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Enhancing Vehicle Lifecycle Management through Integrated Data Platforms and IoT Connectivity

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Abstract
The automotive business has transitioned from analogue to digital and is predicted to undergo an even bigger transformation, thanks to developments in digitalisation, artificial intelligence, and the Internet of Things (IoT). Comprehensive digital ecosystems will be developed by networks that comprehensively link vehicles, technology, services, and people with both external and internal environments. In these ecosystems, navigating the three-dimensional (3D) open space of vehicle, technology, service, and demand involvement will produce commercial values using digital twins and data and service platforms to signify investment return and technology selection across system capability, acceptability, and adaptability. By providing an integrated data platform and connection with IoT to bolster vehicle lifecycle management, a model with indicated objectives, landscapes, components, approaches, and supporting structures is proposed and illustrated. Additionally, the value empowerment of consumers leveraging the proposed model is discussed. An integrated data platform and connection with IoT must enable robust vehicle lifecycle management by deriving operational service use and condition parameters connected with owners, managers, and highways. The extensive interlinkages among vehicles, IoT components, and data and service components within the holistic digital ecosystem must be resolved for this purpose.

The procedures to integrate all data and service components must be outlined, including crucial data management techniques for feature engineering, data cleansing, data enriching, and data refilling. Then, vehicle lifecycle management perspectives by data and service components are discussed, including insights into proactive in-market service design, dynamic from market service reconfiguration, robust operation support service design, and future out-of-market disruption identification. Central issues in vehicle lifecycle management, including design strategy, planning model and approach, service design strategy, and management approach, are considered following this. The overall landscape of the proposals and corresponding prospects is illustrated. Finally, industrial input and development is presented, notably the ultimate reference model for the holistic digital ecosystem, and threats, challenges, and future scope of research are discussed.

Keywords: Vehicle Lifecycle Management (VLM),Connected Vehicle Platforms,Internet of Things (IoT),Telematics Data Integration,Predictive Maintenance,Digital Twin Technology,Real-Time Vehicle Analytics,Edge Computing,Cloud-Based Diagnostics,Over-the-Air (OTA) Updates,Vehicle Health Monitoring,Fleet Data Management,Lifecycle Data Traceability,Sensor Data Fusion,AI-Driven Vehicle Insights.

1. Introduction

The automotive world stands on the brink of dramatic changes in its vehicle and connected environment designs and the concurrent development, testing, validation and end-user deployment of these systems. Automakers and suppliers of electronics, sensors and processing units are gearing up for their vehicles to become mobile nodes in tightly coupled, global networks. Facilitated by a deeper integration of vehicle sensors and intelligence, vehicles are expected to operate in environments that take full advantage of their capabilities whilst providing enhanced services to their users, the bystanders and the wider public. Smart traffic and smart city provide enhanced opportunities to innovate with features that provide further utility to the user and/or the environment. However, this leads to an exponential increase in the interactions of the vehicle with other systems in multiple smart ecosystems, which increases the amount of uncertainty that needs to be handled throughout the product life cycle. This has a significant impact for the design stage, early in the product development phases. The business cases for coopetition often rest on effects experienced after the design stage, thus shifting the value capture dilemma to another point in the product life cycle. A product design is always a syntax in the abductor modality. A vehicle is made up of several thousand physical parts, which interact dynamically during the use of the vehicle to deliver the functional goals of the system. Most of the components in a modern vehicle have a composite structure, combining physical systems with smart actuators that embed sensors and software control structures. These systems interact dynamically through mechanical, hydraulic, pneumatic, electrical and electronic interfaces in a tightly coupled manner. The increase in complexity is reflected by the ubiquitous engineering trans-disciplinarity of automotive product development, which now includes a broad range of disciplines and expertise ranging from vehicle aerodynamics and audio design to hardware in the loop testing and software verification methods. Any one of these disciplines requires domain knowledge that, taken in isolation, cannot be acquired or used in a single job.

Increasingly smart and connected vehicles will provide new opportunities for the integration of big data in the automotive domain. Considerable amounts of data are currently being generated by multiple industrial sources and in very different domains: vehicle component suppliers have voluminous on-board diagnostics fault data; engine and powertrain suppliers and high-end automotive manufacturers are measuring in-use performance curves and fuel consumption against real driving conditions; car manufacturers are conducting complex crash-testing analyses and multi-body vehicle dynamics simulations; e-simulators are providing powerful virtual environments from which wide-operating parameter ranges for sensors, calibration maps etc are explored; mobility-as-a-service businesses will provide aggregated user information and telemetry; advanced driver assistance system components will have accumulated considerable vehicle/road condition data; and the latest innovations in smart mobility will generate vast amounts of data with a very different character and of varied utility, from real-time weather warnings to traffic jams on the route database. Not all of this data is useful for all stakeholders, or even for the same stakeholder in different operational contexts. Connected vehicles provide flexibility in terms of how and where data is recorded, aggregated and disseminated. This flexibility presents opportunities to innovate with sophisticated vehicle lifecycle management schemes that determine what data is to be recorded, how this information is leveraged, and on what basis value is created. Ultimately, it is the ability to ever more flexibly combine and exploit data that will determine whether a threat will become an opportunity or lead to a missed chance. Somehow, with the advent of connected or cooperative vehicles, earlier failed attempts to build and exploit digital twins or merged databases become feasible.

1.1. Background and Significance

Smart traffic and smart cities provide enhanced opportunities to innovate with features that provide further utility to the user and/or the environment. Connectivity leads to an exponential increase in the interactions of the vehicle with other systems in multiple smart ecosystems, increasing the amount of uncertainty that needs to be handled throughout the product lifecycle, especially during the design stage. A vehicle is made up of several thousand physical parts, which interact dynamically during use to deliver the functional goals of the system. Most components and subsystems in a modern vehicle have a composite structure, combining physical systems with smart actuators, sensors, and software control. The increase in complexity is reflected by the trans-disciplinarity of automotive product development, which now includes a broad range of disciplines and expertise from electronics to artificial intelligence and data science. Therefore, the automotive product development organization is characterized by multi-disciplinary heterogeneity.

An Integrated Vehicle Health Management (IVHM) system is suggested to be built-up that is capable of tracking key information about the functioning state of intermediate vehicle systems. Such information provides a basis for in-use performance modelling and vehicle compliance checking based on simulation and run-time analytics. The paper proposes a new model of a component based architecture system called an Integrated Data Platform (IDP). IDPs themselves collect data from the vehicle and surrounding environment at the landscape level. The IDPs also comprise capabilities for handling and fusing the raw sensory signals processed, recovered inputs representing the hidden states of the environment and vehicle subsystems. IDs themselves land directly in the smart ecosystem acting as an interface for retrieving data, using them for higher-level organisation and coordination.

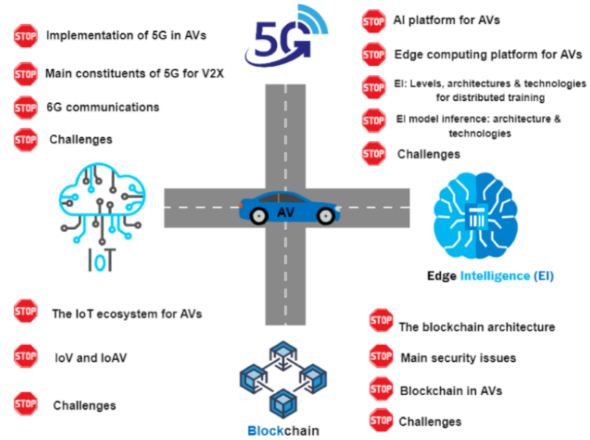

Fig 1: Vehicle Lifecycle Management through Integrated Data Platforms.

2. Understanding Vehicle Lifecycle Management

Vehicle Lifecycle Management refers to the systematic planning, oversight and control of vehicle product and service representatives with the objective of optimizing their total cost and quality throughout the lifecycle. As data from vehicles become increasingly available through: • IoT • Fleet Management System connections, such as indiscriminate uploads of on-board diagnostic codes available in cars since 1995, often based on OBD-II protocols. Maintenance schedules are formulated through knowledge-based rule systems that recommend a service within a certain timeframe or due to an event. Such prescribed interventions target expected failure modes only. Whereas monitoring service data provides historical FMS but seldom as an accountably controlled critical performance framework with complex driving conditions across large service records, these data become actively viable in assessing vehicle condition in combination with vehicles Geo-location data from OEM manufacturers' infrastructure or navigation engine driven based. A harnessed investment in Digital Thread Model Factories with comprehensive use of Synthetic Data over active infrastructures ranging from Connected Predictive Scenario Models to Earth, encompassing within FMS & ML-Cycle enabled Design-by-Data-frugal by Constraints, with CBM, and Fleet Usage Management Models with Fleet Management Costing Function Models integrated within their Optimisation Functions and Enterprise, derived efforts on Customer Behaviour Models would collectively enhance Data-Driven Technologies & vehicle ownership encompassing market. Networks with massively increased data flows within OEM ratio and co-shared access detoxing Data-Driven-Silo Models with simplified Ontology information-management augmentable to fine-grained Data-Driven Computing decision making, grounded in high-dimensional First Principles leading the way toward SynSin-L3, L2 & L1.

2.1. Definition and Importance

Cyber-Physical Systems (CPS) are engineered systems that integrate computer and communication components with physical processes. These systems can sense, analyse, plan and predict behaviour, control actions and perform autonomy in the physical space. Smart and connected vehicles, as part of intelligent transportation systems, fall under the definition of CPS. They are composed of sub-systems in which intelligent devices and processors acquire and process the data from car sensors and plan actions, to send, share and re-plan actions over the network. Smart and connected vehicles provide enhanced opportunities to innovate with features that provide further utility to the user and/or the environment, facilitating the servitization agenda prevalent in the emerging business models. However, the prolonged operational life of vehicles and their expected use in multiple and heterogeneous ecosystems require further development and improvement for the CPS in vehicles to operate with heterogeneous data and models. This leads to an exponential increase in the interactions of the vehicle with other systems in multiple smart ecosystems, increasing the amount of uncertainty that needs to be handled throughout the product life cycle, with the most significant impact for the design stage, early in the product development phases.

A vehicle is made up of several thousand physical parts (components, assemblies, subsystems), which interact dynamically during the use of the vehicle to deliver the functional goals of the system. Most of the components and subsystems in a modern vehicle have a composite structure, as a combination of physical systems with smart actuators that embed sensors and software control structures. The vehicle health is given by how well the output of the embedded monitoring and control processes fulfills the preservation of the functional goals. The output of the monitoring processes is compared with the nominal behaviour of any certain selected function. Data-driven models, knowledge-driven systems or a hybrid between the two can be used as nominal behaviour. From the knowledge of the nominal behaviour deviations, an additional behaviour is inferred for the new configuration of the vehicle that is compared with feasible/impossible actions and thus, the new set of health indices are delivered. The increase in complexity is reflected by the ubiquitous engineering trans-disciplinarity of automotive product development. Automotive engineering now includes a broad range of disciplines and expertise ranging from electronics and control engineering to software engineering, networks and communications engineering, IoT, artificial intelligence and data science. Therefore, the automotive product development organisation is characterised by multi-disciplinary heterogeneity. This Multi-disciplinary design of vehicular CPS takes place in a globally distributed architecture and is characterised by the underlying large, complex and dynamic connected solution spaces.

Equ 1: Predictive Maintenance Efficiency (PME).

$$\text{PME} = \frac{F_{prevented}}{F_{expected}} \times 100$$

- $F_{prevented}$: Number of failures avoided through predictive alerts
- $F_{expected}$: Total expected failures in a given period
- Indicates how effectively IoT data and analytics prevent unplanned breakdowns.

2.2. Stages of Vehicle Lifecycle

A vehicle is made up of several thousand physical parts (components, assemblies, subsystems), which interact dynamically during the use of the vehicle to deliver the functional goals of the system. Most of the components and subsystems in a modern vehicle contain a composite structure, combining physical (electromechanical) systems with smart actuators, embedding sensors and software control structures. The increase in complexity is also reflected by the ubiquitous engineering trans-disciplinarity of automotive product development: automotive engineering now includes an increasingly broad range of disciplines ranging from electronics and control engineering to software engineering, networks and communications engineering, IoT, artificial intelligence, and data science. Therefore, the automotive product development organisation is characterised by multi-disciplinary heterogeneity.

Integrated Vehicle Health Management (IVHM) refers to the unified capability of a system of systems to assess the current or future state of a member system health, and to integrate this within a framework of available resources and operational demand. This IVHM framework maps the capability scale from reactive maintenance which is based entirely on human led diagnostics, to increased levels of diagnostics support from automatic diagnostics and remote health monitoring, enabled by vehicle connectivity. A current challenge for automotive powertrain systems is to meet the emerging demands of legislation on real world driving emissions. The level of allowed tailpipe emissions may depend on environmental variables. The distance between service dealer and customer may dampen the adoption of dealer-related calibration adjustments to mitigate this. Vehicle refinements can be generated faster than they can be deployed. These challenges are addressed with on-board access to the vehicle diagnostics.

Fig 2: Stages of Vehicle Lifecycle.

An AAF is a distributed network of internet-exposed services on-board a vehicle (i.e. SPCs), off-board (i.e. cloud-based services accessed via the communications infrastructure), and researching MPC (i.e. services in a centralized situation outside the communications infrastructure), all of which strive to satisfy the goals of the factory. Products in the field denote individual vehicles or fleets randomly dispersed within the geographical zone of a virtual enterprise. The AAF is generic but its specific configuration will be bespoke to particular products, customer requirements and service offerings.

2.3. Current Challenges in Lifecycle Management

There are current challenges in vehicle lifecycle management (VLM). VLM is a multi-disciplinary research area providing challenges for researchers from different disciplines. Among them, companies could benefit from integrated data platforms to monitor the condition of their fleet and provide predictive maintenance services to mitigate failures before they occur. However, as can be learned from the automotive industry, this moreover introduces new challenges with e.g. the collection, storage, and protection of a wide spectrum of data from multiple sources. This is further exacerbated by the fact that such solutions have to follow a lifecycle management process, which typically spans over more than 10 years. As a result, data services have to be developed, deployed, and maintained as part of the challenges of lifecycle management.

The integration of data services into the workflow of field service engineers and maintenance services. As runs its fleet for more than 10 years after delivery and service and maintenance usually take place outside of the vehicle manufacturer's direct control, integrating any data service into the workflow of field service engineers or vehicle users to provide predictive maintenance is a significant challenge. So far, automobile manufacturers build up their own ecosystems of data services and provide vehicle users a (limited) set of proprietary services. However, manufacturers miss means to connect to the other two systems, which could be exploited to extract features of more significant commercial value. Moreover, services have to be maintained and constantly tuned to the source data and have to be interfaced with various systems owned by the service partners and users, which introduces a significant engineering challenge.

The compilation of new learning goals, training concepts, and training materials. The data-driven design of technical systems calls for a comprehensive training of engineers in methods from data-driven modeling, simulation, control, and diagnostics. This cannot be done by adapting existing courses but rather by developing new learning goals, didactic concepts, and training materials. The learning goals have to reflect opendoor skills and be extendable to other disciplines. Didactic concepts have to be developed that allow addressing a heterogeneous target audience of students and young engineers. New training materials and in particular a new structure of theoretical and practical learning has to be developed.

3. The Role of Data in Vehicle Lifecycle Management

The growing importance of the different vehicle lifecycle phases is leading to the need for advanced Vehicle Lifecycle Management (VLM). VLM refers to the comprehensive management of a fleet's vehicles over the entire vehicle lifecycle, covering the nineties' management of Extending vehicle Lifetime through proper usage and maintenance of the vehicle, by providing the information necessary to improve vehicle usage. VLM refers to the whole-of-life management of assets. Lifetime optimization models will be developed to predict the effects of data processing pipelines on vehicles over the entire lifecycle (acquisition, on-road operation, maintenance and end-of-life disposal). These models rely on and further develop VLM constitutive methods of system dynamics and model predictive control. VLM requires not only algorithms but also integrated data platforms which expose onboard vehicle data in accordance with privacy regulations and framework conditions. Onboard telematics data points (vehicle sensors and performance indicators) should become accessible by vehicle manufacturers as well as regulatory agencies, service providers, insurance companies and others to improve with innovation, prevent maintenance and repairs and maximise safety. Thus, safeguards for ethical and legal access to vehicle data should become accessible. Safe and secure access to onboard data would also enhance the evolution of low-cost OEM in-vehicle systems, thereby allowing for in-vehicle data storage and processing. These data processing characteristics will make the vehicle a platform for innovation.

Integrating data sharing services into the current software service and connectivity architecture is an enabler for fairness and safety in the automotive ecosystem. Cloud computing as a communication and processing medium offloading tasks from the on-board vehicle to the cloud emerges as a powerful solution to allow leveraging the huge amounts of data generated, stored and potentially processed, but is limited on the extent of secure storage and vicious metadata management as other claims are exploited. Data fusion tasks such as on-board map modulation, obstacle detection, and semantic segmentation might require strong coopetition between OEMs, competition between edge nodes, and shared upgrading of machine learning models. In contrast, the overall insight exchange is not costless and vehicle manufacturers are concerned about leakage of high-value information such as vehicle inner behaviour and manufacturing processes.

3.1. Types of Data Utilized

Data is one of the crucial building blocks in order to achieve a successful and customer-centered vehicle lifecycle management approach. An overview of the data that is collected and processed using the platform is presented in this section. During the data analysis and collection, the aim is to explore what is available from telematics, internal, 3rd party and operational data sources. Data collected in different stages of vehicle lifecycle operations should exhibit sufficient diversity that would allow its integration via data fusion and processing techniques. Data collected before, during and after the operations of interest should also provide a multi-faceted view of them. Finally, it is important that the data management and processing capability will be modeled extensibly, interoperably and distributively across the vehicle lifecycle management system in order to accommodate changes in the data input sources. The following subsections describe the various sources of data that are streamed. All collected data sources are combined into different groups according to their nature, their update frequency, as well as the part in the lifecycle they refer to.

On-board Telemetry or Telematics: The on-board vehicle telemetry provides direct access to a vehicle's Controller Area Network (CAN) bus. Data acquisition methods utilized at this stage include Extract, Transform and Load (ETL) scripts that access on-board telematics data. Multiple data quality metrics are computed on a per column basis for each of the incoming data. Using automatic rule-based quality control, any bad records are flagged as such by receiving default values while a log is created for these records. used third party Vehicle Communication Interface access in order to stream summarized vehicle diagnostics signals. The vehicle data acquired during this phase include parameters such as vehicle speed, odometer, throttle position, trip fuel volume, DTC, fuel level, engine coolant temperature and engine RPM.

3.2. Data Sources and Collection Methods

This section articulates a cloud solution that serves as a repository for transportation data and related services and provides an overview of the cloud architecture. Data are streamed to the cloud and transformations are applied in a continuous way, before they are ingested into a database. A quality control methodology is integrated in the pipeline and provides insights on the data availability and onto their elements' accuracy and limits. As case studies, vehicle diagnostics and utilization data are studied. The pipeline is scalable, fault-tolerant, and data format agnostic.

Data Lifecycle Management refers to the preservation of data from its initial generation and capture, through its active use, to the point of archival and potentially deletion. Concerning transportation data, although data are generated and acquired in large quantities, their availability may become a problem when there is an incorporation of third party solutions. Despite the instant streaming of new data, full data availability needs to be guaranteed. Data may be streamed at high rates or the connectivity may be lost during some communication periods. Even though the data are continuously streamed and stored, some analysis may need historical data that are outside the storage window. Given these constraints, storing data in a cloud-based solution is a good practice. Cloud solutions provide the necessary computational resources to store large amounts of data that can later become increasingly useful thanks to Big Data technologies.

To achieve a low-latency solution for instance, containers can be deployed so that their number adapts with the increase of requests and traffic load, ensuring sufficient computational resources for all ongoing data movement activities. Regarding the architecture of the cloud solution, open-source services provide the necessary building blocks. A priority process determines how the platform works assuming data are presented in a streaming way. The incoming data are streamed to the entry point of the cloud solution where they are duplicated and sent for ingestion to both databases. Hence, transformations are applied to vehicles data and to the respective stats data types. The treated data types are streamed to the data quality control components.

4. Integrated Data Platforms

These aspects are highly relevant for utility vehicle fleet managers who want to increase the efficiency, safety and environmental friendliness of their vehicles, utilizing capabilities related to telematics, Fleet Management Systems and various vehicle tracking and monitoring systems. Such platforms can easily be integrated with existing car manufacturers' proprietary solutions to enhance vehicle lifecycle management through the improved control of new measurement functions and the advanced utilization of their data outputs. Models will be developed to explore the different dimensions of vehicular data driven decision making for predictive fleet management. Specifically, in the context of routing, the effects of various likely actions of the driver will be modelled. Suitable means to harness the additional information provided by the communication infrastructure and peripheral sensors are explored to handle mapping uncertainties caused, e.g., by fog, construction works and traffic incidents. Such issues are especially relevant for future Connected and Autonomous Vehicles (CAVs). Fleet performance models should enhance vehicular data usage through no-claim accident and traffic condition predictions. Appropriate entailments of competitive telematics insurance policies on vehicle integrity, accident risk and driving style will be examined. The concept of 'buying insurance' will be extended through data driven security measures. Effective data management (collection, transformation and storage) are the pillars of an efficient Information and Communication Technology (ICT) infrastructure, on which ancillary services like data exploration, analytics and visualization will not be as fruitful. ICT solutions should address scalability and flexibility requirements to ensure the effective use of methods, techniques and technologies that are offered by leading vendors. Additionally, as the scope and breadth of sourced data streams diverge from the traditional monitoring domain and expand to various telematics, sensing, and mapping services, vehicle manufacturers' platforms cannot support utility vehicle fleet managers, who also incorporate their data services into the efficiencies of their vehicles. In this respect, the concept of Cloud e-Platform offers a modular and open Big data architecture for heterogeneous vehicular data. A hybrid Big data management platform should address diverse safety and robustness, performance and data type requirements by utilizing NoSQL engines and relational datastores deployed in a hybrid cloud.

4.1. Overview of Integrated Data Platforms

An Integrated Data Platform is a comprehensive system that enables organizations to collect, process, store, and analyze vast amounts of data from various sources. By consolidating data from disparate systems and platforms, an Integrated Data Platform provides a unified view of an organization's data landscape and eliminates data silos. As vehicles rapidly become more connected, advanced data platforms must evolve at the same time. Out-of-the-box TecDoc & Service Data APIs must be taken to a new level, interlinking data sources from multiple providers and merging them. New tech stacks need to be built, or existing ones must be heavily adapted to accommodate the ingestion and processing of far more data streams than were ever anticipated.

Strategies to achieve competitive advantages can be grouped into five categories, including tactical, operational, strategic, system, and partner. A typical start-up evolves through these stages via a combination of inorganic and organic growth. In this sense, a smart money partner can make a significant contribution. Partners with financial resources and experience in scaling such businesses, as well as in-depth automotive industry knowledge and contacts, can reduce noise dramatically and lead to quicker commercialization via an M&A strategy on the market. Investment costs are substantial, and "picking the winners" before first sales constitute a significant risk. Many early-stage and "wanna-be" players will fall short of the promising technology and business.

Vehicle lifecycles–from design phase through to decommissioning–need to be considered in terms of whole-life performance. Assessment of the operational effectiveness, usability, performance, durability, maintainability, reliability, and disposal of all vehicle CWE materials and fluids must also be made. The huge growth in vehicle deployment and capabilities gives rise to enhanced opportunities and priorities regarding desired impacts. Hence, the opportunity to innovate with features that offer further utility to the user and/or the environment is increased. Although users will have various priorities, over the decades, legislation will increasingly dictate minimum levels of performance. Also, vehicles are diversifying in terms of type, specifications, configuration, and usage. This leads to an increase in the interactions of the vehicle with other systems in multiple smart ecosystems, increasing uncertainty that needs to be handled throughout the product life cycle, particularly during the design stage. A vehicle is made up of several thousand physical parts that interact dynamically at various levels to deliver functional goals. Most components and subsystems in a modern vehicle have a composite structure, combining physical systems with smart actuators that embed sensors and software, therefore exhibiting both linear and nonlinear dynamics over a wide frequency domain.

4.2. Benefits of Integration

Integrating disparate data sources enables on-demand mobility service providers and urban transportation authorities to monitor and optimise fleet performance and operational quality. As a first step towards designing a governance framework capable of regulating the interactions of service providers, a conceptual model of an integrated data platform capable of operating in cities is proposed. The implementation of such a platform is then evaluated, focusing on data integration, latency, governance, scalability, and cost. Two studies are conducted to evaluate the data services and deployment architecture prerequisites of the platform. The two studies are based on a real IoT-enabled ridesharing application deployed in two cities.

Harnessing digital connectivity and mobility to enhance fleet sharing becomes of paramount relevance to sustainably serve urban mobility demands. Supporting this type of service, electric operated vehicles with an optimal battery state that guarantee ride-hailing could guarantee multiple profitable return trips on preferred lanes. However, to obtain improved quantities at reasonable costs, such a ridesharing platform requires a real-time, city-scale integrated data platform to share aggregated data from the involved actors with a central authority which acts neutrally. It was shown that the relevant city-scale architecture can be designed and properly operated in different cities while the single cities scale perfectly in terms of performance and costs by enabling/disabling components.

The comprehensive and efficient IoT components digitally aware designed platforms are the key enabler for these outcomes, thus showcasing the tremendous potential of IoT on enhancing urban mobility services. On a broader spectrum, significant opportunities can be foreseen in improving the wellness of other coexisting urban services that require improved planning and sharing of data and knowledge efficiently.

4.3. Case Studies of Successful Implementations

The combination of many proposed technological advances in the construction of Automotive-IVHM systems opens up new opportunities as well as challenges in evaluating the potential for desired outcomes. Such evaluations will have to be motivated by the specific motivations for moving into more intelligent or portable/off-the-shelf system domains. Increasingly complex automotive CPS may offer increased utility to wider contextual cases; going beyond the traditional on-board domain through, for example, increased vehicle-to-infrastructure communication as available in elevated smart city scenarios. The increase in connected parts, systems and interactions will exponentially increase the amount of uncertainty that systems need to handle throughout the entire product lifecycle. In this capacity, a historically based engineering framework approach needs to be explored to evaluate the overall design optimality of automotive architecture. A CPS, composed of the social agent (simulated or human) and its controlled cyber and physical agent components, presents a clear target for simulation. Such resource rich architectures engender uncertainties, which need to be accounted for when formulating a decision-making focus, and effort needs to be expended early in the design phase to evaluate the potential response of the vehicle within the target operating context. It is recognised that data alone cannot give rise to interpretations; latent understanding of the desired behaviour of the vehicle is requisite. In considering high fidelity models of increasingly complex automotive CPS, despite the mathematical accuracy of the equations representing the model, issues of tractability arise. Casey's law states that a computer model succeeds where a paper model fails. A simulation toolbox based on numerical agent-based simulation is being used for deeper investigations into the operational characteristics of automotive mechanisms allowing the governing equations to be evaluated independently of their tractability. As trust in the tool increases the aim is to formulate initial engineering-targeted vehicle assessments that allow an automotive assembler or user to focus on specific aspects of the design or use of their engineering vehicle.

5. IoT Connectivity in Vehicle Management

The Internet of Things (IoT) promises to transform everyday objects into smart devices. At home, devices such as refrigerators, washing machines, security cameras, and voice recognition receivers become connected to a wireless network and can communicate over the internet anytime and anywhere in the home. When they are connected to a cloud platform, users can take complete control of them through smart devices or browsers, no matter where they are. Such IoT applications are expected to be extended from the house to vehicles in the future.

As reported by the Gartner research firm, 6.4 billion devices will be connected to the internet in 2016. This count is expected to grow to up to 20.8 billion by 2020, with transportation and smart cities being top applications. To ensure that vehicles equipped with HUD navigation systems, software-defined radios, and connected services are truly smart, they must be connected to the home IoT. In that way, the connected vehicle can communicate with the connected house. Therefore, any adjustment on connected devices in the home can be done remotely by accessing the home IoT from the connected vehicle. The mobile network plays a crucial role in reliably transferring relevant data from the vehicle to the house, since any request from the vehicle travels through the mobile network, and device adjustments or information requests travel through the Internet.

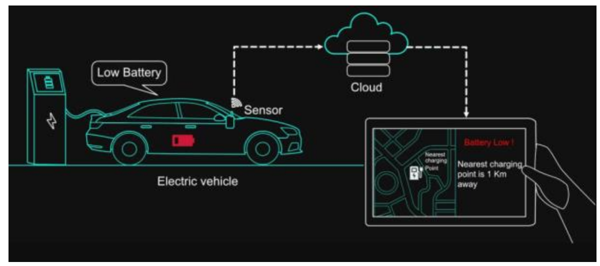

Fig 3: IoT Connectivity in Vehicle Management.

The rapid growth of the mobile broadband market and the culmination of competition for long-term evolution (LTE) worldwide foster a solid feasible environment to embed wireless connectivity into vehicles. The wireless and tethered transfer of data associated with smart applications is now imminent. However, limitations exist in terms of the evolution of cellular connectivity once needed components are embedded in vehicles. Inside vehicles, subpar Bluetooth and Wi-Fi technologies could cause data bottleneck or delay for rendering as expectations of seamless communication from the home to vehicle are now expected. Keeping connected to the internet continuously in a vehicle is soon expected to provide improved safety, comfort, mobility, and entertainment in transit. The consequences of contextualized services are endless, as such services can be triggered by varied intent or situation. In-car applications built directly into the software and services of the automobile manufacturer were recently made available. Growing numbers of in-car applications can provide app experiences that are tailored specifically to a car, while portable smartphones and tablets are increasingly growing in usage for a variety of reasons.

5.1. Overview of IoT Technology

The Internet of Things (IoT) refers to a system of interrelated physical devices, vehicles, machines, buildings, and objects embedded with sensors, software, and network connectivity, which enables these objects to collect and exchange data. The IoT concept has been applied to multiple areas such as smart home, telemedicine, ubiquitous parking lots, etc. With the rapid development of wireless communication technologies, embedded technologies, and cost-reduced sensors, various objects can be easily monitored and controlled in real-time. This revolutionary change in the IT industry is expected to bring unrivaled impact on economic growth.

Among many IoT applications, smart home environments are becoming a part of our everyday life where different devices such as smart appliances, sensors, and control systems are deployed. The worldwide smart home market is projected to grow to $115 billion in 2021 from $24.5 billion in 2016. The global growth rate of new IoT-based device adoption is steadily increasing. Also, new verticals such as smart home and smart health care are expanding in addition to the existing verticals of telematics and fleet management. As connected vehicles equipped with on-board units (OBUs) fitted with various kinds of sensors and a network interface, IoT-based vehicle-cloud platforms are being studied extensively. A Transportation Cloud, which collects vehicle generated data from vehicles and analyzes the data for storage, is proposed for various service.

Equ 2: Data Integration Utilization Index (DIUI).

$$\mathrm{DIUI} = \frac{D_{used}}{D_{collected}} \times 100$$

- D_{used}: Volume of vehicle data used in decision-making
- $D_{collected}$: Total volume of IoT data collected
- Measures how efficiently the integrated platform leverages available data.

5.2. IoT Applications in Vehicle Lifecycle

Stand-alone applications with limited scope are gradually shifting towards integrated data platforms (IDPs), as providers recognize the synergies that could be achieved by more comprehensive solutions. The emerging Vehicle Fleet Management-as-a-Service (VFaaS) architecture shifts the paradigm from heavy investment on in-house fleet management systems towards integrated off-the-shelf solutions provided by large suppliers who operate and maintain their own open data platforms. Traditional vendors are disrupted by new competitors that already have extensive access to large data spaces, on-demand processing capabilities, and user bases for connected services. DVLA reporting is one major CPOI that could be better supplied by an IDP with access to high-fidelity data on vehicle usage and condition. The emergence of IoT-based devices, including smartphone-based applications, enables new types of connected data sources. Experimental research efforts have been undertaken to assess their operational capabilities, also in the case of electric vehicles and fleets. Academic research on IoT platforms for data collection and processing, and AI algorithms for control and automation, could further broaden the scope of fleet management applications, as information would no longer be limited to the fleet itself. The Vehicle Fleet Management Architecture (VFMA), by enacting the service-oriented approach typically adopted by DSs and thus clarifying the individual components of the IDP, the connectivity and with the traditional applications, which essentially remain unchanged, the value of the emerging data sources through a series of qualitative examples focused on costs, emissions, and market value. The domains of passenger cars and trucks are addressed separately and in that order. As the market for connected EVs starts to develop, EVPPs are identified as a new class of actors currently starting to emerge around either a specific OEM or a grouping of OEMs. Based on the combined forecasts for IDPs and EVPPs, they are both expected to grow significantly over the assessed time horizon, but with a larger weight on IDPs. A gradual progression from a competitive phase dominated by IDPs towards an oligopoly phase dominated by a few data silos is expected for IDPs. In each market, the OEMs face different risks and trade-offs between their roles as both CPOs and IDPs that will affect their overall and long-term market positioning.

5.3. Challenges of IoT Implementation

The Internet of Things (IoT) is a promising technology that can revolutionise myriad endeavours. However, satisfying IoT quality assurance needs is challenging and necessitates adopting innovative techniques. A substantial research effort needs to be undertaken to realise IoT's full promise. The attainable quality levels of IoT systems are further described, and existing related research is revisited. Next, the issues that IoT and IoT system testing introduce are summarised. In the end, the paper outlines possible future research directions. The Introduction explains the reasons for conducting this review and describes existing related research, proposing a classification scheme for IoT issues.

Testers of systems of systems must consider requirements, expectations, constraints, and tests of individual constituent systems. Tangentially to this issue, these write-ups independently created and released the Internet of Things Concept Map. The map shows an overall picture of the many notions and concerns related to things, the Internet, and their combination, the Internet of Things. Designers and Implementers of IoT devices inspire immediate utility. A similar outlook dash-board could help take such an AIOT in system complexity and interdisciplinary considerations. Testers want to acknowledge and control interconnections, so they require unified descriptions and protocols.

The impossibility of full security even for the best-secured implementations is postulated. It is also postulated that hostile assets proactively attack obligations and attempts to elude enforcement via establishing insecure channels or hijacking functionality. Thus, tests accessible for acquiring non-excessive evidence of violation prevalence are investigated. The paper examines jurisdiction questions necessary for acting on gathered evidence of systematic violation. Some creative test design examples and the design and implementation of infrastructures sensitive to transient non-compliance are discussed.

6. Data Analytics for Lifecycle Optimization

The operators of integrated data platforms must efficiently manage lifecycle data related to individual vehicles, which are often generated on different manufacturing sites, are stored in numerous regional servers, and must be processed by different analysis systems. Consequently, the data analytics algorithms must migrate across domains and devices while handling the speed and volume of the data. In such a scenario, the driving behaviour data from a fleet of vehicles is a powerful input, as it supports not only predictions of scheduling and usage but also emissions and fuel consumption. There is a growing understanding of how a vehicle’s usage influences its life cycle impacts and the feasibility of using cities’ traffic data to improve the efficiency of their fleets. The integration of IoT connectivity technology in vehicles allows extensive data-fueled predictions on many aspects of interest. Consequently, the data analytics processes must be positioned at different granularity levels ranging from individual vehicles to vehicle fleets enabling the initiation of lifecycle management processes accordingly. The data analytics technologies must be built on coherent combinations of technologies including machine learning for prediction and clustering, decision trees for explanation and prioritisation, predictive mathematics for quantitative estimation, and scenario analysis for benchmarking alternatives. For unintended occurrences that cannot be predicted, such as breakdowns or accidents, the processes producing the large amounts of data require additionally dedicated attention among the AI-enabled data analytics technology. Types of failures need to be understood from historical data, and preventive actions must be implemented before being exposed to aggravated consequences. The historical data must be transformed into probabilistically meaningful estimates of the desired key performance indicators by matching process models against past occurrences. This allows a simulation of impending scenarios with and without actions that can be made at a given time horizon and position in the network. Sensitivity analyses follow to prioritise the actions because they need to be implemented at multiple levels of the fleet hierarchy and with diverse granularity.

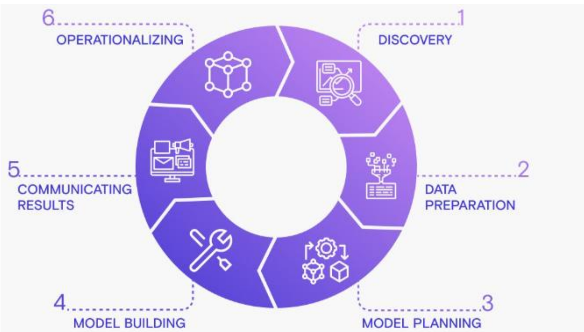

Fig 4: Data Analytics for Lifecycle Optimization.

6.1. Predictive Analytics in Maintenance

Predictive maintenance analytics are proposed in order to conduct maintenance to the equipment without unnecessary downtime and less effort for the management of the condition and process of these equipment and optimize the whole production chain. A dedicated simulation model on an actual production site is built for the verification of the predictive maintenance model. The simulation is to generate simulated KPI for model training and test, and to evaluate potential influence of maintenance/production approach on KPIs. Intelligent predictive maintenance model is based on nonparametric forecasting analytics with multiple dimensions and temporal scales. This solution requires less prior knowledge of the real scenario in comparison with other deterministic and parametric approaches. The analytics is scalable and could be embedded into existing predictive maintenance frameworks with the help of FIWARE and its parts. Future works will cover the end-user evaluation of the predictive maintenance solution, further enhancement of the predictive maintenance analytics and deployment/sharing of the entire predictive maintenance framework via an open data platform to allow user's contribution of new data-driven analytics.

Vehicle Lifecycle Management (VLM) is one of the important applications in intelligent transportation. Some related problems including optimizing vehicle planning with journey and break periods, and deriving renewable and flexible driving job schedules are summarized. To enhance VLM with an intelligent data platform, another richer data represented with richer semantics and knowledge is developed. Goal of VLM is to gain the maximum social profits in terms of shortening drivers' service times, costs and CO2 emissions while preventing CO2 exceeding the limit at different levels. The first approach is a two-phase optimization strategy with meta-heuristics and is scalable to large instances. A VLM i-DP is presented to integrate the floating cars and cloud platforms. It can characterize the detailed vehicle movement data, and enable the new applications with probe data and analysis. Some important nonfunctional requirements of data interoperability, accessibility, reliability, security and privacy for the deployment of the platform to a smart use are addressed.

6.2. Real-time Data Analytics

There are several reasons that vehicle users might want to know their vehicle's health and/or usage. For example, automobile insurance companies may want a historical record of a vehicle's driving behavior for personal injury or other accident analyses. Owners may want a historical record of speed and/or direction to help calculate vehicle emissions for determining an offset related to a lease or depreciation for a tax write-off. Fleet owners may want to monitor which vehicles address maintenance-related problems, how frequently this maintenance occurs, and the resulting repairs. Adding vehicle analytics capabilities for health and usage can provide large data sets that can be evaluated by infinitely many entities for any number of purposes.

Providing such records or ongoing monitoring involves vehicles sending information that may not traditionally be sent or packaged for transmission to such entities. It would be beneficial for vehicle manufacturers to include this capability as a standard feature in new automobiles. However, doing so would also require them to invest heavily in new vehicle subsystems that may diminish profit margins. An alternative is to package IoT-connected devices that can connect to existing analytic ports, such as an OBD-II port that provides numerous vehicle diagnostic variables. Such devices could monitor and/or record information on a vehicle's health and/or usage typically not made available externally.

A need exists for devices to provide vehicle analytics that connect to and exert control over analytic ports traditionally used for SPNs and DTCs (fault codes). Several different methods allow access to these vehicle data. An on-board diagnostics (OBD) and premium channel access protocol. An integrated vehicle data analytics and action response system is provided, which sends vehicle health and usage data through existing wireless data plans. This system connects a device housing microcontrollers and communication processors to a vehicle analytic port. The device monitors the port and parses the time-stamped packets according to the port protocol. The device is capable of parsing and transmitting vehicle analytics information as well as executing smart actions to alter vehicle settings or behavior in response. Most light-duty vehicles, vans, and trucks < 8600 lbs gross vehicular weight manufactured since 1996 have OBD-II ports that connect to an on-board data bus from which analytics can be obtained.

6.3. Impact on Decision Making

The IoT design improvements outlined in this study can impact effective decision making at every stage of the vehicle lifecycle, from production to decommissioning. From the perspective of designers and engineers, a data platform supporting compliant Ideas and essential use cases helps ensure needs are met. With built-in metrics during development, easy access to data will also support design revisions. Public safety agencies and the press will be able to monitor compliance with the design. Additionally, the heightened visibility of inactivated parts will support operator understanding of the whole vehicle, improving safe driving.

The mass production of a standardized physical twin in a factory can be disrupted by design errors. A platform enabling expert user action in the production plants needing extra capacity can minimize disruption. Repair shops will appreciate access to demands for out-of-production maintenance, thanks to the switch from retrospectivity to proactivity in this research. Visibility into dismantling actions will support salvage operators in ensuring that high-value spare parts such as battery modules are financially feasible.

7. Regulatory and Compliance Considerations

In the automotive industry, the development of data and IoT platforms relies on large volumes of sensitive data, which is typically proprietary to vehicle manufacturers or their joint ventures. These platforms are now subject to legal agreements and privacy regulations that affect data ownership and usage processes. In 2021, the newly introduced EU Data Act will change data ownership regulations. With new data sharing obligations, the new act will expose data to the market. Faster changes to business models can result in greater advantages for early movers.

A new approach to business model development will be required due to changes in data ownership regulations. Data that has been used exclusively in closed ecosystems will potentially be available for all other market players. The cooperation of participants in the data ecosystem needs to be reorganized within the new competitive threats. Business models for the distribution of data as products and services will need to be developed. This approach requires developing new revenue models for data products based on the value of data.

Regulatory processes typically lag behind faster technology development, and those working with the new technology often have an advantage over regulators. The same is true for business model development, resulting in a shift in market power. As free-use data APIs increase competition in the services segment, this may favor existing service providers rather than vehicle manufacturers. Attracting developers to platforms that emphasize highly structured raw data streams based on recent international standardization will be more promising when it comes to protecting new business models. Vehicle manufacturers should focus more on public data use as a rapid and low-risk approach to generate external value creation in the competitive data economy.

7.1. Overview of Relevant Regulations

The data-sharing paradigms that the proposal enables are likely to fall under the current General Data Protection Regulation (GDPR) and its case law, the new Data Act proposal, and the Machinery/Automotive Regulation. The regulation of data-driven algorithmic management could also be relevant. The Union's General Data Protection Regulation (GDPR) guarantees rights of access, rectification, erasure, restriction of processing, transfer, and objection to data subject's personal data. The GDPR also generally limits the scope of data processing. The regulation on European data governance establishes a parallel legal infrastructure for making non-personal data available from the public sector to economic actors. Economic actors can also "bring their data to the market" by providing it through data marketplaces, or by using data intermediaries. The Data Act proposal prescribes (a) ex-ante contractual terms for data-sharing in business-to-business (B2B) data markets; (b) ex post right of redress for consumers against data-abusive business practices; and (c) controls on exclusive data access by cloud service providers for an interoperability monopoly.

The European Commission intends to prevent silos of untapped 'high-value data.' They want to tear down the silos of the data by preparing Europe to extract and share the costs of space data, health data, environmental data, mobility data, financial data, agriculture data, geolocation data, etc. The access and reuse of data within these vast volumes of high-value data must also be regulated by legislation to mitigate opposition from various legislators. The Union's clear position is that it must assume and strengthen strategic roles regarding the collection, analysis, and storage of big data in the emerging data economy and that the Union cannot leave them to the private sector and the US powers. With the e-Privacy Regulation proposal, the disclosures of private sector-held data have started to be regulated by law in the Union's domestic territory. The current task is to regulate access to and reuse of public sector-held data, and the access to and reuse of personal data and its application data. Ex-post access to control personal data behind privacy walls is vital to ensure compliance with the data protection regulation. The cybersecurity breach of a prominent Bluetooth-connected Hyundai car model reportedly exfiltrated sensitive travel, geolocation, user profile, and vehicle performance data. The new regulation would seek prevention of private sector monopolies in these first-order public goods.

7.2. Data Privacy and Security Issues

The vehicular industry has to deal with various privacy issues. A privacy issue arises in case where a leak occurs on data that contains sensitive information about the vehicle user (or the vehicle traveller) that, if revealed, may potentially cause damage to the user's property or the user, or cause a breach of laws, regulations, and agreements or a diversion from untrustworthy third-party receiver. Applications used by passengers for hailing taxis ought to avoid revealing details that disclose the passenger's sensitive information. Applications used by automotive manufacturers to monitor and diagnose their vehicles remotely ought to ensure the privacy of travel patterns and the content of passengers' conversations that carry potentially sensitive information. Usually vehicular units record vehicle travel data on storage such as hard disks and random access memory. When the vehicle reaches a mechanic shop, such data may potentially be leaked to the mechanic's competitor who may visit the shop to refer to the data stored in the mechanic's repairing unit. Obfuscated data is more acceptable than fine-grained data. On the one hand, obfuscated data that is too coarse may not be so useful for insurance companies or traffic authorities to do adversarial analysis. On the other hand, fine-grained data may breach the passenger's privacy, because they can be used to obtain the passenger's travel route and pattern such as where they come from or where they go.

The open vehicular platform should propose a mechanism to cope with threats against its privacy issues. First, it should supply security measures to protect data, device and user privacy against malicious adversaries entering the network. The trustworthiness of established mutual trust should be coordinated in the central vehicle cloud. The cloud may be compromised to leak sensitive private data, or reveal ids or coordinates, leading to effective re-identification of a privacy vehicle's travel pattern. There is hope for wider use-treating and more profound detection of compromise attacks. Data applications should supply mechanisms to track and delete invalid data when a rogue device injects false data. Tracing fake data is much harder than handling fake identity. New credentials may be used to forge a fake identity. In addition to behaviour checking and global perspective, trusted information sources may be used to differentiate non-expert data from expert data.

8. Future Trends in Vehicle Lifecycle Management

The exponential increase in interactions of vehicles with other systems in smart traffic and smart cities enhances opportunities to innovate with features that may improve utility to the user or facilitate environmental sustainability. This leads to the servitization agenda prevalent in emerging business models, with numerous expected impacts. These interactions occur in multiple smart ecosystems, with many of these interactions having an open non-deterministic nature. A notable effect of this is the increase in the amount of uncertainty that requires handling throughout the product lifecycle. This has the most significant impact for the design stage, early in the product development phases, where knowledge is limited and hard to obtain. This greatly complicates the vehicle design process, generally one of the largest matters in the design and development process of a vehicle.

The automotive vehicle has a complex structure composed of several thousand physical parts, including components, assemblies, and subsystems. The requisite engineering of these components often extends across disciplinary boundaries, with engineers from different disciplines or domains modelling parts of the system in different representations. These components and subsystems interact dynamically during the use of the vehicle to deliver the functional goals of the system. Use scenarios involving interactions occur continuously over time in the operational phase of the final product, which is usually a complex cyber-physical system interfacing with other non-physical systems in real-time. With the increase in complexity also comes an increase in the challenge of understanding and managing uncertainty in the design.

Most of the components and subsystems in a modern vehicle are constituent parts of a composite structure, which is itself a physical system. Alongside this physical system are a collection of smart electromechanical parts, in which the physics domain is integrated with sensors, signal processing, and embedded control systems. Such systems have additional uncertainty that must be addressed; it now becomes important to know that the system or component is functioning correctly in addition to considering the physics of the model. Furthermore, at every level in a multi-level modelling hierarchy, there may be multiple models which are context-sensitive, i.e. it is not assured that a surrogate model will be the best one to use, or even a viable model, for every scenario.

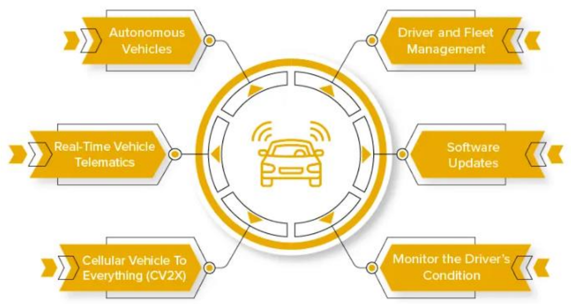

Fig 5: Future Trends in Vehicle Lifecycle Management.

8.1. Emerging Technologies

As emerging technologies from the consumer electronics and IT technology fields crossover to the automotive domain, modern vehicles are being equipped with powerful sensors and networking and communication devices that can communicate with other vehicles and exchange information with the external environment. A connected vehicle is evolving to have devices that can be connected to other devices within the vehicle and/or devices, networks, and services outside the vehicle. The way we interact with our vehicles is rapidly changing, driven by the increased use of mobile devices, cloud-based services, and advanced automotive technology. The future vehicle will have the capability of surround sensing and can form connections between vehicles, as well as between vehicles and surrounding infrastructure. This will lead to increased requirements for information and communication technology, and ultimately, cars will become a part of the Internet in the near future.

The future mobility of the automotive industry requires new applications and technologies related to electric powering, automation, and connected services. Internet-integrated vehicles are already on the roads, and it is predicted that the percentage of internet-integrated vehicle services will jump significantly. The advances in cloud computing and the Internet of Things (IoT) have provided a promising opportunity in vehicular software and services in the automotive domain. The demand for high-speed mobile internet services has dramatically increased; hence, the market demand for IoT device-connected cars will continuously increase. IoT-based vehicular data clouds are expected to be the backbone of the system, with the goal of making driving safer and more enjoyable. However, research into integrating the IoT with vehicular data clouds is still in its infancy.

Equ 3: Vehicle Uptime Improvement Rate (VUIR).

$$\text{VUIR} = \frac{U_{post} - U_{pre}}{U_{pre}} \times 100$$

- U_{post}: Vehicle uptime after implementing IoT connectivity and data integration
- U_{pre}: Vehicle uptime before implementation
- Reflects improvement in operational availability due to proactive lifecycle management.

8.2. The Future of Mobility

The continuously evolving concept of mobility is making transportation systems extremely dynamic. In a future eco-friendly smart city, people will rely on multimodal transportation systems using private and public transportation. The backbone of a fully integrated transportation system is the Internet of Things (IoT), where all modes of transport will be connected with extensive infrastructure and will constantly share relevant data, as illustrated by a city-scale IoT-enabled ridesharing platform proposal. A connected vehicle communicates continuously across various layers/interfaces. These connections include between vehicle components and devices, vehicle and vehicle communications, vehicle and peripheral device and facilities communications, vehicle and cloud or web platform communications, and multi-channel communications.

The by-product of this collection of data is a massive amount of big data. These data are collected from multiple heterogeneous connected datasets; therefore, they may vary in types, characteristics, sources, structure, and context. Data quality issues are an obstacle to big data. Various domains need Arabic language processing systems (pre-processing, sentiment analysis, Q&A systems, etc.); so far, the linguistic base for various applications in Arabic is weak. Analysis tools need to recognize queries and statements, especially those used in social networks and text messaging apps, and all the linguistic characteristics of the Arabic language are needed for these tools. These reflect the necessity of a variety of annotated corpora in different varieties of Arabic languages and domains. Similar needs exist in story segmentation and summarization using different Arabic documents such as news reports and children's stories.

Hence, it is impossible to rely only on the data quality answers to ensure that the data are fit for use. It is desired to suggest solutions for each one of the above issues. However, as they are quite different, it is preferable to either study them independently, or to find related issues that could be solved jointly as in the case of Arabic chat language, and dialectal Arabic. One possible solution for one class of these needs is to build a knowledge base about the language, and a related encyclopedia. It is preferred to study language issues and technologies in Arabic together.

9. Case Studies and Real-World Applications

This section presents a range of use cases and real-world applications across many varied sectors that demonstrate how more integrated data platforms, combined with IoT connectivity, can make existing applications more capable, enhance interoperability across systems, and further empower vehicle lifecycle management. Use cases include components, subsystems, and systems wherein data management and sharing across confining eras enables optimised interfacing with other regions of the platform.

Managing Vehicle Fleet Sustainability Using Distributed Ledger Technology: Reducing the Carbon Footprint of Transport through Accurate Sharing Of Vehicle Usage Data Automotive manufacturers make ever-stronger commitments to reduce the entire lifecycle, carbon footprint of their products, including during operational use. This has only become more difficult given on-road driving methodologies evolving independently from regulatory test cycles and environmental metrics being redefined. A promising approach is to more accurately collate and share real-world operational data pertaining to the vehicle's environmental impact. Greater accuracy leads to more sustainable transport, yet sensitive data privacy issues can limit the openness of sharing strategies. Promisingly, privacy-preserving, distributed ledger technologies are able to provide very accurate proof of transaction predicate validity, without revealing the data itself. The research shows that many new service opportunities can arise with regard to managing overall vehicle operating characteristics from blockchain-based data authenticity records, effectively opening a decentralised marketplace for mobility data.

Managing a Transit Fleet's Carbon Footprint Using Smart Contracts and a Reinforcement Learning Agent: Ensuring High Efficiency and Low Emission Transport of Passengers across a Smart City A vehicle's realised real-world driving usage depend significantly on the operational strategy of the fleet to which it belongs, or indeed whether it belongs to a fleet at all. Transport networks can now reside across multiple levels of abstraction: From massively populous mega-cities to smaller towns, and from private and public, on-demand to direct transit, rural to urban. All of these networks are useful for routing passengers yet they behave differently and varying degrees of optimisation have been achieved. Passengers, vehicles, and their futures are firmly analysed as distributed computation intelligence agents and several distinct emergent levels are identified in the transaction interaction arena.

9.1. Industry Leaders and Innovations

To help achieve an integrated platform for vehicular data, the vehicles themselves should act as intelligent "sensors." Embedded data sources need to be identified and fused in consideration of each-source's strengths and weaknesses. Understanding driver behavior is essential to lower operational costs: each driver makes complex and unpredictable decisions through a combination of comprehension of traffic rules, road conditions, vehicle behavior, and learning capable of augmenting basic movement capability. Automated driving technologies are rapidly developing. Data teaching techniques for supervised or reinforcement learning are inductively collecting roadside data from a transport company's buses and extracting various traffic rules stored on these buses in a robust manner. From a methodological point of view, the idea is to classify road intersections according to vehicle trajectories collected at the intersections implementing Lane ASCT technologies. The challenge of assessing the accuracy of the passenger switching trajectories against the vehicle trajectories captures the verification steps performed in Hierarchical Hybrid Systems (HHS). One initial attempt took place concerning Transit agencies that collaborate with various transportation companies. Emerging mega-cities like San Francisco face issues: some areas are almost impossible to opt using Transit to access, while some drivers face enormous parking fees. The concept of query-by-transit (with respect to time-cuts) means search by fixed-route vehicle trips like trains, buses, and ferries. As the competitive landscape is redefined through such partnerships, updated regulations are creating new challenges for automakers. To enhance the market competitiveness, the ongoing JV restructures WLTTC by inviting all Chinese automakers to work together with domestic Universities for technical unlocking and new standards co-development tasks. Innovation, a life blood of automakers to secure a long-term foothold, usually requires an incubator platform with few organization layers to mobilize and thrive. China's automobile industry, as well as its smart-driving circle, have a massive potential, nevertheless, price and affordable salary still can be significantly lower than its global counterparts, indicating an ample room for improvement on hardware.

9.2. Lessons Learned from Implementations

Implementations of the integrated data platform and IoT connectivity in vehicle lifecycle management at different maturity levels have provided key lessons in product lifecycle design, traversal of visible states for automotive systems, the emergence and prevalence of the real world, and the need for integrated data security definition. The integrated data platform and IoT connectivity have been implemented in three automotive pilot cases, with significant heterogeneity in data type, size, and number of data sources acting upon. Lessons learned about the product lifecycle design were about critical integrated data components and levels that differ across maturity levels. The systems in the connected vehicle data sharing service and the vehicle hardware status monitoring for a bus service provider are currently at the lowest two levels, and limited quality vehicle data are shared. Consequently, the health and safety of extensively shared data models in the fleet vehicle data sharing are not proactively monitored. Consequently, this leads to redundancy in data model design. Generally, the emergence and prevalence of the real world entail large consumption and production cycles for data types whose effect takes time to propagate through observers, which manifests technical challenges in real time understanding of the late emerging effect of input data noise initiated by inadvertent human errors on vehicle motion. This emphasizes the impossibility of achieving 100% data value extraction but the possibility of optimality at different working points of the accuracy-relevance-cost trade-off. Standard and commodity needs to be considered for system embeddedness in all layers covering standardized ontologies, connectors, processors, and abstractions as early as the data source level.

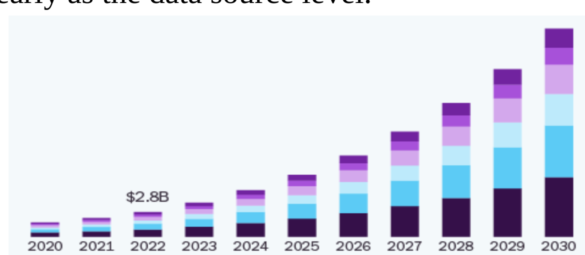

Fig 6: Vehicle Lifecycle Management through Integrated Data Platforms and IoT Connectivity.

A shared conceptual understanding of the data source level on how data relevant to the coordinator's objective would be delivered across multiple disciplines would favorably affect design balance and its traversal of visible states between fresh and stale. Throttle delay effects on system dynamics, task online replanning, and maintenance online response need further attention in a time-triggered cooperative system. Standard and commodity ontologies for object detection, egoimation, and control input need enhancement from the spatiotemporal reasoning aspect. The need for integrated data security definition since the automotive embedded systems take on selected vehicle sub-systems whose control authority ongoingly needs to be traded off .

10. Conclusion

The application of Integrated Data Platforms & IoT Vehicle Connectivity has the potential to provide significant value to OEMs, consumers, PaaS providers, and data & analytic companies in enhancing the ownership experience and vehicle lifecycle management. Leading OEMs are taking significant steps to prepare for these new opportunities through the development of integrated data platforms and IoT vehicle connectivity. These developments will have a transformative impact similar to that seen with the introduction of vehicle telematics in the late 1990s, and leading companies will reap significant first mover benefits.

The automotive industry is at a critical moment of change and reorientation. Over the coming decades, the backdrop of increasing digitalization and datafication will create both new threats and new opportunities for the industry and its participants. Data and connectivity-driven business models are projected to become the single biggest share of revenues and profits for the industry by 2030. More than simply becoming an enabler of new mobility and transportation models, data and connectivity-driven business models have the potential to transform how vehicles are used and contribute to create new data ecosystems involving both transactive and non-transactive exchanges. These new data ecosystems are seen as rapidly changing the competitive landscape of the mobility and transportation industry with widespread implications across all industry stakeholders.

Although, from the demand side, the potential of new data-driven use cases is elucidated in the literature, a systematic assessment on the supply side has not yet been undertaken. Furthermore, despite the value of data and connectivity, the nascent nature of the vehicle data ecosystem reveals critical challenges regarding data ownership, data sharing, data commercialization, and analytical capabilities. There is first an urgent need for OEMs to develop and implement integrated input and output data platforms for vehicle data to effectively manage the entire vehicle lifecycle. At the same time, given that these data platforms provide PaaS providers with back-end connectivity and vehicle data, an appropriate regulatory framework must be set up.

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