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Utilizing Fleet Data: Towards Designing a Connected Fleet Management System for the Effective Use of Multi-Brand Car Data

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Abstract

The connected car has recently evolved from a theoretical concept to reality. Especially in professionally managed fleets, car connectivity promises additional benefits in terms of costs, environment, and maintenance. However, many fleet managers are unaware of using connected car data and still associate telematics with retrofitting each vehicle. Thus, we aim to develop a connected fleet management system to increase fleet operations' efficiency and effectiveness by utilizing multi-brand data from car manufacturers' backend shared by data marketplaces. Thereby, we follow a design science research approach using inputs from the existing body of knowledge and the practical problem domain. Drawing on the theory of effective use, we propose meta-requirements and tentative design principles and instantiate them in a prototype artifact.

Keywords: Connected Car, Fleet Management, Data Marketplace, Design Science, Effective Use Theory

1. Introduction

With the ongoing proliferation of connected cars, in-vehicle data has become a key theme on the automotive industry agenda and, thus, an essential source of value creation (Carter et al., 2018; Kaiser et al., 2021). To harness the game-changing opportunities of this tremendously growing amount of data, not only original equipment manufacturers (OEMs) but also insurers, rental companies, and repair shops, among other players in the connected car ecosystem, seek to offer data-driven services (Sterk et al., 2022). In exploring car data monetizing, leading consultancies identified data-based fleet management as one of the industry's most impactful use cases (Arif et al., 2019; Carter et al., 2018). In fact, the share of private vehicles is declining, leading to a greater demand for professionally managed fleets (Pütz et al., 2019). Consequently, it is not surprising that McKinsey & Company forecasts the global connected fleet solutions market to grow at around 23% annually, becoming a $75.79 billion industry by 2025 (Carter et al., 2018).

While numerous data-driven fleet management use cases, such as predictive maintenance (Killeen et al., 2019) or driver monitoring (Walnum & Simonsen, 2015), are being discussed in research and practice, effective implementation is hindered by the problem of data access (Kaiser et al., 2019; Martens & Mueller-Langer, 2020). More precisely, while OEMs exclusively access car data, independent service providers must identify alternative access options, for instance, installing retrofit solutions (e.g., dongles) (Kaiser et al., 2019). However, this is fraught with severe drawbacks, such as expensive hardware, time-consuming installation, and limited data quality (Martens & Mueller-Langer, 2020). Nonetheless, the emergence of data marketplaces (e.g., Caruso Dataplace) offers another approach to accessing car data without hardware and installation, directly from OEMs (Kaiser et al., 2021; Martens & Mueller-Langer, 2020). Since car data marketplaces remain in their infancy and currently provide limited data, fleet management is a solid starting point for connected service design due to its high utility and manageable data requirements (Arif et al., 2019). However, scholars have scarcely touched on designing connected car or fleet services incorporating the concept of data marketplaces (Sterk et al., 2022). Hence, we pose the following research question: *How to design a connected fleet management system in order to use car data from data marketplaces effectively?*

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We address this question by conducting a design science research (DSR) project (Kuechler & Vaishnavi, 2008), using knowledge from a preceding literature review as well as practical insights from interviews with domain experts. Thereby, we derive theory-grounded meta-requirements and tentative design principles justified by the theory of effective use (Burton-Jones & Grange, 2013). We then instantiate them in a connected fleet management system based on in-vehicle data collected in a field test initiated by Caruso Dataplace (Mokeev et al., 2021). Finally, we evaluate our artifact by means of a focus group workshop and further expert interviews. Overall, we contribute to the body of design knowledge on connected service development, specifically focusing on fleet management data and its effective use. Practically, our research informs fleet managers on how connected car data can be utilized and how to design an effective fleet management system.

2. Related Work and Foundations

Connected Cars harbor the potential to deliver a unique customer experience while bringing cost and revenue benefits to mobility enterprises (Coppola & Morisio, 2016). To date, OEMs have sought to monetize valuable car data by offering digital services such as BMW ConnectedDrive or Mercedes me connect, enabling concierge services, remote diagnostics, and on-street parking information, among others (Kaiser et al., 2021). However, such data is not only of interest to OEMs but also to independent service providers (e.g., suppliers, workshops, insurers) who are forced to explore alternative technical gateways granting similar access options (Kaiser et al., 2019). The most common solution is retrofitting a telematics-equipped dongle into the on-board diagnostics (OBD) port to allow remote car data access (Coppola & Morisio, 2016; Pütz et al., 2019). According to Martens and Mueller-Langer (2020), despite initial optimistic forecasts for OBD dongle adoption, the market remains fragmented, and scaling up is challenging for several reasons. First of all, OBD dongles are characterized by time-consuming installations and expensive hardware purchases. Moreover, they are limited in terms of car park coverage, data point availability, as well as quality of the data collected. To counteract these drawbacks, another opportunity for third-party data access has emerged—without hardware or installation, directly from the OEMs. In fact, aspiring car data marketplaces such as Caruso Dataplace or Otonomo act as neutral intermediaries allowing OEMs to sell standardized data to independent service providers (Kaiser et al., 2021; Martens & Mueller-Langer, 2020). The significant benefit is that data from multiple OEMs can be made available via a single point of access (Martens & Mueller-Langer, 2020). In practice, though, marketplaces remain dependent on data access conditions (e.g., pricing or data coverage) set by OEMs.

Fleet Management is an essential instrument in the successful administration of a company's transportation activities (Redmer, 2022). Especially when operating diversified car fleets, managers can benefit from the multi-brand data accessed by retrofit-dongles or third-party marketplaces (Martens & Mueller-Langer, 2020). In general, fleet management systems (FMS) improve the efficiency and productivity of cars and drivers by mitigating the risks associated with their fleet investments (Salhieh et al., 2021), such as purchasing, placement, and maintenance of the fleet (Arulraj et al., 2019). Accordingly, an FMS allows enterprises to keep track of their fleet conveniently and cost-effectively (Karmanska, 2021). With the rapid proliferation of connected cars, the global FMS market witnesses tremendous growth (Carter et al., 2018; Kerber & Gill, 2019), which also entails a higher academic relevance in this area. Current research, for instance, addresses predictive maintenance by developing machine learning algorithms (Killeen et al., 2019) or dashboards (Arulraj et al., 2019) for an existing FMS. Moreover, the driving behavior of fleets is analyzed to reduce risky behavior through app notifications (Levi-Bliech et al., 2018). Similarly, lowering fuel consumption is also studied by identifying environmentally and economically beneficial driving modes (Walnum & Simonsen, 2015). In parallel, as companies become more environmentally conscious, the issues of reducing air pollutant emissions (Longo et al., 2016) and providing strategic decision support for fleet electrification come to the forefront (Schmidt et al., 2021). However, the research has not considered developing an FMS utilizing data from third-party marketplaces to date.

Theory of Effective Use. Effective use is vital to achieving the benefits of an information system. To this end, Burton-Jones and Grange (2013, p.633) established the effective use theory, in which they define *"effective use as using a system in a way that helps attain the goals for using the system."* Their conceptualization describes effective use based on three dimensions forming a hierarchy, as every lower-level dimension is necessary but not sufficient for the next higher-level dimension. Initially, (1) user access to the system's representations must be unimpeded by the surface and physical structures (transparent interaction). Thereby, (2) the ability to obtain representations that faithfully reflect the domain

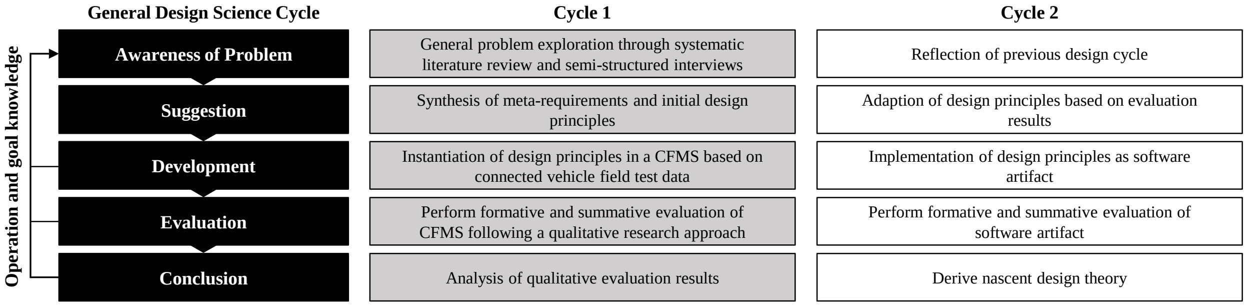

Figure 1. Design Science Research Methodology based on Kuechler and Vaishnavi (Kuechler & Vaishnavi, 2008)

represented by the system is improved (representational fidelity). Eventually, (3) the latter increases the users' ability to act on faithful representations they obtain from the system to improve their state in the domain (informed action). In our case, for instance, fleet managers need to access accurate vehicle information via comprehensive dashboards (transparent interaction), providing a representative overview of the current fleet condition and driving behavior (representational fidelity) that enables decision-making to optimize fleet processes such as vehicle ordering, maintenance, or invoicing (informed action).

3. Design Science Research Methodology

To provide a connected fleet management system (CFMS) based on vehicle data, we conduct a DSR project as described by Kuechler and Vaishnavi (2008) as it strongly emphasizes an iterative procedure in rapid iterating cycles, enabling flexible artifact development. Overall, our DSR project comprises two consecutive design cycles consisting of five phases each (Figure 1). This paper reports the results achieved during the first cycle, starting with the awareness of the problem perceived in practice. We ensure both rigor and relevance by using inputs from the existing body of knowledge (rigor) and the practical problem domain (relevance) (Hevner, 2007).

Awareness of Problem. We rely on a previously conducted systematic literature review (Sterk et al., 2022) focusing on data-driven business models in the connected car domain. To include recently published articles, we repeated the literature review following the methodological suggestions by Webster and Watson (2002). Thereby, we extended the search term[1] by Sterk et al. (2022) for the keyword *fleet** to shift focus to the fleet perspective and queried several databases[2] in title, abstract, or keywords. Our renewed search obtained 1121 studies, of which 779 remained after duplicates were removed. We then analyzed each article's title and abstract, yielding 133 articles. Afterward, we reviewed all full texts applying three inclusion criteria—the study must (1) address the fleet domain, (2) be available in English, and (3) be peer-reviewed—resulting in 34 relevant articles. Subsequent forward and backward search yielded 20 additional articles, resulting in a total of 54 papers.

To further refine and validate the awareness of the problem, we performed an explorative study using qualitative interviews with 21 fleet domain experts operating in five different areas: corporate fleet ($n = 11$), car subscription ($n = 4$), car sharing ($n = 2$), ride pooling ($n = 1$), and fleet service provider ($n = 3$). An interview overview including unique labels is provided in Table 1. The interviews were conducted through open questions along predefined discussion points to gain a deeper understanding of the real-world phenomenon. Thereby, we adopted a semi-structured approach to ensure similarity in the general structure of each interview. All interviews were recorded and transcribed before being coded and analyzed by two researchers using MAXQDA and Excel. When analyzing the transcribed interviews, we opted for qualitative content analysis according to Mayring (2000), as it is a flexible research technique that facilitates the analysis and interpretation of qualitative data (Krippendorff, 2019). Finally, our data analysis enabled us to justify the research gap regarding its practical relevance before artifact development (Sonnenberg & Vom Brocke, 2012).

Table 1. Interview and Focus Group Overview

DSR Phase	Method	Domain	NI (NE)*	Label
Awareness of Problem	Interview	Corporate Fleet	11 (11)	Alpha 1-11
Awareness of Problem	Interview	Car Subscription	4 (4)	Beta 1-4
Awareness of Problem	Interview	Car Sharing	2 (2)	Gamma 1-2
Awareness of Problem	Interview	Ride Pooling	1 (1)	Delta 1
Awareness of Problem	Interview	Service Provider	3 (3)	Epsilon 1-3
Evaluation	Focus Group	Service Provider	1 (5)	Zeta 1
Evaluation	Interview	Corporate Fleet	4 (6)	Eta 1-4
Evaluation	Interview	Service Provider	3 (6)	Theta 1-3

*NI = Number of interviews or focus group workshops; NE = Number of experts involved

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[1] "business model*" AND (connected OR data* OR digital*) AND (fleet* OR car* OR vehicle* OR automotive*)

[2] AIS Electronic Library, Emerald Insight, IEEEXplore Digital Library, ProQuest, ScienceDirect/Scopus, Web of Science

Suggestion & Development. Next, we reviewed the theory of effective use (Burton-Jones & Grange, 2013) that should guide the design of the CFMS to improve overall fleet management effectiveness. Based on the issues identified in the interviews and literature and the adopted kernel theory, we then derived meta-requirements (MRs). Drawing on the MRs, we formulated design principles (DPs) for artifact development following the suggestions of Gregor et al. (2020). In the development phase, we instantiated the proposed DPs based on in-vehicle data of 89 cars collected in a field test initiated by Caruso Dataplace (Mokeev et al., 2021). Thereby, we developed a prototypical CFMS in Microsoft Power BI, enabling fleet managers to utilize car data effectively.

Evaluation & Conclusion. Finally, the CFMS was evaluated according to the human risk and effectiveness strategy by Venable et al. (2016). We opted for this strategy as the design risk (i.e., potential problems the design may face) of the proposed artifact is user-oriented. First, we conducted a formative ex-ante evaluation using an exploratory focus group workshop (Tremblay et al., 2010) with five decision-makers from a leading connected car company (Table 1). This allowed us to gather feedback for further improvements by demonstrating our tentative DPs and artifact and discussing completeness, consistency, and applicability. After implementing the changes, we applied a summative ex-post evaluation through seven semi-structured interviews with twelve fleet experts (Table 1). In this step, we demonstrated the instantiated artifact to the participants by a click-through. Afterward, they gave feedback on effectiveness, efficiency, and consistency with the real-world context leading to inputs for the second cycle to deliver the final DPs and artifact.

4. The Design Science Research Project

4.1. Awareness of Problem

By analyzing the literature corpus and the interviews conducted, we identified eight critical issues encountered by fleet experts that vehicle data could potentially address. In doing so, we divide the identified issues into three dimensions—economic sustainability (I1, I2), environmental sustainability (I3, I4, I5), and vehicle health (I6, I7, I8)—and define them as follows. While the economic dimension covers the fleet's long-term financial viability, the environmental facet involves resilience to climate change. Finally, vehicle health refers to keeping the fleet in optimal use during its economic life by maintaining its condition.

Economic Sustainability. From a fleet manager's perspective, the total cost of ownership (TCO) is vital for identifying cost-saving opportunities and reducing operating costs stemming from fuel, maintenance, tires, or repairs (Fatin Amirah et al., 2013; López-Ibarra et al., 2020). Nevertheless, due to a lack of information on current mileage and energy consumption (**I1**), the potential for transparently managing and effectively optimizing costs is still little (Fatin Amirah et al., 2013). In this regard, one of the experts interviewed (Beta 4) emphasized that *"the topic of cost transparency is still in its infancy. Even the big fleet management companies still work with Excel."* Analyzing current fleet data would thereby help address the poor predictability of TCO (**I2**) and provide a basis for future resource planning and strategic decision-making (Redmer, 2022). Ultimately, monitoring fuel consumption could help decide what portion of the fuel costs the company and the driver should bear (Bätz et al., 2020).

Environmental Sustainability. With ongoing climate change, environmental sustainability has become a crucial strategic pillar for fleet managers globally (Karmanska, 2021). Consequently, ambitious greenhouse gas reduction targets dominate current discussions about fleet management. Thus, as electric mobility has proven to be a powerful technology for decarbonizing the transportation sector (Longo et al., 2016; Schmidt et al., 2021), multiple fleets are changing their car policies from internal combustion engines (ICEs) toward battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs) (Karmanska, 2021). However, without effectively accessing information (**I3**) about vehicle usage, sufficient calculation of a fleet's carbon footprint is limited (Bätz et al., 2020; Walnum & Simonsen, 2015). Moreover, in setting up their strategy toward a low carbon economy, companies are expected to establish reporting tools (Salhieh et al., 2021) faithfully reflecting the fleet's carbon footprint (Gonder & Simpson, 2007). Nevertheless, they still struggle to implement such a CO_2 reporting (**I4**). Ultimately, a sustainability strategy should also include appropriate measures to raise drivers' partially limited awareness of sustainable driving (**I5**). To this end, one interviewee (Alpha 7) explicated that *"employees opted for PHEVs primarily because of the tax advantage, never drove electric, and left the charging cable in its original packaging."*

Vehicle Health. Another prominent concern fleet managers face is maintaining vehicle conditions to ensure long-lasting vehicle health and driver safety (Coppola & Morisio, 2016). In some cases, however, fleet managers lack detailed information about the current health of the fleet (**I6**). In particular, they cannot remotely check vehicle conditions due to lacking access to relevant data such as error messages, missing supplies, or illuminated indicator lights (Killeen et al., 2019). Hence, preventive actions cannot be initiated to reduce maintenance calls and associated vehicle downtime (**I7**) (Fatin Amirah et al., 2013). Regarding this, one interviewed expert (Epsilon 3) mentioned that they *"usually only find out too late when maintenance intervals are not adhered to, or vehicles run without oil for weeks, causing enormous costs."* This aspect is closely related to drivers' decreasing responsibility for vehicle care (**I8**), occurring primarily in shared fleets.

4.2. Suggestion

In general, adequate fleet management is essential for successfully governing an enterprise's transportation activities (Redmer, 2022). This requires effective use of a fleet management system enabling the enterprise to improve vehicle and driver efficiency (Karmanska, 2021; Salhieh et al., 2021). For this purpose, we structured our MRs along the three dimensions of the effective use theory (Burton-Jones & Grange, 2013)—transparent interaction (MR1, MR2), representational fidelity (MR3, MR4), and informed action (MR5, MR6)—as it perfectly fits our research endeavor. Finally, based on the six MRs, we continued our research by identifying DPs for the CFMS following established guidelines (Gregor et al., 2020). We thereby divide our DPs into the two areas of fleet management—strategic (DP1-DP3) and operational (DP4-DP6). The translation process from MRs to corresponding DPs is depicted in Figure 2.

Strategic Fleet Management. To increase *transparent interaction* of strategic activities, fleet managers require to access detailed information regarding the overall fleet operating cost (**I1**), usage (**I3**), and condition (**I6**). This means providing unimpeded access to the vehicle data, as well as their transparent representation in the CFMS (**MR1**). Thereby, the system should contain a comprehensive set of key performance indicators (KPIs) that keep management informed and track fleet progress (Schmidt et al., 2021). However, to capture overall fleet sustainability, the KPIs need to cover not only economic but also environmental performance and vehicle health. Furthermore, to visually display the most important information on a single screen, the CFMS requires graphical dashboards providing relevant information at a glance (Few, 2006). Therefore, we propose the following design principle.
DP1: *Provide the CFMS with essential KPIs and their visualization via comprehensive dashboards in order to access the current fleet status.*

Intending to achieve *representational fidelity*, the CFMS is required to provide consolidated information regarding fleet status for reporting at an enterprise level (**MR3**). Correspondingly, a single report template must support meaningful KPIs and visualizations. Especially companies shifting toward a low-carbon economy are expected to implement reporting tools faithfully reflecting the fleet's CO_2 emission (**I4**) (Karmanska, 2021). Another example is the reporting of PHEVs' engine utilization—the share of kilometers driven electrically—to determine the extent to which the car's potential is utilized (Gonder & Simpson, 2007). However, beyond reporting environmental KPIs, cost-related data (e.g., fuel cost) is crucial (**I1**) for leveraging strategic action (López-Ibarra et al., 2020). Therefore, we propose the following design principle.
DP2: *Provide the CFMS with a reporting tool including essential KPIs and visualizations within a single template in order to reflect the current fleet status.*

Finally, to increase fleet managers' ability to take *informed action*, the CFMS should help identify ways to improve fleet performance, for example, by estimating operational fleet cost (**I2**). Accordingly, as a sound basis for static strategic decision-making, the system should permit calculating future costs, energy consumption, or emissions (**MR5**). The aim is to compare the current KPIs from the faithful representation of the reporting tool with target KPIs defined by a calculation tool, thereby estimating potential savings. This could help fleet managers improve future fleet status by, for example, capping fuel costs and thus having the company pay only a portion of the expenses to optimize fuel consumption and utility factor (Bätz et al., 2020). Therefore, we propose the following design principle.
DP3: *Provide the CFMS with a planning tool for calculating expected or desired KPIs based on specific parameters in order to improve the future fleet status.*

Operational Fleet Management. To increase *transparent interaction* of operational activities, fleet managers require vehicle-specific information on operating cost (**I1**), usage (**I3**), and condition (**I6**). Accordingly, the CFMS must provide a tabular overview of all vehicles, including meaningful KPIs, which must be filterable by specific cars, brands, models, or engine types (**MR2**). Hence, transparent and unhindered interaction is enabled by only displaying data items that match the defined criteria. For instance, comparing vehicles of the same models or powertrains helps identify those with conspicuous driving behavior. Therefore, we propose the following design principle.
DP4: *Provide the CFMS with a fleet overview that can be filtered by vehicle specifications in order to access vehicle condition and usage information.*

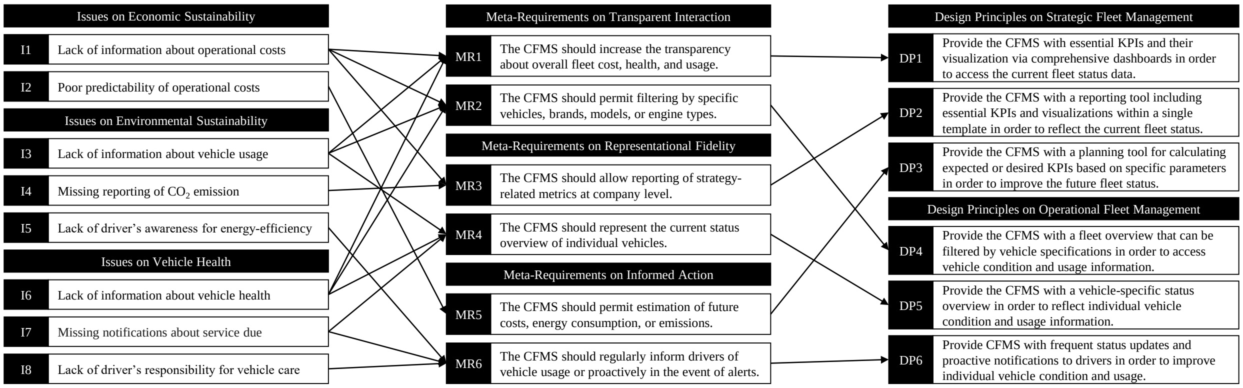


Figure 2. Mapping of issues, meta-requirements, and design principles for the CFMS

Next, to obtain *representational fidelity*, the CFMS should ensure a detailed status overview of each vehicle (**MR4**) including representations that faithfully reflect driving behavior (**I3**), vehicle condition (**I6**), or warnings such as overdue services (**I7**). Thereby, fleet managers can remotely check relevant data such as fuel consumption, missing supplies, or illuminated indicator lights (Killeen et al., 2019). Accordingly, the CFMS provides a detailed look at vehicles that became conspicuous (informed action) to initiate maintenance measures if necessary and thus avoid vehicle downtime (Levi-Bliech et al., 2018). Therefore, we propose the following design principle.

DP5: *Provide the CFMS with a vehicle-specific status overview in order to reflect individual vehicle condition and usage information.*

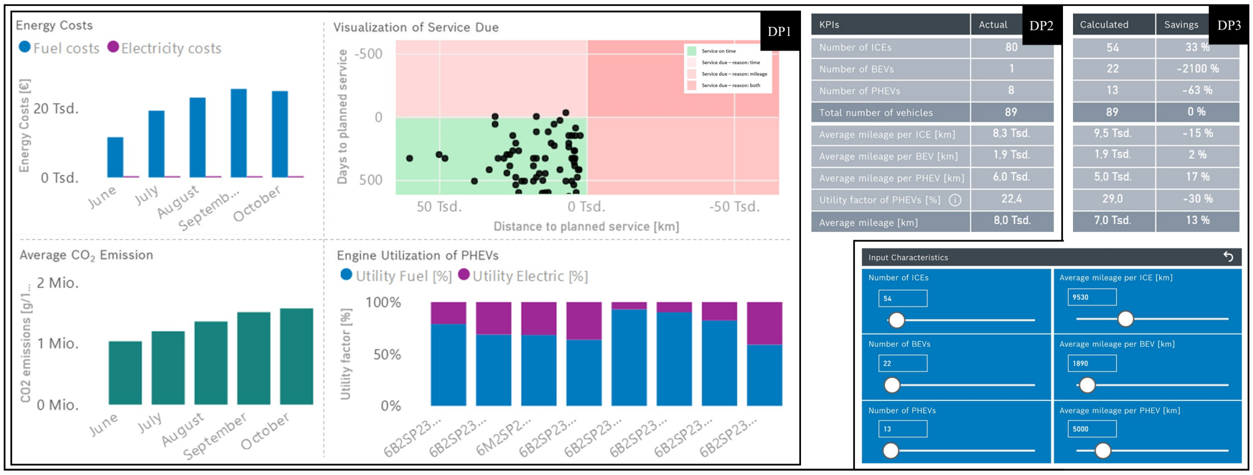
Finally, to improve fleet managers' ability to take *informed action* at the operational level, the CFMS should allow communication of the faithful representations of individual vehicles to respective drivers. The latter should raise their awareness of environmentally and cost-saving driving and ensure adequate vehicle care (**I5, I8**). This means regular updates informing drivers (**MR6**) about their driving behavior and proactive notifications with appropriate actions in case of warnings (**I7**). For instance, the CFMS could alert drivers to their above-average fuel consumption or unfriendly driving habits through monthly updates that compare their driving behavior to the average driving behavior of similar vehicles in the fleet (Walnum & Simonsen, 2015). Furthermore, if the maintenance intervals are not adhered to, the drivers of the affected cars should be informed that a service appointment must be made. Therefore, we propose the following design principle.

DP6: *Provide CFMS with frequent status updates and proactive notifications to drivers in order to improve individual vehicle condition and usage.*

4.3. Development

To instantiate our DPs into a prototypical CFMS, we used car data from a field test initiated by Caruso Dataplace (Mokeev et al., 2021). The field test data set included pseudonymized data in JSON format collected from 213 vehicles over five months in 2020. Initially, we transformed the JSON files into a tabular form and excluded files that were either empty or had an error message. In our data preprocessing, we set minimum data requirements for each vehicle due to the different data availability among the five participating OEMs. Accordingly, we specified *mileage* as a mandatory data point for all cars and energy resources depending on the powertrain: *fuel level* for ICEs, *state of charge* for BEVs, and both for PHEVs. Ultimately, a total of 89 vehicles remained for artifact development consisting of 80 ICEs, eight PHEVs, and one BEV. Following our data processing, we mapped our DPs to concrete features and implemented them using Microsoft Power BI. Figure 3 and 4 depict the DPs addressed by the prototype.

Strategic Feature Implementation. Initially, we instantiated **DP1** by defining a comprehensive set of KPIs based on the available field test data (Table 2). For example, we determined fuel consumption by calculating the differences in fuel level values from two consecutive data transmissions. Then, depending on the sign, we knew whether the car consumed fuel (-) or was refueled (+), allowing us to calculate fuel consumption in a given time. The procedure for electric vehicles was analogous. To determine energy costs, CO_2 emissions, and utility factors, we needed additional information that did not come directly from the vehicle; we obtained it from the sources listed in Table 2. Next, we implemented graphical **dashboards** visualizing the previously calculated KPIs. Building on this, we integrated the **reporting tool** described in **DP2** by listing the KPIs in tabular form and displaying essential



KPIs	Actual	Calculated	Savings
Number of ICEs	80	54	33 %
Number of BEVs	1	22	-2100 %
Number of PHEVs	8	13	-63 %
Total number of vehicles	89	89	0 %
Average mileage per ICE [km]	8,3 Tsd.	9,5 Tsd.	-15 %
Average mileage per BEV [km]	1,9 Tsd.	1,9 Tsd.	2 %
Average mileage per PHEV [km]	6,0 Tsd.	5,0 Tsd.	17 %
Utility factor of PHEVs [%] ⓘ	22,4	29,0	-30 %
Average mileage [km]	8,0 Tsd.	7,0 Tsd.	13 %

Input Characteristics

Number of ICEs: 54
Average mileage per ICE [km]: 9530
Number of BEVs: 22
Average mileage per BEV [km]: 1890
Number of PHEVs: 13
Average mileage per PHEV [km]: 5000

Figure 3. Instantiation of DP1, DP2, and DP3 within the CFMS prototype

charts on a single page. Next, we instantiated **DP3** by implementing the **calculation tool**. Here, we defined what-if parameters allowing users to simulate the impact of changing individual KPIs (e.g., fuel consumption) on the remaining KPIs (e.g., fuel cost) using sliders. Additionally, we adopted the KPI visualization from the reporting tool with the *actual* values and added columns with the *calculated* values and corresponding *savings*.

Table 2. Overview of KPIs and field test data points

No.	Key Performance Indicator	Field Test Data Point
1	Mileage	Mileage, timestamp
2	Total fuel consumption [l]	fuel level, timestamp
3	Total electricity consumption [kWh]	state of charge, timestamp
4	Average fuel consumption [l/100km]	mileage, fuel level, timestamp
5	Average electricity consumption [kWh/100km]	mileage, state of charge, timestamp
6	Fuel cost [€][1]	fuel level, timestamp
7	Electricity cost [€][2]	state of charge, timestamp
8	Total CO_2 emission [t][3]	fuel level, timestamp
9	Average CO_2 emission [g/km][3]	mileage, fuel level, timestamp
10	Engine utilization of PHEVs [%][4]	mileage, fuel level, state of charge, timestamp
11	Service due based on days and distance [km]	next service distance, next service date, timestamp

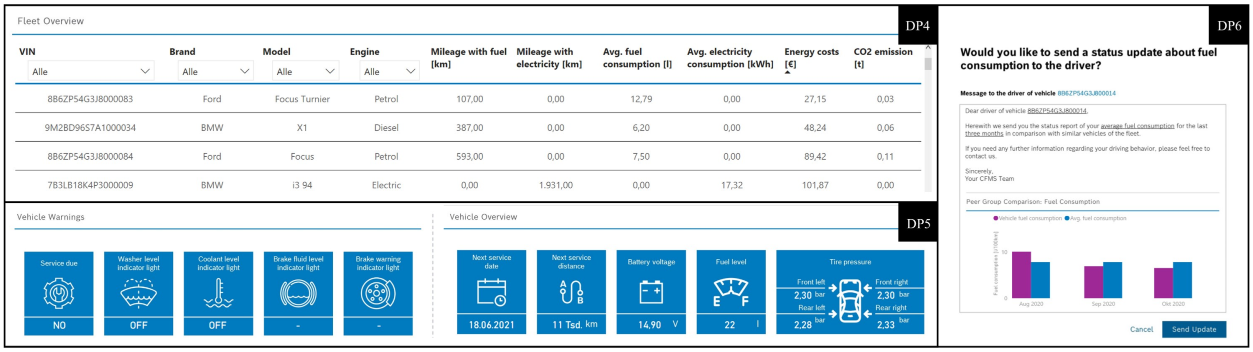
[1] Constant fuel prices were assumed based on local German fuel prices in April 2022
[2] Constant electricity prices were assumed based on an analysis of the BDEW e.V. (2022)
[3] Constant CO_2 emissions were assumed based on a report from Deutscher Bundestag (2019)
[4] Necessary data on PHEV models were taken from test reports of the automobile club ADAC (2022)

Operational Feature Implementation. To instantiate **DP4**, we created a tabular **fleet overview** of all vehicles containing information regarding vehicle identification number, brand, model, and engine type. Moreover, we added additional columns containing the previously defined KPIs for each vehicle. We then implemented a filter function allowing users to find or compare specific vehicles by filtering either by vehicle identification number, brand, model, or engine type. Next, we deployed **DP5** by allowing users to click on a specific vehicle in the fleet overview to view a car's detailed **vehicle status**. The overview contains further information regarding missing supplies, illuminated indicator lights, or service information obtained from the field test data. Ultimately, **DP6** was realized by extending the vehicle status overview and adding graphs displaying upcoming service needs and fuel consumption compared to other fleet vehicles. Thereby, we added click-dummy buttons to send drivers **proactive notifications** in case of an overdue service and **status updates** comparing the driver's fuel consumption with its peer group.

4.4. Evaluation and Conclusion

The first evaluation of our CFMS served as a formative ex-ante assessment to ensure the artifact's completeness, consistency, and applicability (Venable et al., 2016). For this purpose, we conducted an explanatory **focus group workshop** with five decision-makers from a leading connected car company operating as a service provider (Table 1). One author guided the focus group through our tentative DPs and the prototype artifact and asked the participants to comment on the initial version. For instance, we collected feedback regarding the design, order, or arrangement of individual features, buttons, and graphs. Afterward, we incorporated their recommendations leading us to the DPs and artifact presented previously.

We then performed a summative ex-post evaluation by conducting seven **semi-structured interviews** with twelve fleet experts operating in two areas: corporate fleet (n = 6) and service provider (n = 6) (Table 1). In this course, we demonstrated the improved artifact to the participants by having them assess each DP and feature regarding effectiveness, efficiency, and consistency. Firstly, concerning **DP1**, the experts praised the clear and transparent presentation of the graphical **dashboards**. In particular, the visualizations of environmental KPIs, such as engine utilization for PHEVs, were perceived as beneficial. In addition, it



VIN Alle	Brand Alle	Model Alle	Engine Alle	Mileage with fuel [km]	Mileage with electricity [km]	Avg. fuel consumption [l]	Avg. electricity consumption [kWh]	Energy costs [€]	CO2 emission [t]
8B6ZP54G3J8000083	Ford	Focus Turnier	Petrol	107,00	0,00	12,79	0,00	27,15	0,03
9M2BD96S7A1000034	BMW	X1	Diesel	387,00	0,00	6,20	0,00	48,24	0,06
8B6ZP54G3J8000084	Ford	Focus	Petrol	593,00	0,00	7,50	0,00	89,42	0,11
7B3LB18K4P3000009	BMW	i3 94	Electric	0,00	1.931,00	0,00	17,32	101,87	0,00

Would you like to send a status update about fuel consumption to the driver?

Message to the driver of vehicle 8B6ZP54G3J800014

Dear driver of vehicle 8B6ZP54G3J800014,

Herewith we send you the status report of your average fuel consumption for the last three months in comparison with similar vehicles of the fleet.

If you need any further information regarding your driving behavior, please feel free to contact us.

Sincerely,
Your CFMS Team

Figure 4. Instantiation of DP4, DP5, and DP6 within the CFMS prototype

was suggested by one expert (Eta 4) to use KPIs (i.e., mileage) for the plausibility check of fuel invoices. When discussing **DP2**, the experts (Eta 1, Theta 3) indicated the respective **reporting tool** as highly useful. Since the corporate controlling currently has to report CO_2 emissions to the management once a year, the CFMS could automate this task. However, one participant (Theta 2) emphasized the need for holistic TCO reporting (e.g., lease, tire, and maintenance costs) for different management levels: Aggregated costs at strategic and detailed costs at operational levels. Notably, **DP3** and the respective **calculation tool** was evaluated as the most exciting and innovative. The participants (Eta 1, Eta 3, Theta 3) liked the parameters variable by sliders that could replace the current less comfortable calculations via Microsoft Excel. Thus, the tool would be helpful improve transparency and justification of decisions and strategies. However, the experts desired to consider the investment in the in-house charging infrastructure depending on the number of BEVs. Concerning **DP4**, one expert (Eta 2) noted that the **fleet overview** is a vital feature, but it is already the status quo for common fleet management systems. Nevertheless, the participants (Eta 4, Theta 1) highlighted the need for an additional driving behavior analysis per vehicle that would provide added value, for instance, to ensure optimal and route-related vehicle deployment. Regarding **DP5**, the experts (Eta 2, Eta 3) argued that the **vehicle status** overview is particularly suitable for cars with no permanently assigned driver due to lacking responsibility for occurring issues. Thus, pool vehicles needing maintenance could be predictively taken out of service until the required repair is made. They further recommended introducing color differentiation in the visualization of vehicle supplies and indicator lights (e.g., *green=good*, *red=bad*). Finally, concerning **DP6**, one expert (Eta 1) noted that **proactive notifications** and **status updates** should be directed either to drivers (e.g., for leasing) or fleet managers (e.g., for sharing), depending on the periods of vehicle use. Overall, the feature was perceived as saving time and resources and would add significant value, mainly through automated service reminders.

5. Discussion and Conclusion

Building on the completion of cycle 1, our work reports on identifying issues, MRs, and tentative DPs, as well as developing and evaluating a prototypical CFMS. Initially, we identified issues in three dimensions (i.e., economic sustainability, environmental sustainability, and vehicle health) confirmed by both methodological approaches, a literature review and expert interviews. However, while the existing body of knowledge provided us with relatively high-level insights (e.g., transparency on TCO, CO_2 emission, or vehicle condition), the practical problem domain yielded in-depth insights that could be addressed explicitly through vehicle data usage (e.g., cost prediction, engine utilization, or service reminders). Building on that and drawing on the effective use theory (Burton-Jones & Grange, 2013), we developed MRs and DPs and instantiated them in a prototype artifact. Finally, we evaluated the artifact using a focus group workshop and expert interviews, highlighting additional functions we plan to incorporate in the second cycle.

From a theoretical perspective, our work contributes to the body of design knowledge for data-driven car service development in general and fleet management systems in particular. We thereby implemented an artifact in the form of a prototypical fleet management system (level 1 contribution (Gregor & Hevner, 2013)) and evaluated it using a human risk and effectiveness strategy (Venable et al., 2016). In this regard, we took the first steps toward developing a nascent design theory by formulating tentative DPs. Building on this, we aim to contribute to the prescriptive knowledge base (potential level 2 contribution (Gregor & Hevner, 2013)) in the second cycle. Generally, we consider our work as an "improvement" in the DSR knowledge contribution framework (Gregor & Hevner, 2013), as it represents an efficient and effective solution for a known problem. More specifically, our evaluation results indicate that fleet management systems' effective use can be increased by offering a calculation tool (DP3) for planning expected or desired KPIs, leading to improved transparency and justification of strategic decision-making. Furthermore, the system creates awareness among drivers regarding vehicle health and usage through proactive notifications and status updates (DP6), increasing environmentally friendly and cost-efficient driving, as well as process efficiency.

In terms of practical contribution, our proposed artifact provides a user-centric solution to help enterprises effectively manage their carpools, thereby improving economic performance, environmental sustainability, and vehicle health. From a strategic perspective, the CFMS provides users with the required fleet information via comprehensive dashboards and KPIs (DP1) that can be displayed in aggregate form for internal reporting (DP2). In addition, strategic decisions can be prepared transparently by simulating different scenarios (DP3). Next, from an operational standpoint, the CFMS provides an overview of all vehicles and essential metrics (DP4). It also enables a detailed display of specific vehicles that stand out (DP5). Based on this, status updates regarding energy consumption and service notifications help improve drivers' environmental awareness and maintenance responsibility (DP6). Finally, our DPs provide practical guidance for automotive companies to develop novel data-driven services beyond fleet management.

As with any study, ours is subject to limitations. First, it is unlikely to have identified all potentially relevant articles in our literature review. Second, our sample of participating experts does not claim to be exhaustive, as we only spoke to representatives of corporate mobility, car subscription, car sharing, ride pooling, and fleet service providers. Unfortunately, experts active in logistics or leasing companies have not been taken into account yet. Nevertheless, due to our approach consisting of both literature and expert interviews, we are confident that we have ensured both rigor and relevance, thus creating a solid foundation for problem awareness. In addition, we plan to involve a broader range of experts in the second design cycle. Third, while we believe that focusing on the theory of effective use (Burton-Jones & Grange, 2013) and evaluating human risk and effectiveness (Venable et al., 2016) is most appropriate for developing design knowledge for a CFMS, the consideration of another theoretical lens may have led to a different set of DPs. Within the second cycle, we will therefore refine our tentative DPs based on our evaluation results before implementing them into a software artifact.

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