenda

There are still some gaps in the evidence. Firstly, while a number of studies show that the architecture is feasible, they offer only limited evidence over a long period regarding maintenance costs, emissions, safety and the quality of service when the system is in continuous use. The Saudi studies should establish before-and-after operational baseline figures that are long enough to distinguish the effects of the technology from those caused by seasonality or changes in demand. Secondly, models created using data from temperate climates may not be directly applicable to high-temperature operations. Research should measure the impact of heat on battery consumption, sensor reliability, the tyres, cooling loads and maintenance predictions.

Third, interoperability research should shift from interface design to cross-operator semantics; a common model for fleet state would make it easier to combine information from the public sector, from logistics, from industry and from charging without requiring identical vendor platforms. Fourth, cybersecurity research needs to look at the operational consequences of attacks, illustrating how compromised data affect routing, charging, dispatch and maintenance.

Fifth, sustainability assessment should include the energy consumed by edge nodes, cloud analytics and high-frequency communications when comparing architectures at scale. Finally, digital-twin

research should demonstrate when greater model fidelity materially improves decisions. The most useful future studies will connect technical metrics such as latency or prediction accuracy with outcomes such as fewer breakdowns, lower energy intensity, safer operation and more reliable services.

10. CONCLUSION

IoT-enabled connected fleet management has the potential to serve as a practical link between the digitalisation of vehicles and the achievement of smart, sustainable mobility in Saudi Arabia. Benefit is not derived from sensing or connectivity by themselves; it arises from a closed loop in which reliable vehicle data pass through the appropriate networks, are processed using both edge and cloud resources, are transformed into predictions and optimisation decisions, are then implemented by people or systems, and are finally checked against the actual outcomes.

The evidence points to five key areas of focus: interoperable vehicle data, scalable connectivity and computing, integrated operational analytics, security by design, and clear sustainability governance. Although routing, predictive maintenance, charging coordination and digital twins can improve performance, there are differences in their level of maturity and the amount of data they require. By using a step-by-step approach, organisations can start off with reliable visibility and then gradually introduce intelligence, infrastructure integration and simulation.

Fleets provide a controlled environment in which the smart-mobility technologies of Saudi Arabia can be tested, evaluated, and expanded. By using common data models, implementing cybersecurity measures, and employing a balanced set of performance indicators, connected fleets will be able to increase reliability and asset productivity while at the same time promoting safer and more resource-efficient transport. Further research should focus on obtaining longitudinal evidence from Saudi Arabia, incorporating climate-aware models, ensuring interoperable data semantics, and establishing quantified connections between digital decisions and mobility outcomes.

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