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Systematic Review

Vehicle Feature Activation in Software-Defined Vehicles Based on a Conceptualization of Vehicle Lifecycle Upgrades

Yannick Lindebauer [1,*], Richard von Esebeck [2] and Thomas Vietor [1]

[1] Institute for Engineering Design, Technische Universität Braunschweig, Hermann-Blenk-Str. 42, 38108 Braunschweig, Germany; t.vietor@tu-braunschweig.de
[2] Volkswagen AG, P.O. Box 1679/1583, 38436 Wolfsburg, Germany; richard.von.esebeck@volkswagen.de
* Correspondence: yannick.lindebauer@tu-braunschweig.de

Abstract

The transition toward software-defined vehicles (SDVs) enables vehicle functionality to evolve beyond production through software-driven mechanisms. Despite growing industrial adoption, industry sources differ in the terminology and scope used to describe this phenomenon. Whether the scientific literature provides a common conceptualization of feature activation after vehicle production remains unclear. A systematic literature review of five scientific databases was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines, followed by an integrated analysis of the identified concepts, terminology, and definitions. The results reveal substantial conceptual and terminological fragmentation, with existing studies describing the phenomenon from multiple partially overlapping perspectives rather than providing a unified definition. Based on these findings, a hierarchical conceptual model of vehicle lifecycle upgrades is proposed, distinguishing between internal vehicle upgrades, realized through software-based mechanisms on existing hardware, and external vehicle upgrades, requiring the integration of additional physical components. This distinction provides a conceptual foundation for delimiting software-enabled feature activation from hardware-based vehicle evolution. Furthermore, the proposed framework positions vehicle lifecycle upgrades within the SDV paradigm and establishes a basis for future research, industrial communication, and the systematic classification of software-enabled vehicle evolution.

Keywords: software-defined vehicle; automotive; over the air; upgrade; update; electronic control unit; feature

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1. Introduction

The automotive industry is characterized by the simultaneous presence of extremely high product variability and very large production volumes [1]. At the same time, vehicles are far from simple products; rather, they constitute highly complex, networked mechatronic systems. Consequently, the automotive domain represents a unique combination of scale, variability, and technical complexity.

In parallel, the industry is undergoing a profound and continuous transformation. Initially driven by the transition from internal combustion engines to electrified powertrains, this shift has evolved into a holistic transformation of the vehicle as an integrated system [2,3]. In this context, the concept of the software-defined vehicle (SDV) has emerged, reflecting a paradigm shift in value creation, from predominantly mechanical components toward software-intensive mechatronic systems. The SDV paradigm aims at seamless integration into broader digital ecosystems, encompassing technologies and domains such

as the internet of things (IoT), vehicle-to-everything (V2X) communication, data-driven and real-time vehicle diagnostics, advanced driver assistance systems (ADAS) up to fully autonomous driving, over-the-air (OTA) updates, as well as enhanced user-centric functionalities in infotainment, connectivity, and personalization [3–5]. Closely related, the notion of connected vehicles overlaps with the SDV concept, particularly with respect to connectivity and OTA capabilities, although the scope and emphasis may differ.

Enabling this transformation requires substantial advancements in electrical/electronic (E/E) architectures, with electronic control units (ECUs) playing a central role as enablers of vehicle functionality [2,3,6]. As a consequence of the transition toward SDVs, software has become the primary driver of innovation and differentiation. At the same time, customer expectations regarding vehicle individualization are increasing, with a growing demand for extended functionality and deeper integration of digital services [5,7].

To address these expectations, original equipment manufacturers (OEMs) provide extensive configuration options that span both hardware and software domains. In embedded systems, particularly in automotive systems, functionalities are predominantly realized through ECU software. This software must accommodate a broad spectrum of features and variants, while simultaneously handling dependencies across hardware and system components. As a result, software complexity increases significantly, further compounded by the need for continuous evolution, such as the integration of new functionalities or the deactivation of existing ones over time.

A naive approach to managing this complexity would involve developing fully customized software for each individual system variant. However, such an approach is infeasible in practice, as even minor modifications would require complete reimplementation, leading to prohibitive development effort and cost. Instead, the industry commonly adopts the principle of software parameterization. In this approach, configuration elements, typically implemented as parameters, are embedded as placeholders within the source code during development and assigned concrete values at later stages [8]. This is often realized through the development of a software platform that inherently contains all potential functionalities and configuration options. Specific vehicle variants are then derived through selective configuration, effectively shifting complexity from code development to configuration management. This enables efficient variant creation and modification without the need for extensive code changes.

Traditionally, customers define the functional scope of their vehicle during the ordering process, either via online configurators or through dealership interactions. From a technical and sales perspective, this process is feature-driven: selected features determine the vehicle configuration, which is realized during production. Toward the end of the manufacturing process, the software is parameterized to reflect the customer-specific configuration. This process is also known as end-of-line programming [9]. While this approach allows for a certain degree of individualization, it is largely limited to a single point in time—namely, prior to or during vehicle production. Modifications after vehicle production are typically restricted and require physical intervention, such as the integration of additional hardware components in service workshops.

The emergence of SDVs, and in particular the availability of OTA mechanisms, fundamentally changes this paradigm. Software modifications can now be deployed remotely, eliminating the need for physical service interactions. OEMs can not only update existing functionalities after vehicle production but also extend the functional scope of vehicles by introducing entirely new features. This technological capability enables a new form of customer interaction: the ability for customers to activate or unlock vehicle functionalities at a time of their choosing after purchase.

OEMs have recognized this capability as a basis for new business models within the SDV ecosystem. However, across the automotive landscape, there is no consensus regarding the definition, scope, or terminology of feature activation mechanisms after vehicle production. Individual OEMs employ their own terminology and conceptualizations, often with inconsistent internal and external communication. Examples include "Functions on Demand," "We-Upgrades," "BMW ConnectedDrive Upgrades," "Digital Features and Services," "Features on Demand," "Connected (Car) Services," "Digital Extras," "In-Vehicle Premium Features," "In-Vehicle Connected Features," "OTA Software Updates," and "Subscriptions," with these terms reflecting varying interpretations and scopes.

A similar lack of standardization exists within the supplier ecosystem and across industry initiatives. While some stakeholders restrict the concept to software-based feature activation enabled by OTA mechanisms, others extend its scope to the integration of additional hardware components or hybrid approaches. Furthermore, the underlying business models differ significantly, ranging from one-time purchases to subscription-based offerings.

Overall, the automotive industry therefore lacks a standardized conceptual framework and consistent technical delineation for feature activation after vehicle production. Existing terminology is frequently influenced by product and marketing strategies rather than rigorous definitions, and no universally accepted terminology has emerged.

To address this need, this paper conducts a systematic literature review to investigate whether the academic literature provides a consistent and reliable definition of feature activation after vehicle production. Based on the findings, a conceptual framework is developed and a definition is proposed within the broader SDV context.

The main contributions of this paper are as follows:

- A comprehensive systematic literature review on feature activation after vehicle production, addressing the question of whether existing literature provides a consistent and reliable definition.
- The introduction of vehicle lifecycle upgrades as an overarching conceptual framework for vehicle evolution after production, distinguishing internal vehicle upgrades based on existing hardware capabilities from external vehicle upgrades requiring additional physical components, and positioning feature activation within the broader SDV concept.

The remainder of this paper is structured as follows. Section 2 introduces the necessary background on SDVs, connected vehicles, and the distinctions between features and functions as well as updates and upgrades in the automotive context. Section 3 reviews the related literature and positions the contribution of this work within the existing body of research. Section 4 describes the research methodology, followed by Section 5, which presents the results of the systematic literature review. Based on these findings, Section 6 analyzes the identified concepts using an integrated analysis framework. Section 7 derives the definitions and positions them within the broader SDV concept. Finally, Section 8 discusses the findings, outlines the limitations of the study, and concludes the paper.

2. Background

This section introduces and defines a set of key concepts that are considered essential for understanding both the broader context of the automotive industry and its emerging linkage to feature activation after vehicle production. These concepts are not only required to establish a common conceptual foundation, but also serve as the building blocks for deriving a consistent and consolidated definition, which represents a central outcome of this paper.

2.1. Software-Defined Vehicle

The concept of the SDV has, over recent years, evolved into a widely adopted term and has been defined across a variety of studies [10–12]. In Máté et al. [12], for instance, the SDV is described as a high-level paradigm in which the primary share of value and functionality is no longer rooted in hardware, but rather in software. Consequently, functionalities can be continuously extended, refined, and improved throughout the vehicle's lifecycle, most notably through OTA updates [13,14]. These OTA updates constitute a fundamental prerequisite for SDVs, as they enable the remote and incremental deployment of software changes without requiring physical intervention [12].

The concept of the SDV is defined by several core characteristics [12]. Software becomes the primary driver of functionality and innovation, requiring a transition in the underlying E/E architecture toward centralized compute platforms. SDVs are furthermore intrinsically linked to increasing levels of driving automation, up to full autonomy. A defining characteristic is the ability to remotely modify and extend vehicle software via OTA mechanisms, which decouples the vehicle's functional scope from its production state and enables continuous post-production evolution. This architectural separation of software and hardware allows functionalities to be developed and deployed independently of hardware lifecycles, ultimately enabling a high degree of vehicle personalization and dynamic customer-driven configuration.

In its entirety, the SDV paradigm can be understood as a key enabler for the realization of feature activation after vehicle production. By decoupling functionality from static hardware constraints and enabling remote updates and upgrades, it removes the necessity for customers to visit workshops for feature activation or modification. This inherent flexibility forms the technological foundation upon which feature activation after vehicle production can be effectively implemented.

2.2. Connected Vehicle

Closely related to the SDV paradigm is the concept of the connected vehicle. A connected vehicle is equipped with applications, services and technologies, that connect it with its surroundings [15]. Connectivity enables a data flow, i.e., communication between the vehicle and external ecosystems. Two primary drivers can be identified for advancing this development [16]. On the one hand, there is a strong and increasing emphasis on improving vehicle safety, with the overarching goal of reducing the number and severity of accidents. In this context, connected vehicles are expected to play a pivotal role. On the other hand, a growing demand for high-speed internet connectivity can be observed. This demand originates not only from customers, who increasingly expect seamless digital experiences within the vehicle, but also from the vehicle itself, as modern automotive systems rely on continuous data exchange to support functionalities such as advanced driver assistance systems.

In the context of feature activation after vehicle production, connectivity plays a crucial role, as it enables the remote activation and management of features throughout the vehicle lifecycle.

2.3. Feature & Function in the Automotive Context

At this point, it is important to explicitly distinguish between the terms feature and function, as this differentiation becomes particularly relevant for the subsequent definition of feature activation after vehicle production. In both academic literature and industrial practice, these terms are often used interchangeably. However, such a conflation overlooks a crucial conceptual distinction and therefore we define the terms as follows:

A function refers to the underlying technical capability or behavior of a system, in accordance with the understanding from [17], independent of whether it is realized through software, hardware, or a combination of both. It captures what the system is technically able to perform. In contrast, a feature describes a characteristic or capability of the vehicle [18] from the customer's perspective. It represents how this capability is perceived, packaged, and ultimately experienced by the user. Notably, a single feature may encompass one or multiple underlying functions, e.g., a feature such as "adaptive cruise control" encapsulates a range of technical functions, including sensor data processing, control logic, and actuator coordination.

This distinction is of central importance in the context of feature activation after vehicle production. Customers do not directly interact with or purchase individual functions; instead, they select and acquire features. The realization and activation of these features, however, fundamentally depend on the correct configuration, integration, and orchestration of the underlying technical functions within the vehicle system [19].

2.4. Upgrade & Update in the Automotive Software Context

Both concepts, upgrade and update of software, play a central role in the realization of software-driven vehicle functionalities and, in particular, in the context of feature activation after vehicle production. From a purely technical perspective, however, such a distinction is not always explicit, as both updates and upgrades are typically realized through similar software distribution and deployment mechanisms (e.g., OTA delivery). In industrial practice, the terms are also not used consistently and are often used interchangeably, with "OTA update" frequently serving as a generic term for software changes delivered over the air.

Nevertheless, a meaningful differentiation can be established based on the intent and effect of the respective changes. In line with established perspectives from software engineering and automotive literature [19,20] we therefore distinguish between updates as evolutionary improvements and upgrades as functional extensions.

Accordingly, we define an update as a modification of already existing software functionalities within the vehicle. Its primary purpose is to improve or maintain the current system state, including, for instance, bug fixes, performance optimizations, and security patches. In this sense, updates can be understood as evolutionary improvements, as they refine and stabilize existing functionality without fundamentally altering the functional scope of the vehicle. From a customer perspective, updates are typically perceived as maintenance or quality improvements of already available features.

In contrast, an upgrade introduces new functionality that was previously not available in the vehicle. This can include entirely new features, extended capabilities of existing systems, or the activation of pre-installed but previously inactive functionalities. Accordingly, upgrades represent functional extensions that expand the system's capabilities and directly enhance the value proposition of the vehicle. In modern SDVs, such upgrades are increasingly delivered via OTA mechanisms, enabling manufacturers to provide additional features even after the vehicle has been delivered to the customer.

3. Related Work

In this section, related literature is reviewed. In doing so, it highlights adjacent research domains that provide relevant theoretical and conceptual contributions, and it discusses existing studies within the automotive context.

The concept of offering functionalities as services, often through subscription-based business models, is not novel and has been extensively studied across multiple domains [21]. In particular, the paradigm of "X-as-a-Service" has gained significant traction, encompassing

well-established concepts such as software as a service [22–24], platform as a service [25], and mobility as a service [26]. These approaches share the fundamental principle of decoupling ownership from usage, thereby enabling flexible, on-demand access to functionalities and resources [27].

Beyond these established service models, more granular paradigms such as function as a service [28] have been investigated, particularly within the field of cloud computing and IT systems. Prior research has explored architectural implications, economic models, and operational challenges associated with such service-oriented approaches. Furthermore, several systematic literature reviews [29,30] have synthesized the state of research in these domains, highlighting both technological enablers and business-driven motivations for adopting service-based delivery models.

In contrast, within the automotive domain, the concept of feature activation after vehicle production has not yet been examined in a holistic and systematic manner, i.e., in a systematic literature review. While individual contributions address specific aspects relevant to feature activation after vehicle production, such as OTA mechanisms [31], software modularization, digital ecosystems, and monetization strategies, a comprehensive conceptualization as an integrated phenomenon remains largely absent. Existing studies instead tend to focus on enabling conditions and boundary factors required for the realization of such approaches [32–34], including technical infrastructure, regulatory constraints, customer acceptance, and lifecycle management considerations. However, these works do not converge toward a well-founded definition or structured framework that captures feature activation after vehicle production in its entirety.

4. Research Methodology

This section is guided by two research questions (RQs), which form the foundation for the subsequent research methodology:

- RQ1: Does the academic literature provide a common understanding, i.e., a unique and consistent definition, of feature activation after vehicle production?
- RQ2: How can a feature activation mechanism after vehicle production be defined in the context of automotive ECU software parameterization, and how can this definition be positioned within the broader SDV concept?

To address these research questions, this section presents the research methodology adopted in this work. The objective is to systematically derive a well-founded definition of feature activation after vehicle production and to position it within the broader SDV concept. An overview of the research methodology, including the linkage between individual steps and the research questions, is illustrated in Figure 1.

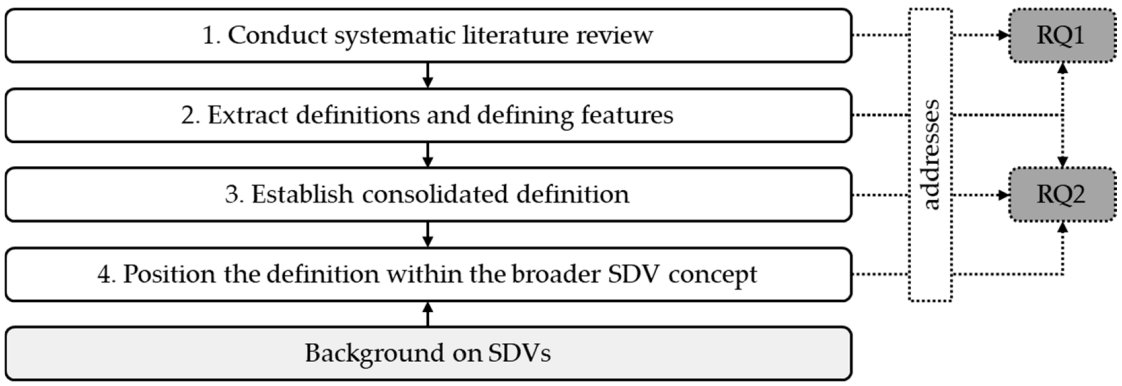


Figure 1. Methodology and approach for answering the research questions.

Prior to conducting the research presented in this paper, an exploratory review of publicly available commercial sources from the automotive industry was conducted to obtain an overview of how feature activation after vehicle production is understood and implemented across the industry. Publicly available websites, technical documents, and other relevant materials from leading automotive manufacturers and original equipment suppliers were examined. The companies considered were identified based on the leading automotive companies and automotive original equipment suppliers reported by Statista [35,36]. The review was intended to examine whether a consistent understanding of the concept could be observed across different companies and contexts, including the terminology used, the scope attributed to feature activation, and the types of functionalities considered. The observations from this preliminary review indicated considerable variation in terminology and conceptual understanding and therefore motivated the systematic investigation of the academic literature presented in this paper.

Although the concept of feature activation after vehicle production is increasingly relevant in practice, to the best of our knowledge, it has not yet been systematically and comprehensively examined in the academic literature. To assess whether the scientific literature provides a clear and consistent understanding of the concept, a systematic literature review (1) was therefore conducted.

From the publications identified through this review, explicit definitions and underlying defining characteristics were extracted (2). These elements were subsequently subjected to a structured and comparative analysis. Based on this analysis, and informed by the authors' practical experience in SDVs, ECU software parameterization, and related areas, a consolidated conceptualization and definition of feature activation after vehicle production was developed (3). Finally, the resulting definition was positioned within the broader SDV concept (4), drawing on the foundational background introduced in Section 2.

5. Systematic Literature Review of Scientific Publications

This section presents the systematic literature review approach used to identify and collect definitions of feature activation after vehicle production from the academic literature. It further provides a transparent account of the overall review process. The systematic literature review followed established methodological guidelines for evidence-based research in software engineering [37–39] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [40], supporting a structured, rigorous and reproducible review process. A completed PRISMA 2020 checklist indicating where each item is addressed is provided in Appendix A (Table A1). The review was not prospectively registered.

5.1. Search Process

The development of the search strategy followed an iterative procedure. Multiple candidate search strings were designed, tested, and refined with the objective of identifying publications that provide definitions or conceptualizations relevant to feature activation after vehicle production.

The final search string consists of two complementary components. The first component captures terminology associated with feature activation mechanisms. The second component ensures the contextual relevance of the retrieved publications by restricting results to the automotive domain. The resulting search string is as follows:

("function on demand" OR "functions on demand" OR "function-on-demand" OR "functions-on-demand" OR "feature on demand" OR "features on demand" OR "feature-on-demand" OR "features-on-demand" OR "on demand function" OR "on-demand function" OR "on demand feature" OR "on-demand feature" OR "on demand upgrade" OR "on-demand upgrade"
OR "ota upgrade" OR "over the air upgrade" OR "over-the-air upgrade" OR "ota software upgrade" OR "over the air software upgrade" OR "over-the-air software upgrade"
OR "software-enabled function" OR "software-enabled feature" OR "software-based function" OR "software-based feature"
OR "ota activation" OR "over the air activation" OR "over-the-air activation"
OR "ota feature" OR "over the air feature" OR "over-the-air feature"
OR "ota function" OR "over the air function" OR "over-the-air function"
OR "remote activation" OR "remote feature" OR "remote function"
OR "feature activation after" OR "function activation after" OR "post-production feature activation" OR "post-production function activation" OR "post-purchase feature activation" OR "post-purchase function activation" OR "post-sale feature activation" OR "post-sale function activation")

AND

("automotive" OR "car" OR "vehicle" OR "sdv")

The term OTA update was deliberately excluded from the final search string despite its conceptual proximity. During the iterative refinement of the search strategy, preliminary searches indicated that including OTA update substantially increased the number of retrieved publications while reducing result specificity. To assess this effect more systematically, a targeted sample-based assessment was conducted to examine the additional publications retrieved through the inclusion of OTA update and to determine their thematic relevance to the research objective. The results showed that the additional publications predominantly focused on the technical realization of OTA software distribution, cybersecurity, communication architectures, update orchestration, or software maintenance processes rather than on the conceptualization or definition of feature activation mechanisms after vehicle production. Further details on the sample-based assessment, including its procedure and results, are provided in Appendix B.

Since the objective of this study is not to investigate OTA technologies themselves, but rather to identify and analyze definitions of feature activation after vehicle production, the inclusion of the broader term OTA update would have introduced a disproportionately high number of semantically unrelated publications. This would have reduced the precision of the search process and substantially increased the manual screening effort without providing commensurate analytical value.

In contrast, the term OTA upgrade exhibited a stronger semantic alignment with feature extension and functional enhancement after vehicle production, thereby yielding a considerably higher proportion of relevant publications. Consequently, the final search string prioritizes terminological specificity over maximal retrieval breadth in order to maintain the methodological focus and relevance of the identified literature.

Based on domain expertise and established practices in automotive and software engineering research, five scientific databases were selected for the literature search. The databases and the number of records identified from each source are reported in the PRISMA flow diagram in Figure 2, which also documents the overall study selection process.

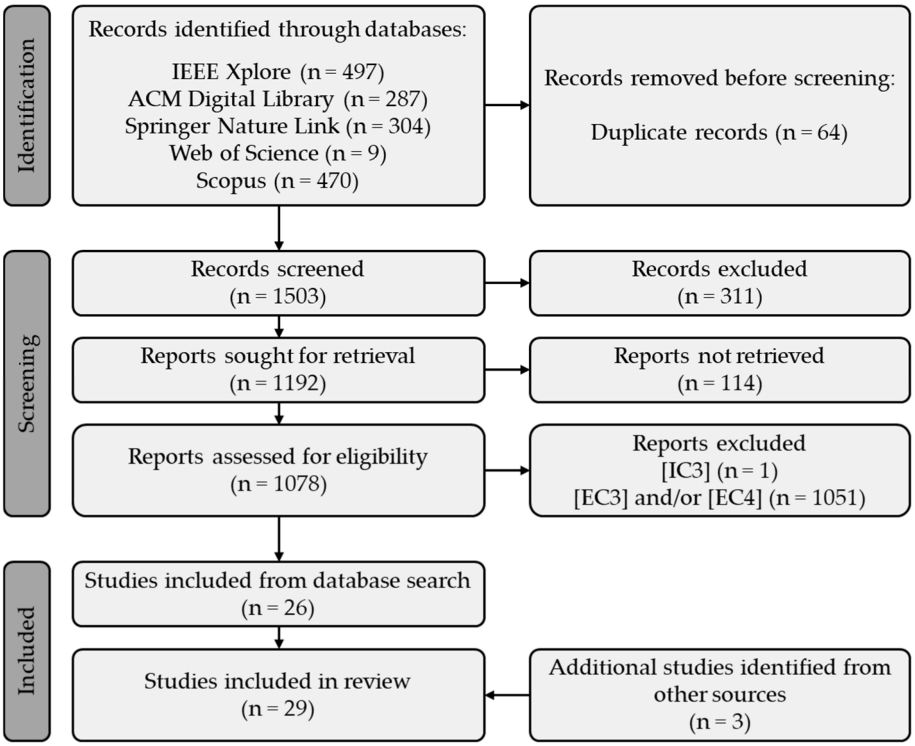


Figure 2. PRISMA 2020 flow diagram.

To ensure transparency and reproducibility, the search strategy was adapted to the specific search interfaces of the selected databases. The database-specific search settings, including the respective search fields, are documented in Appendix C (Table A3). This documentation provides a detailed overview of how the conceptual search strategy was operationalized for each database while maintaining the intended scope and terminology across the individual searches.

The literature search was conducted iteratively throughout the review process, with the final search update and validation performed on 14 September 2026.

5.2. Selection Criteria, Data Extraction, and Coding

To ensure a systematic and reproducible selection of relevant publications, a structured set of selection criteria was defined, comprising both inclusion and exclusion criteria. Publications were included if they satisfied all of the following inclusion criteria (IC):

- IC1: The publication was published not before January 2000.
- IC2: The publication underwent a peer-review process.
- IC3: The publication is written in English.
- IC4: The publication has already been fully edited.
- IC5: The full text of the publication is accessible through the selected databases.

Publications were excluded based on the following exclusion criteria (EC):

- EC1: The publication is a duplicate.
- EC2: The publication is a Bachelor's or Master's thesis or a technical report.
- EC3: The search terms appear only in metadata, including the title, abstract, or keywords, without substantive discussion of feature activation after vehicle production in the main text.
- EC4: The publication does not address the domain of mobility.

Most inclusion criteria were applied during the initial retrieval phase, depending on the filtering capabilities of the respective databases. The exclusion criteria were subsequently

applied through a multi-stage screening process, beginning with title and abstract screening and culminating in full-text analysis. In particular, determining whether a publication provided a substantive explanation or definition of feature activation after vehicle production required assessment of the full text.

Because the relevance criterion concerned substantive treatment of the concept in the body of the publication, title and abstract information alone was not sufficient for a final inclusion decision. The majority of records were therefore assessed at full-text level against the predefined inclusion and exclusion criteria. Two authors were involved in the screening and classification process: one author performed the initial assessment, and the second author independently cross-checked the decisions and underlying evidence. Divergent assessments were documented in the review material and resolved through discussion until consensus was reached. No third reviewer was required, and no inter-rater agreement statistic was calculated because the procedure was designed as consensus-based cross-checking rather than independent duplicate screening. Duplicate records were identified by comparing bibliographic metadata before the screening process. Selection decisions and reasons for exclusion were retained in the structured review documentation.

Following the screening process, data were systematically extracted from the included publications to capture how feature activation after vehicle production was described and conceptualized in the literature. The extraction included both explicit definitions and substantive explanations of the concept. The type of treatment was recorded using two predefined coding categories: Definition and Explanation. Definition was assigned when a publication provided an explicit definitional statement or an equivalent formal delimitation, whereas Explanation was assigned when a publication described the meaning, mechanism, characteristics, or applications of the concept without providing a concise explicit definition.

For each included publication, the extraction unit was the textual passage in which feature activation after vehicle production was explained or explicitly defined. The extraction variables comprised bibliographic information, terminology and abbreviations, the relevant supporting passage, category (Definition or Explanation), defining characteristics, industry involvement, use of industry examples, and conceptual perspectives addressed by the publication.

In addition to the predefined coding categories, the extracted passages were analyzed to identify recurring defining characteristics and conceptual perspectives. Terminology, defining characteristics, and candidate conceptual perspectives were coded inductively from the extracted passages. The identified conceptual perspectives were subsequently compared and consolidated into conceptual clusters during the analysis presented in the following sections. Publications could therefore contribute to multiple clusters where their extracted evidence addressed more than one conceptual perspective. Borderline cases were retained only after consensus and were documented together with the supporting passage.

The analysis followed a hybrid coding approach. The predefined coding categories, including Definition and Explanation, were applied deductively based on the established extraction framework, whereas terminology, defining characteristics, and conceptual perspectives were identified inductively from the extracted passages. One author conducted the initial extraction and coding, and a second author independently cross-checked intermediate results, source passages, category assignments, and cluster memberships. Disagreements were resolved through structured discussion and consensus. The coding framework was iteratively refined when recurring concepts or ambiguous boundaries became visible; earlier records were revisited after such refinements to maintain consistent application. A supplementary overview of the individual cluster assignments and their underlying justifications is provided in Appendix D (Table A4), ensuring transparency and traceability of the cluster-based analysis.

5.3. Summary of Results

Figure 2 summarizes the outcome of the literature search and selection process. The initial database search yielded 1567 records (1503 with duplicates excluded), supplemented by three publications identified through manual search. After screening, 29 publications remained for the final review.

These publications were subsequently categorized based on the depth of their treatment of feature activation after vehicle production:

- Explanation: The concept is described in greater detail, often including examples.
- Definition: The publication provides an explicit definition of the concept.

Of the 29 selected publications, 20 were classified as Explanation, and 9 as Definition. Table 1 provides an overview of the selected publications. In addition to their categorization, it indicates whether a given paper demonstrates industry involvement based on the affiliations of its authors. If at least one author is affiliated with an industrial organization, the corresponding entry in the column "Industry Involvement" is marked as "Yes." Furthermore, the table identifies whether a publication substantiates its explanation or definition by referring to industry-based examples, applying the same evaluation logic.

Table 1. List of selected publications & further information.

ID	Reference	Year	Category	Industry Involvement	Industry Examples	Terminology & Abbreviations
1	[41]	2014	Explanation	No	No	Features on demand, Software-as-a-Service (SaaS)
2	[42]	2016	Explanation	No	No	Plug and Play (PnP), On-demand feature
3	[43]	2016	Explanation	No	Yes	Features on demand
4	[44] *	2017	Definition	Yes	No	Function on Demand
5	[45]	2018	Definition	Yes	No	Function on Demand
6	[46] *	2018	Explanation	Yes	No	On-demand function or service, OTA update-driven feature activation
7	[47]	2020	Definition	No	No	After-sale updates, After-sale upgrades, Over-the-Air-Updates, Function-on-Demand
8	[48]	2020	Explanation	Yes	No	Feature on Demand
9	[49]	2021	Explanation	No	No	Function on demand, On-demand functions
10	[50]	2021	Explanation	No	Yes	Over-the-air software upgrades, post-purchase customization
11	[10]	2022	Explanation	No	No	OTA upgrade, Subscription services
12	[51]	2022	Definition	No	Yes	on-demand features (ODFs)
13	[52]	2023	Explanation	Yes	Yes	-
14	[53]	2023	Explanation	Yes	No	-
15	[54]	2023	Definition	No	Yes	Functions on Demand, Preinstalled functionality as a service, After-purchase add-ons
16	[55]	2023	Definition	No	No	Internal product upgrades
17	[56]	2023	Explanation	No	Yes	Digital Add-on
18	[57]	2023	Explanation	No	No	Physical-Feature-on-Demand, Digital Features

Table 1. *Cont.*

ID	Reference	Year	Category	Industry Involvement	Industry Examples	Terminology & Abbreviations
19	[58]	2024	Explanation	No	No	Optional paid features and subscriptions
20	[59] *	2024	Definition	Yes	No	Features on demand
21	[60]	2025	Explanation	Yes	No	-
22	[61]	2025	Definition	No	No	Function-on-demand
23	[62]	2025	Explanation	No	Yes	Features on Demand, Connected technology or telematics
24	[63]	2025	Explanation	Yes	No	Feature-as-a-Service (FaaS)
25	[64]	2025	Explanation	Yes	No	-
26	[65]	2026	Explanation	Yes	No	Features-on-Demand (FoD), Software-as-a-Service (SaaS)
27	[66]	2026	Explanation	Yes	No	Features on Demand, Functions on Demand
28	[67]	2026	Definition	No	Yes	Add-on-Feature, OTA upgrades, Post-purchase upgrades, Upgradeable add-on strategy
29	[68]	2026	Explanation	Yes	No	function-on-demand, subscription-based services

* Identified through manual search.

In total, 13 of the 29 selected publications demonstrate industry involvement through their authorship. By category, industry involvement is present in 10 of 20 Explanation publications and 3 of 9 Definition publications. Industry examples occur in 8 of the 29 publications: 5 of 20 Explanation publications and 3 of 9 Definition publications provide an industry example.

The final column of Table 1 lists the terminology and abbreviations used in the respective publications to denote feature activation after vehicle production.

Figure 3 illustrates the temporal distribution of the selected publications. Although the search covered the period from 2000 onwards, no relevant publications were identified prior to 2014. Until approximately 2020, only a limited number of relevant studies were published. However, a noticeable increase in publication activity can be observed in subsequent years.

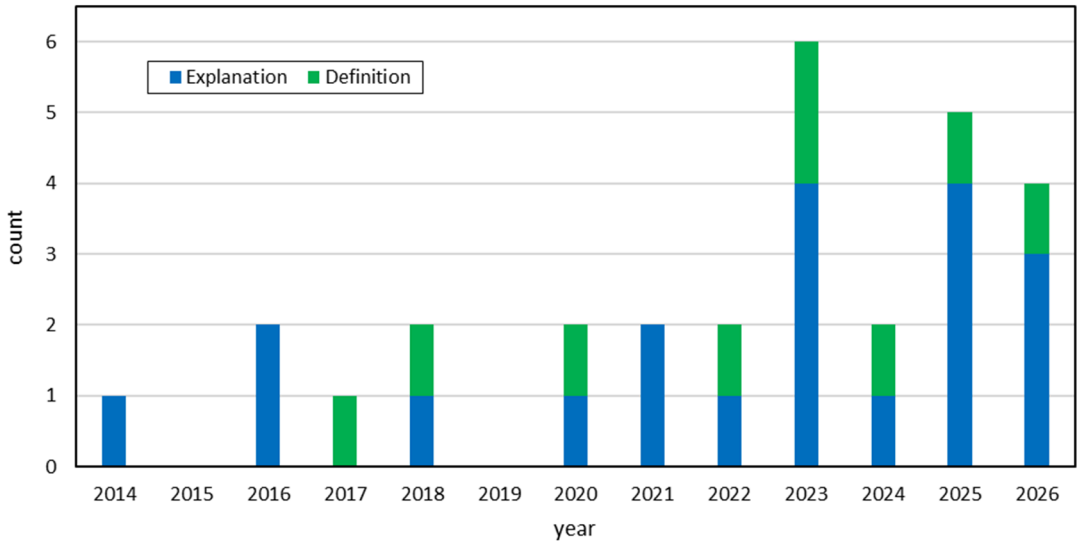


Figure 3. Distribution of selected publications by year.

This trend aligns with broader developments in the literature on SDVs, where a significant rise in academic attention has been reported starting around 2020 [12]. The increasing relevance of feature activation after vehicle production can be attributed to the emergence of SDVs and enabling technologies such as OTA mechanisms. Nevertheless, isolated earlier contributions indicate that the concept predates the SDV paradigm, albeit with more limited scope and adoption. This observation is consistent with the findings from the initial review of commercial sources, which revealed that OEMs had already begun to introduce rudimentary forms of feature activation after vehicle production prior to the widespread adoption of SDV concepts.

In summary, feature activation after vehicle production began to emerge in the mid-2010s and has gained increasing relevance in both academia and industry, driven by the ongoing digitalization and connectivity of vehicles.

5.4. Limitations

Despite the systematic design of the literature review, several limitations must be acknowledged. First, the scope of the review is constrained by the five databases selected for the search. Although these sources provide broad coverage of relevant literature across software engineering, automotive engineering, and related disciplines, relevant publications indexed exclusively in other databases may not have been captured. The use of manual search and backward and forward snowballing was intended to mitigate this risk, but cannot fully eliminate it.

Second, the completeness of the retrieved evidence depends on the terminology represented in the search string. Despite iterative refinement and the inclusion of multiple terminology variants, publications using alternative or less established terms may not have been identified. This limitation is particularly relevant to the deliberate exclusion of the term OTA update. Including this term substantially increased the number of retrieved records while reducing their specificity with respect to the research objective. To examine this effect beyond the initial search observations, a targeted sample-based assessment of the additionally retrieved literature was conducted. No additional publication relevant to the conceptualization or definition of feature activation after vehicle production was identified within the assessed sample. Further details on the procedure and results of this assessment are provided in Appendix B. Nevertheless, the thematic proximity between OTA updates and feature activation means that the possibility of relevant publications being missed by excluding OTA update cannot be completely ruled out. The exclusion therefore represents a deliberate precision–recall trade-off rather than evidence that the broader terminology is entirely irrelevant.

Third, a degree of subjectivity cannot be excluded from the full-text assessment required to determine whether a publication provides a substantive explanation or definition of feature activation after vehicle production. This applies in particular to borderline cases where the conceptual treatment is limited or where the relevant terminology is used without a clearly delimited conceptual meaning. To mitigate this risk, the screening, extraction, and classification results were independently cross-checked by two authors. Discrepancies regarding relevance, category assignment, and conceptual interpretation were resolved through structured discussion and consensus, with methodological decisions and intermediate results documented throughout the review process.

Finally, the inductive identification and consolidation of conceptual perspectives into five clusters involves an interpretive component. Although the clustering was based on the extracted passages and defining characteristics and followed an explicitly documented procedure, alternative conceptual groupings may be possible. This limitation is inherent to the synthesis of heterogeneous conceptual evidence and was addressed by retaining

non-exclusive cluster membership, documenting the underlying supporting passages, and revisiting earlier classifications when the coding framework was refined.

6. Analysis of Collected Definitions

This section addresses research question 1, which asks whether a consistent understanding of feature activation after vehicle production exists in the academic literature. To systematically answer the research question, the analysis follows an integrated approach that combines terminology, conceptual perspectives, and associated publications within a unified framework. Rather than treating these aspects separately, they are jointly analyzed through a cluster-based structure that captures the different perspectives identified in the literature.

First, Section 6.1 presents the integrated analysis framework and introduces the conceptual clusters derived from the literature. Within this framework, terminology and publications are explicitly mapped to the clusters, enabling a transparent and traceable interpretation of how the concept is used and described across studies.

Second, Section 6.2 synthesizes the findings of this integrated analysis. It consolidates the key observations regarding conceptual overlaps, terminological inconsistencies, and complementary perspectives, and provides a structured answer to research question 1.

6.1. Integrated Analysis Framework and Cluster-Based Interpretation

Figure 4 presents the result of the integrated analysis and illustrates how feature activation after vehicle production is conceptualized within the academic literature. At the center, the figure represents the overarching concept under investigation. From the extracted evidence, five conceptual clusters were derived, each capturing a recurring and conceptually distinguishable perspective: Cluster A describes feature activation after vehicle production in terms of functional variability over time, Cluster B focuses on system integration and deployment, Cluster C emphasizes OTA-enabled activation, Cluster D addresses the unlocking of preinstalled capabilities, and Cluster E frames the concept within a service-oriented software paradigm.

The cluster formation was based on the inductive analysis of the extracted passages and defining characteristics described in Section 5.2. Candidate concepts were first identified from the reviewed publications and subsequently compared across studies. Semantically overlapping concepts were consolidated where they expressed the same underlying analytical perspective. This procedure resulted in five clusters that represent the recurring conceptual perspectives identified in the evidence. No minimum frequency threshold was imposed for cluster formation. Cluster membership was non-exclusive; a publication was assigned to each cluster for which the extracted evidence provided explicit conceptual support. Accordingly, the clusters should be understood as overlapping analytical perspectives rather than mutually exclusive categories.

For each cluster, Figure 4 combines two complementary layers. The first layer represents the terminology used in the literature. Equivalent variants in capitalization, singular and plural form, and hyphenation were consolidated for analytical and visual purposes. The figure reports the normalized terminology identified in the reviewed literature and associated with each cluster to illustrate recurring terminology within the respective conceptual perspective. These terms are not exclusive to individual clusters and may occur in multiple conceptual contexts. To maintain readability, recurring terms are therefore not repeated across all clusters. The second layer maps the corresponding publications to the clusters, providing traceability between the extracted evidence, the identified conceptual perspective, and the underlying literature. The resulting mapping provides the basis for the cluster-specific interpretation presented below.

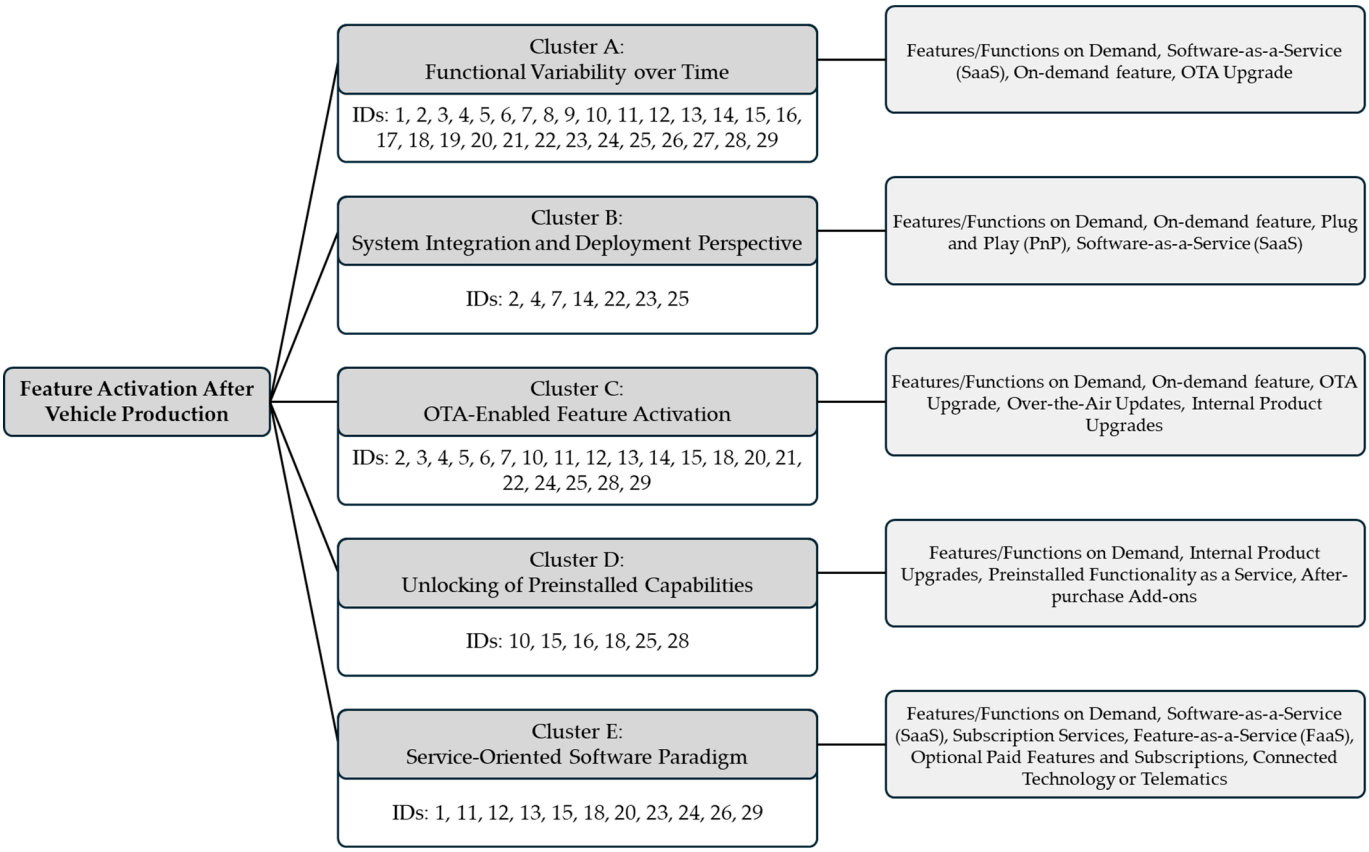


Figure 4. Integrated mapping of conceptual clusters, terminology, and associated literature related to feature activation after vehicle production (publication IDs are based on Table 1).

The individual cluster assignments and their underlying justifications are documented in Appendix D (Table A4), providing a transparent link between each publication, its assigned conceptual cluster(s), and the supporting evidence identified in the extracted passages.

Cluster A constitutes the common conceptual baseline of the reviewed literature and is represented by all 29 included publications. It captures the fundamental notion that vehicle functionality can be activated, modified, or extended after vehicle production. Recurring terminology includes functions on demand, features on demand, and on-demand feature. Across the assigned publications, feature activation after vehicle production is predominantly conceptualized as an additional dimension of functional variability that extends beyond the configuration established at the time of vehicle production or initial purchase. The associated literature emphasizes changes in vehicle functionality over time, dynamic configuration, and the possibility of modifying the functional state of a vehicle during its operational lifecycle.

Cluster B captures an engineering-oriented perspective centered on the integration and deployment of additional functionality within an existing vehicle system. The terminology includes plug and play and on-demand feature, while the corresponding publications emphasize the technical conditions under which new functionality can be introduced safely and compatibly. The associated evidence addresses aspects such as system integration, configuration compatibility, safe deployment, and the interaction between newly introduced functionality and the existing vehicle system. In this cluster, the central concern is therefore not functional variability itself, but the technical realization of such variability within an already deployed vehicle.

Cluster C focuses on the role of OTA mechanisms as an enabling means for feature activation after vehicle production. The associated terminology includes OTA upgrade, OTA update, after-sale upgrades, and OTA update-driven feature activation. The corresponding publications describe remote software distribution and activation, thereby reducing or eliminating the need for physical service intervention. The cluster demonstrates that OTA capabilities provide an important mechanism for implementing feature activation throughout the vehicle lifecycle. At the same time, the evidence indicates that OTA is an enabling mechanism rather than a defining property of the underlying concept, since feature activation after vehicle production is not conceptually restricted to OTA-based implementation.

Cluster D addresses the activation of capabilities that are already technically available within the vehicle. The associated terminology includes preinstalled functionality as a service, internal product upgrades, after-purchase add-ons, add-on-feature, and upgradeable add-on strategy. The corresponding publications describe scenarios in which hardware capabilities are already present, while access to the associated functionality is enabled or extended at a later point in the vehicle lifecycle. Some contributions additionally connect this mechanism with paid activation, subscriptions, or add-on strategies. The cluster therefore highlights the distinction between the technical availability of a capability and its actual accessibility or functional availability to the customer. At the same time, this perspective represents only a specific subset of the broader phenomenon, since it presupposes the prior availability of the required technical capabilities.

Cluster E frames feature activation after vehicle production within a broader service-oriented and commercial paradigm. The terminology includes software-as-a-service, subscription services, optional paid features and subscriptions, and feature-as-a-service. The associated publications conceptualize vehicle functionality as part of an ongoing service provision rather than solely as a fixed product characteristic determined at the time of purchase. Accordingly, the emphasis shifts towards subscription-based access, recurring or usage-related value creation, and the integration of digital service models into the vehicle lifecycle. Compared with the other clusters, this perspective places greater emphasis on the commercial and service-related implications of feature activation than on its specific technical implementation.

6.2. Synthesis and Answer to Research Question 1

The cluster-based analysis reveals that feature activation after vehicle production is not conceptualized in the literature as a clearly bounded phenomenon. Instead, the reviewed publications approach the concept from several overlapping perspectives that differ in their analytical focus, terminology, and underlying assumptions. The non-exclusive cluster assignment reflects this structure: individual publications frequently address more than one perspective, linking, for example, functional variability with OTA-based deployment, or post-purchase activation with service and subscription models.

A first key finding concerns the different dimensions through which the concept is described. Cluster A captures the functional perspective by framing feature activation as a means of introducing variability over time. Cluster B addresses the technical dimension by focusing on system integration and deployment. Cluster C identifies OTA as an enabling mechanism for remote implementation. Cluster D focuses on the relationship between technical availability and subsequent activation of preinstalled capabilities, while Cluster E places the concept within service-oriented and commercial models. These perspectives are related, but they do not describe the same conceptual dimension. Rather, they represent different ways of framing the phenomenon depending on the specific aspect considered relevant by the respective publication.

A second finding concerns the terminology used to describe these perspectives. The analysis shows substantial terminological overlap across clusters. Terms such as features on demand and functions on demand occur in publications that address different conceptual perspectives, while other contributions employ distinct terms for related approaches. Consequently, terminology cannot be used as a sufficiently reliable basis for delimiting the concept. The conceptual meaning of a term depends on the characteristics and perspective associated with its use in the respective publication. This finding is further reflected in the presence of multiple terminology variants within the reviewed literature.

A third finding concerns the distinction between the phenomenon itself and the mechanisms or models through which it is realized. The cluster analysis indicates that OTA primarily describes an enabling mechanism, whereas service-oriented concepts such as software-as-a-service, feature-as-a-service, and subscription services describe associated commercial or service models. Likewise, the activation of preinstalled capabilities represents a specific implementation or product configuration, rather than a definition of the overall phenomenon. These aspects therefore contribute to the characterization of feature activation after vehicle production, but they cannot individually be regarded as sufficient defining criteria.

The evidence must additionally be interpreted with regard to the nature and depth of the underlying contributions. Explicit definitions and detailed conceptual explanations provide stronger evidence for determining defining characteristics than brief mentions or terminology-only references. At the same time, contributions with industry involvement or commercially oriented perspectives remain relevant for illustrating how the concept is framed and applied in practice. The synthesis therefore distinguishes between evidence supporting conceptual definition and evidence that primarily demonstrates terminological breadth or application context.

Based on these findings, research question 1 can be answered as follows: the academic literature does not provide a common, unique, and consistently applied definition of feature activation after vehicle production. Instead, the concept is characterized by multiple partially overlapping conceptualizations that emphasize different dimensions, including functional variability, technical implementation, enabling mechanisms, preinstalled capabilities, and service-oriented business models.

The results indicate that a unified conceptualization therefore requires a clear separation between the defining characteristics of the phenomenon and the mechanisms, implementation conditions, and commercial models associated with it. In particular, the analysis suggests that neither specific terminology, OTA deployment, preinstallation, nor a particular commercial model is sufficient to define the concept on its own. The identified conceptual perspectives and their underlying characteristics consequently provide the analytical basis for deriving a consolidated definition in Section 7.

7. Definition for Feature Activation After Vehicle Production

Findings from the systematic literature review and the initial review of commercial automotive industry sources revealed substantial conceptual and terminological fragmentation across academia and industry. Existing literature does not provide a unique and consistently applied understanding of feature activation after vehicle production. Consequently, a consolidated conceptual model is required that integrates the identified perspectives while establishing clear boundaries regarding scope and terminology.

Building upon these findings, this section addresses research question 2 by deriving a consolidated definition of feature activation mechanisms after vehicle production in the context of automotive ECU software parameterization and by positioning this definition within the broader SDV concept.

To achieve this objective, a hierarchical conceptualization is developed that combines insights from the systematic literature review with the previously introduced background concepts and the authors' practical experience in the relevant domain. The resulting model distinguishes between different forms of vehicle evolution after production and systematically positions feature activation within this broader conceptual context.

7.1. Conceptual Structure of Vehicle Lifecycle Upgrades

Vehicle functionality can continue to evolve beyond the point of vehicle production and initial delivery to the customer. Such modifications extend, enhance, or alter the capabilities of a vehicle throughout its operational lifecycle and can therefore be summarized under the broader concept of vehicle lifecycle upgrades.

Vehicle lifecycle upgrades refer to product enhancements introduced after the completion of vehicle manufacturing. As illustrated in Figure 5, two fundamentally distinct categories can be differentiated based on whether the technical capability required for the upgrade is already available within the vehicle or whether additional physical components must first be introduced. This distinction gives rise to the concepts of internal vehicle upgrades and external vehicle upgrades.

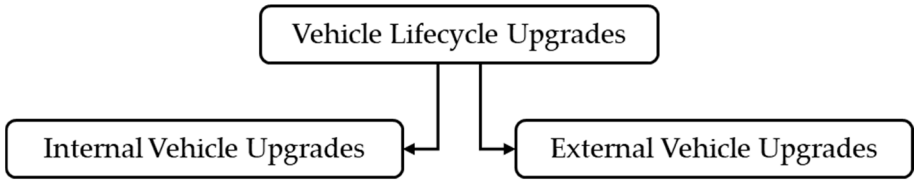


Figure 5. Vehicle lifecycle upgrades, divided into internal and external vehicle upgrades.

The resulting taxonomy is proposed as an author synthesis grounded in the systematic literature review rather than as a definition directly stated by any single source. The literature supports several recurring aspects of feature activation after vehicle production, including the temporal extension of functionality, software-based deployment and configuration, OTA as an enabling mechanism, the activation of preinstalled capabilities, and service-oriented commercialization. The concept of an internal vehicle upgrade consolidates these findings around the activation or extension of functionality based on technical capabilities already available within the vehicle. In contrast, the external vehicle upgrade category is introduced by the authors as an additional delimiting concept to define the boundary of software-based activation where new physical capability must first be installed.

Hardware availability is selected as the primary classification axis because it distinguishes upgrades that can be realized through software-based mechanisms from those that require physical modification of the vehicle and associated service intervention. Alternative axes, including the delivery mechanism, payment model, or preinstallation state, are not retained as primary classification criteria because the review indicates that these aspects describe implementation or commercialization variants that may occur within the same technical category. Contradictory and overlapping uses of the underlying terms are retained in the cluster analysis and resolved at the synthesis level through this explicit boundary definition.

This distinction is relevant from both a customer and an OEM perspective. If an upgrade requires the integration of additional physical components after the vehicle has left the production environment, realization typically depends on a physical service intervention. In such cases, the vehicle must be brought to an authorized workshop where the required hardware modifications are performed by trained personnel. Consequently, access

to such upgrades is inherently linked to physical infrastructure, service availability, and logistical effort.

In contrast, if the required technical capability is already present within the vehicle, the upgrade can generally be realized without physical intervention. In this case, the modification primarily depends on software-related mechanisms, such as configuration changes, parameter adjustments, or software deployment. Especially in the context of SDVs, such upgrades can increasingly be performed remotely and independently of the vehicle's location, for example through OTA mechanisms.

Accordingly, the accessibility and implementation effort of vehicle lifecycle upgrades differ fundamentally between the two categories. This distinction also implies different organizational and technical requirements for OEMs, as hardware-based upgrades require physical service infrastructure, whereas software-based upgrades rely on digital platforms, software management processes, and corresponding vehicle architectures.

7.1.1. Internal Vehicle Upgrades

Internal vehicle upgrades describe enhancements after vehicle production, in which the required technical capabilities are already available within the vehicle's existing hardware configuration. They include concepts commonly described in the literature as features on demand (FoD).

In the context of internal vehicle upgrades, the necessary hardware capabilities must already be available within the vehicle architecture. However, the corresponding software functionality does not necessarily need to be active or even present at the time of vehicle purchase. Functionalities can either be preinstalled but deliberately deactivated or introduced at a later point in the vehicle lifecycle through software deployment mechanisms, such as OTA. Once available within the vehicle software ecosystem, such functionalities can subsequently be activated based on customer demand.

Internal vehicle upgrades are therefore realized through software-based modification mechanisms rather than through physical intervention. The activation process typically involves changes to ECU software configuration states, parameter values, feature flags, access permissions, or comparable software artifacts that influence the behavior of the vehicle system. Consequently, internal vehicle upgrades are fundamentally dependent on software configurability and parameterization capabilities within the underlying E/E architecture.

A defining characteristic of internal vehicle upgrades is that they decouple the point in time of vehicle production from the point in time at which a functionality becomes available to the customer. Features can be activated after vehicle delivery at any stage of the operational lifecycle, provided that the required technical prerequisites are fulfilled. Due to their software-based nature, such activations can typically be performed remotely through OTA capabilities without requiring a physical visit to a workshop.

Furthermore, internal vehicle upgrades enable flexible commercial models. Depending on the OEM strategy, features may be activated permanently through a one-time purchase, provided for a predefined period, offered through subscription-based models, or linked to usage-dependent pricing schemes. OEMs may also provide trial periods that allow customers to evaluate a functionality before committing to a purchase. In addition, activation possibilities can remain available across ownership changes, as the availability of a feature primarily depends on the vehicle configuration and the associated commercial conditions rather than on the original purchaser.

Nevertheless, internal vehicle upgrades remain constrained by the physical capabilities of the vehicle. Only functionalities that can be technically realized by the existing hardware configuration can be activated. The software ecosystem therefore determines which func-

tions can be made available, while the hardware configuration defines the fundamental boundaries of possible feature activation.

This hardware-based classification also determines the scope of the examples presented in Table 2. The examples are intended to illustrate application groups that can constitute internal vehicle upgrades when the required technical capabilities are already available within the specific vehicle configuration.

Table 2. Examples of internal vehicle upgrades enabled through software-based activation.

Advanced Driver Assistance Systems (ADAS): – Adaptive cruise control (ACC) – Highway assist/traffic jam assist – Automated lane change – Advanced parking assistance – Extended driver monitoring functionalities	**Comfort and Convenience Functions:** – Seat heating – Steering wheel heating – Ventilated seats – Additional seat adjustment functions – Ambient lighting extensions
Performance and Driving Dynamics Functions: – Adaptive suspension settings – Driving mode extensions – Performance optimization packages – Steering or drivetrain-related feature extensions	**Lighting Functions:** – Matrix LED or digital matrix headlights – Adaptive lighting functions – Extended illumination patterns
Infotainment and Connectivity Functions: – Smartphone integration functionalities (e.g., Apple CarPlay or Android Auto) – Extended navigation functionalities – Additional multimedia capabilities – Enhanced connectivity features	

The examples in Table 2 are illustrative application groups derived from the authors' multi-year industrial experience with ECU software parameterization, vehicle-function activation, and hardware retrofits at an automotive OEM, as well as from functions observable in OEM configurators and aftersales practice. They are not intended to imply that every listed functionality can be activated in every vehicle or vehicle configuration. Rather, they illustrate the type of functionality that falls within the proposed internal vehicle upgrade category when the corresponding technical prerequisites are already available. Technical feasibility alone does not establish safety approval, homologation, cybersecurity authorization, legal permissibility, regional availability, or commercial availability; these aspects remain dependent on the specific vehicle, the responsible OEM, and the applicable requirements.

A distinction from cloud-based services is required. Cloud-based applications themselves do not inherently constitute internal vehicle upgrades, as they may operate independently of vehicle-side software configuration. Services such as online applications, digital subscriptions, or remote services can therefore exist without modifying the vehicle software state. However, if access to such functionality is controlled through vehicle-side software configuration mechanisms, parameterization, or feature activation logic, the activation process falls within the scope of internal vehicle upgrades.

7.1.2. External Vehicle Upgrades

External vehicle upgrades differ fundamentally from internal vehicle upgrades because the required technical capability is not already available within the vehicle system. Instead, the desired functionality is introduced through the physical integration of additional hardware components after vehicle delivery.

External vehicle upgrades therefore describe extensions of the vehicle's physical configuration after production. Unlike internal vehicle upgrades, their realization requires mechanical or electrical intervention and is typically dependent on physical service infras-

tructure. In most cases, the vehicle must be brought to an authorized workshop, where additional components are installed, integrated, configured, and validated by trained personnel.

Typical examples of external vehicle upgrades across different vehicle domains are summarized in Table 3. They illustrate application groups in which additional physical capabilities are introduced into the vehicle after production and therefore fall within the external vehicle upgrade category according to the proposed classification criterion.

Table 3. Examples of external vehicle upgrades requiring physical vehicle modifications.

Interior and Comfort Hardware: – Replacement or upgrade of seats – Installation of electrically adjustable seats – Seat ventilation hardware – Interior trim modifications	**Sensors and Perception Systems:** – Additional cameras – Additional ultrasonic sensors – Radar sensors – Lidar-related hardware components
Driver Controls and Interfaces: – Replacement steering wheels – Additional control elements – Modified human–machine interfaces	**Lighting and Exterior Components:** – Upgraded lighting systems – Additional exterior lighting modules – Different headlamp configurations
Vehicle Utility and Mechanical Components: – Trailer hitches – Roof systems – Exterior attachments – Additional storage or transport solutions	

As for Table 2, the examples in Table 3 are illustrative application groups based on the authors' industrial experience, OEM configuration and aftersales practice. Their classification does not imply that the respective modification is available for every vehicle or that it can be implemented under all technical, regulatory, safety, cybersecurity, regional, or commercial conditions.

The common characteristic of external vehicle upgrades is that the physical capability required to realize the desired functionality is introduced only after vehicle production has been completed.

Such hardware modifications frequently require corresponding software adaptations to ensure system integrity, functional correctness, and compatibility with the existing vehicle architecture. For purely mechanical modifications, software changes may only become necessary if the modification affects the behavior of vehicle functions or interacts with software-controlled systems. For example, replacing interior components may require adjustments to software parameters if the changed component affects sensor behavior, thermal characteristics, occupant detection, or lighting control strategies.

In contrast, modifications involving mechatronic components generally require mandatory software adaptation. The corresponding ECU software must be reconfigured, recalibrated, or reparametrized to integrate the newly installed component into the vehicle system. Without appropriate software adaptation, the introduced hardware may not operate as intended or may not be accessible by the vehicle control architecture.

For example, after installing a different steering wheel, the relevant ECU configuration must correctly map button inputs to their intended functions. Otherwise, user interactions may trigger unintended system behavior. Similarly, after adding a trailer hitch, corresponding control functions, safety conditions, and vehicle-specific parameters must be enabled and configured within the vehicle software environment.

Importantly, software adaptations required to integrate new hardware must not be confused with feature activation itself. The purpose of such adaptations is to ensure that

the newly installed hardware operates correctly within the existing vehicle architecture. They do not necessarily introduce new customer-facing functionalities.

For example, installing additional cameras may require software modifications to enable image transmission and integration into the infotainment system. However, advanced functionalities enabled by these cameras, such as automated parking assistance or enhanced driver assistance capabilities, represent separate vehicle features that may subsequently become available as internal vehicle upgrades.

Consequently, external vehicle upgrades can expand the technical basis for future internal vehicle upgrades by increasing the available hardware capabilities of the vehicle. However, the reverse relationship does not apply, as software activation alone cannot create hardware capabilities that are physically absent.

7.2. Consolidated Definitions

Based on the preceding analysis, the following concise definitions are derived.

Vehicle Lifecycle Upgrade

A vehicle lifecycle upgrade describes any modification or enhancement introduced after production that extends a vehicle's capabilities during its operational lifecycle. Depending on whether the required technical capability is already available within the vehicle architecture or requires the introduction of additional physical components, vehicle lifecycle upgrades can be distinguished into internal and external vehicle upgrades.

Internal Vehicle Upgrade

An internal vehicle upgrade introduced after production is an activation or extension of vehicle functionality based on technical capabilities already available within the vehicle's existing hardware configuration. Such upgrades are realized through software-based mechanisms, including software configuration, calibration, parameterization, or software deployment, without requiring physical modification of the vehicle.

External Vehicle Upgrade

An external vehicle upgrade is an extension of vehicle capabilities introduced after production through the integration of additional physical components that were not part of the original vehicle configuration and introduce previously unavailable technical capabilities. Such upgrades may require corresponding software configuration, calibration, or parameterization to ensure correct integration and operation within the vehicle system.

7.3. Positioning of Vehicle Lifecycle Upgrades Within the SDV Concept

The derived conceptualization of vehicle lifecycle upgrades must be considered within the broader transformation toward SDVs. The SDV paradigm does not represent a single technology or isolated innovation; rather, it constitutes an interplay of technological, architectural, and organizational developments that fundamentally changes how vehicles are developed, operated, and evolved throughout their lifecycle.

A central characteristic of SDVs is the transition from a product-oriented development perspective toward a lifecycle-oriented evolution paradigm. In conventional vehicle development processes, the majority of engineering activities are completed before the start of production, and the functional scope of a vehicle is largely determined during the manufacturing process. Consequently, the delivered vehicle represents a predefined product configuration that can only be modified to a limited extent through subsequent physical interventions.

In contrast, SDVs extend the evolution horizon of the vehicle beyond production and initial delivery. The development, refinement, and extension of vehicle functionalities

increasingly continue throughout the entire operational lifecycle until the end of life of the vehicle. This continuous evolution is enabled by multiple technological foundations, including software-centric E/E architectures, centralized computing platforms, vehicle connectivity, digital ecosystems, and OTA capabilities.

Within this context, vehicle lifecycle upgrades represent a direct manifestation of the SDV paradigm. As vehicle functionality is increasingly realized through software, the functional scope of a vehicle is no longer exclusively determined by its original production configuration. Instead, vehicle capabilities can be continuously extended, adapted, and enhanced after delivery. However, the extent to which such lifecycle-based evolution can be realized depends fundamentally on whether the required technical capability is already available within the vehicle system or whether additional physical components must be introduced.

Accordingly, the distinction between external and internal vehicle upgrades represents a fundamental differentiation within the SDV concept. External vehicle upgrades require the physical integration of additional components that were not part of the original vehicle configuration. Consequently, their realization remains dependent on physical service infrastructure and cannot be fully decoupled from the vehicle location. Although corresponding software adaptations, such as ECU reconfiguration, calibration, or parameter adjustment, may be necessary to integrate newly introduced components into the vehicle system, the underlying upgrade process remains hardware-driven.

Internal vehicle upgrades, in contrast, represent a characteristic SDV-enabled mechanism for lifecycle-based vehicle evolution. Since the required hardware capabilities are already available within the vehicle architecture and the functionality is realized through software configuration, activation can increasingly be performed independently of physical service locations. OTA capabilities provide the necessary distribution and deployment infrastructure, enabling software configurations, feature states, parameter values, or additional software functionality to be modified remotely. Therefore, internal vehicle upgrades establish a direct link between software-defined architectures, vehicle connectivity, and customer-driven functional evolution.

This distinction also fundamentally changes the role of the customer within the vehicle lifecycle. In traditional vehicle ownership models, customers primarily influence the configuration of their vehicle at the point of purchase. Subsequent modifications are typically initiated and executed through service workshops and therefore depend on external intervention. SDVs introduce a more dynamic interaction model in which customers can actively influence the evolution of their vehicle after delivery. Especially in the context of internal vehicle upgrades, customers can determine when and where a functionality should be activated without requiring physical interaction with the OEM or service workshop.

However, this increased flexibility does not imply that control over vehicle evolution is fully transferred to the customer. Instead, OEMs continue to define the boundaries of possible customization. They determine which functionalities are technically supported, which hardware configurations enable specific features, which software capabilities are available, and under which commercial conditions these capabilities can be activated. Consequently, internal vehicle upgrades represent a controlled form of customer-driven vehicle personalization within an OEM-defined technological and commercial framework.

From an OEM perspective, this capability introduces a fundamental change in the vehicle value proposition. Traditionally, value creation has primarily been associated with vehicle sales, maintenance, and physical modifications performed after purchase. SDV-enabled internal vehicle upgrades extend this model by enabling continuous value generation throughout the vehicle lifecycle. OEMs can provide additional functionalities through various commercial models, including one-time purchases, subscription-based

access, temporary activation periods, or usage-dependent pricing schemes. This creates new opportunities for lifecycle-based revenue generation while simultaneously increasing customer flexibility.

Therefore, vehicle lifecycle upgrades can be understood as a direct manifestation of the SDV paradigm, enabling the continuous evolution of vehicle capabilities beyond the point of production. In particular, internal vehicle upgrades represent a software-enabled mechanism that leverages configurable vehicle architectures, connectivity, and OTA-based deployment to activate or extend functionalities throughout the operational lifecycle. Figure 6 summarizes the positioning of vehicle lifecycle upgrades within the SDV concept by illustrating the relationship between the underlying SDV foundations, the resulting lifecycle evolution capability, and the distinction between internal and external vehicle upgrades.

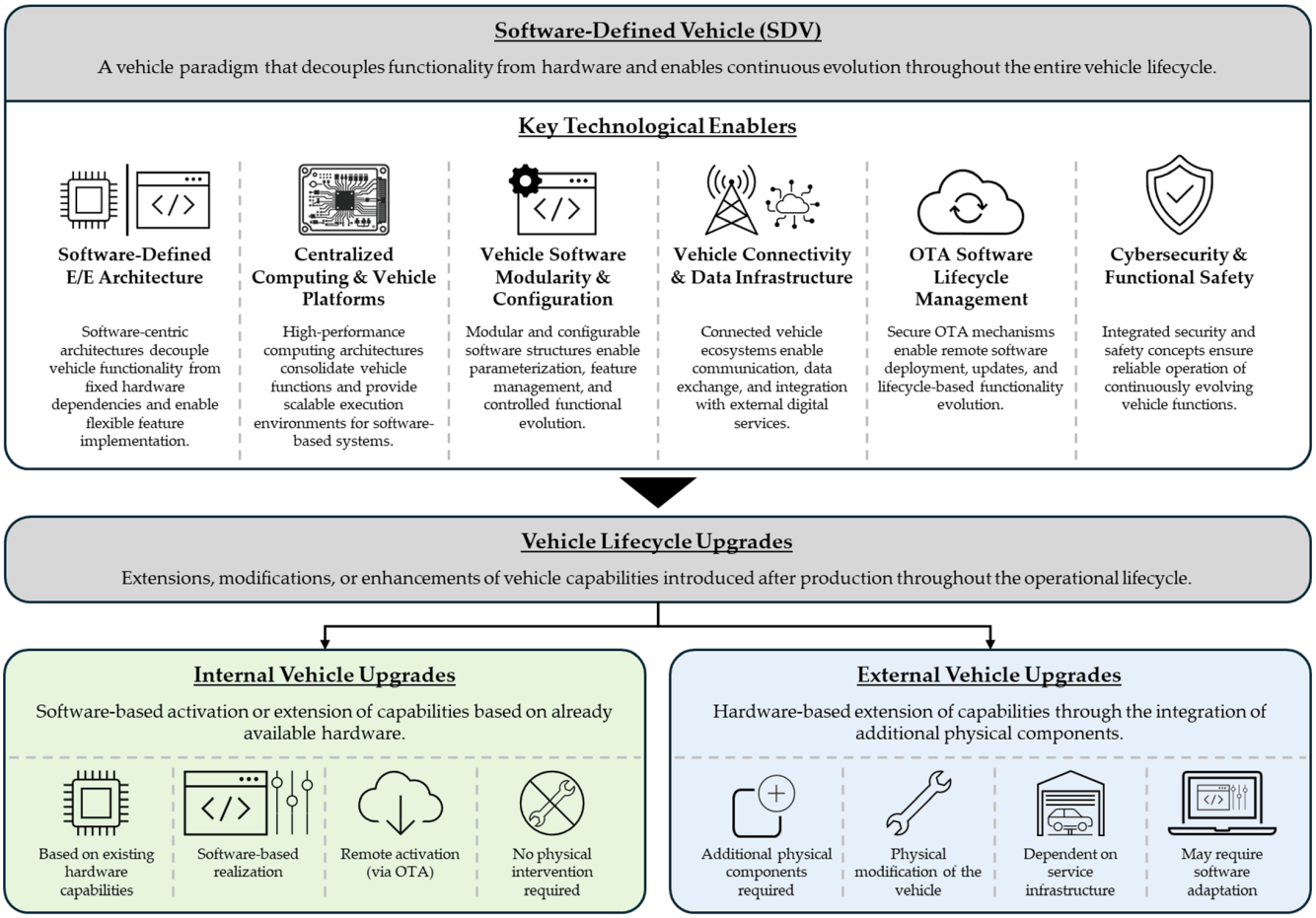


Figure 6. Relationship between SDV key technological enablers and vehicle lifecycle upgrades.

8. Discussion and Conclusions

The systematic literature review demonstrates that, within the body of literature identified through the applied search strategy, feature activation after vehicle production is not conceptualized as a clearly bounded or consistently defined phenomenon. Instead, the literature reflects multiple partially overlapping perspectives, represented by the identified conceptual clusters. These perspectives emphasize different aspects of the same underlying transformation, ranging from functional variability and software realization to enabling infrastructures and service-oriented business models. The observed fragmentation therefore reflects less a lack of research maturity than the absence of a shared conceptual foundation.

A central finding of this work is that existing studies frequently conflate the core concept with its enabling technologies or commercial implementations. OTA capabilities, for example, are often presented as an inherent characteristic of feature activation, although they merely provide a deployment mechanism. Likewise, subscription models, preinstalled functionality, or service-oriented offerings represent specific realization or monetization strategies rather than defining characteristics of the concept itself. In addition, the inconsistent use of terms such as features on demand, functions on demand, or similar expressions further limits comparability across studies and hinders cumulative knowledge building.

To address this ambiguity, this paper introduces vehicle lifecycle upgrades as the overarching concept for modifications introduced after vehicle production and distinguishes between internal and external vehicle upgrades based on the availability of the required technical capability within the vehicle architecture. Internal vehicle upgrades describe software-based activation or extension of functionality using existing hardware capabilities, whereas external vehicle upgrades require the physical integration of additional components. This distinction clarifies that software-based feature activation and hardware-based vehicle extensions are fundamentally different lifecycle evolution mechanisms with different technical prerequisites.

The proposed conceptual framework also positions vehicle lifecycle upgrades within the broader SDV paradigm. SDVs fundamentally shift vehicle evolution from a production-centric to a lifecycle-oriented perspective, enabling functionality to evolve continuously beyond initial delivery. In this context, internal vehicle upgrades represent a characteristic SDV-enabled mechanism that combines configurable software, connectivity, and OTA deployment to realize customer-driven vehicle evolution. At the same time, the framework highlights that the scope of such evolution ultimately remains constrained by the integrated hardware capabilities.

Consequently, the primary contribution of this work is not the introduction of another industry term, but the proposal of a unified conceptual framework that separates the phenomenon itself from its technical realization and commercial exploitation. This provides a consistent basis for classifying existing approaches, guiding future research, comparing SDV-enabled lifecycle evolution strategies, and positioning feature activation within the broader context of SDVs.

Several limitations should nevertheless be acknowledged. First, the systematic literature review depends on the selected databases and search strategy, and publications using alternative terminology may not have been identified. Second, the clustering and interpretation of concepts involve qualitative assessment and may therefore allow alternative classifications. Finally, the proposed definitions were derived for the automotive domain and may require adaptation before being transferred to other software-intensive industries. Further validation in an industrial context is required to assess the applicability of the proposed conceptual framework and to examine whether the defined categories and boundaries adequately reflect practical vehicle development and lifecycle management processes.

In addition, the qualitative synthesis was consensus-based and no inter-rater agreement statistic was calculated. Although the extracted evidence and coding decisions are reported to improve auditability, the assessment of conceptual similarity and cluster boundaries remains interpretive. The evidence base also combines publications with different roles, including explicit definitions, technical explanations, and industry-oriented contributions; these source types were therefore distinguished in the synthesis rather than combined into a single quantitative quality score.

Future research should further investigate the technical realization of lifecycle-based vehicle evolution, particularly the relationship between traditional ECU software parameterization and software-based vehicle lifecycle upgrades. While both approaches modify

SDV behavior, they currently follow different engineering processes and lifecycle contexts. A better understanding of these relationships could support the development of more integrated approaches to vehicle software configuration across the entire vehicle lifecycle and represents a promising direction for future SDV research.

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Data Availability Statement: The data supporting the findings of this study are provided in the manuscript and its appendices, including the review documentation, cluster assignments and their justifications, and the targeted assessment of the search strategy. Longer source passages may be provided upon request, subject to applicable copyright restrictions. The cited publications remain the authoritative sources for full-text verification.

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Abbreviations

The following abbreviations are used in this manuscript:

ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
EC	Exclusion Criteria
E/E	Electrical/Electronic
ECU	Electronic Control Unit
FaaS	Feature-as-a-Service
FoD	Feature(s) on Demand/Function(s) on Demand
IC	Inclusion Criteria
IoT	Internet of Things
OEM	Original Equipment Manufacturer
OTA	Over-the-Air
PnP	Plug and Play
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RQ	Research Question
SaaS	Software-as-a-Service
SDV	Software-Defined Vehicle
V2X	Vehicle-to-Everything

Appendix A. PRISMA 2020 Checklist

The following Table A1 provides the PRISMA 2020 checklist and indicates where each item is addressed in the manuscript.

Table A1. PRISMA 2020 checklist.

Item	Item Description	Section(s) Where Addressed
1	Title	Not applicable [1]
2	Abstract	Abstract
3	Rationale	Sections 1 and 3
4	Objective	Section 1
5	Eligibility criteria	Section 5.2
6	Information sources	Section 5.1
7	Search strategy	Sections 5, 5.1 and 5.2
8	Selection process	Section 5
9	Data collection process	Sections 4 and 5
10	Data items	Section 5.3
11	Study risk of bias assessment	Not applicable
12	Effect measures	Not applicable
13	Synthesis methods	Sections 5.3 and 6
14	Reporting bias assessment	Not applicable
15	Certainty assessment	Not applicable
16	Study selection	Section 5.1
17	Study characteristics	Section 5.3
18	Risk of bias in studies	Not applicable
19	Results of individual studies	Sections 5.3 and 6
20	Results of syntheses	Sections 5.3 and 6
21	Reporting biases	Not applicable
22	Certainty of evidence	Not applicable
23	Discussion	Sections 5.4, 6.2 and 8
24	Registration and protocol	Section 5
25	Support	Funding
26	Competing interests	Conflicts of Interest
27	Availability of data, code and other materials	Data Availability Statement

[1] Deviation statement: The manuscript extends beyond the systematic review by developing, defining, and positioning the concept of vehicle lifecycle upgrades within the SDV context in Section 7; therefore, the title does not identify the paper solely as a systematic review.

Appendix B. Targeted Sample-Based Assessment of the Exclusion of "OTA Update"

To assess the potential effect of excluding the term OTA update from the final search string, a targeted sample-based assessment was conducted. The assessment was designed to examine whether the inclusion of terminology explicitly referring to OTA updates could identify additional publications relevant to the conceptualization or definition of feature activation after vehicle production.

The assessment employed a three-component search structure. The first component comprised terminology explicitly associated with OTA updates and related update concepts: ("on demand update" OR "on-demand update" OR "ota update" OR "over the air update" OR "over-the-air update").

The second component excluded the terminology used in the original search strategy in order to focus the assessment on publications that could potentially be identified through OTA-update-related terminology but not through the terminology of the original search string. The third component restricted the retrieved publications to the automotive domain to maintain consistency with the scope of the systematic literature review.

The resulting search string used for the sample-based assessment was:

("on demand update" OR "on-demand update" OR "ota update" OR "over the air update" OR "over-the-air update")

AND NOT

("function on demand" OR "functions on demand" OR "function-on-demand" OR "functions-on-demand" OR "feature on demand" OR "features on demand" OR "feature-on-demand" OR "features-on-demand" OR "on demand function" OR "on-demand function" OR "on demand feature" OR "on-demand feature" OR "on demand upgrade" OR "on-demand upgrade"
OR "ota upgrade" OR "over the air upgrade" OR "over-the-air upgrade" OR "ota software upgrade" OR "over the air software upgrade" OR "over-the-air software upgrade"
OR "software-enabled function" OR "software-enabled feature" OR "software-based function" OR "software-based feature"
OR "ota activation" OR "over the air activation" OR "over-the-air activation"
OR "ota feature" OR "over the air feature" OR "over-the-air feature"
OR "ota function" OR "over the air function" OR "over-the-air function"
OR "remote activation" OR "remote feature" OR "remote function"
OR "feature activation after" OR "function activation after" OR "post-production feature activation" OR "post-production function activation" OR "post-purchase feature activation" OR "post-purchase function activation" OR "post-sale feature activation" OR "post-sale function activation")

AND

("automotive" OR "vehicle" OR "car" OR "SDV")

Because the search interfaces differ between databases, the search was operationalized using database-specific settings. The respective search fields, filters, and sorting options are documented in Table A2.

The assessed sample comprised the first 50 retrieved records from the three databases—IEEE Xplore, ACM Digital Library, and Scopus—with the results sorted by relevance. Accordingly, a total of 150 records were assessed. The assessment focused on the thematic relevance of the retrieved publications to the research objective, namely whether they provided a definition, conceptualization, or substantive explanation of feature activation after vehicle production.

No additional publications were identified that would have fulfilled the inclusion criteria of the systematic literature review. Nevertheless, the assessment identified publications that were also retrieved through the original search strategy and subsequently included in the review [53]. This overlap indicates that OTA-update-related terminology can retrieve publications relevant to the review, while the assessed sample did not reveal any additional included publications that were not already captured by the original search strategy.

The results of this assessment support the decision to exclude OTA update from the final search string in order to maintain search specificity. However, the sample-based assessment cannot demonstrate that no relevant publication exists outside the assessed sample. Given the close conceptual relationship between OTA updates and feature activation, the possibility that relevant publications using OTA-update terminology were not captured by the final search strategy cannot be completely excluded.

Table A2. Database-specific search settings for the targeted sample-based assessment.

Database	Results	Date	Search Settings
IEEE Xplore	424	21 September 2026	Search in: Full Text & Metadata Publication Year: From 2000 to 2026 Show: Subscribed Content including Open Access content
ACM Digital Library	181	21 September 2026	Search items from: The ACM Guide to Computing Literature Search Within: Anywhere Publication Date: 2000–2026
Springer Nature Link	212	21 September 2026	Search by keyword: the search string Date published: 2000–2026 Languages: English Disciplines: Engineering; Computer science; Business and management; Economics; Science, humanities and social sciences, multidisciplinary
Web of Science	18	21 September 2026	Search in: Web of Science Core Collection Editions: All All Fields Languages: English
Scopus	854	21 September 2026	Search within: All fields Year Range: 2000–2027 Language: English Publication stage: Final Subject area: Engineering; Computer Science; Decision Science; Business, Management and Accounting; Multidisciplinary; Economics, Econometrics and Finance

Appendix C. Database-Specific Search Settings

To ensure the transparency and reproducibility of the systematic literature review, the search strategy was operationalized according to the respective search interfaces of the five selected databases. Table A3 documents the database-specific search settings used for the literature search, including the applied search fields. The table complements the general search strategy described in Section 5.1 by providing the database-specific implementation details for each source.

Table A3. Database-specific search settings used for the systematic literature review.

Database	Results	Date	Search Settings
IEEE Xplore	497	14 September 2026	Search in: Full Text & Metadata Publication Year: From 2000 to 2026 Show: Subscribed Content including Open Access content
ACM Digital Library	287	14 September 2026	Search items from: The ACM Guide to Computing Literature Search Within: Anywhere Publication Date: 2000–2026
Springer Nature Link	304	14 September 2026	Search by keyword: the search string Date published: 2000–2026 Languages: English Disciplines: Engineering; Computer science; Business and management; Economics; Science, humanities and social sciences, multidisciplinary
Web of Science	9	14 September 2026	Search in: Web of Science Core Collection Editions: All All Fields Languages: English

Table A3. *Cont.*

Database	Results	Date	Search Settings
Scopus	470	14 September 2026	Search within: All fields Year Range: 2000–2027 Language: English Publication stage: Final Subject area: Engineering; Computer Science; Decision Science; Business, Management and Accounting; Multidisciplinary; Economics, Econometrics and Finance

Appendix D. Justification of Cluster Assignment

This appendix provides the detailed justification for the assignment of the reviewed publications to the conceptual clusters described in Section 6.1. For each publication, the assigned cluster(s) and the corresponding rationale are reported based on the conceptual content identified in the extracted passages. As cluster membership is non-exclusive, a publication may be assigned to multiple clusters where its evidence supports more than one conceptual perspective. Table A4 therefore documents the basis for the individual assignments and provides additional transparency and traceability for the cluster-based analysis.

Table A4. Publication cluster assignments and justifications (publication IDs are based on Table 1).

ID	Clusters	Justification for Cluster Assignment
1	A, E	The paper describes the dynamic activation and deactivation of vehicle features and explicitly frames this concept in the context of Software-as-a-Service (SaaS). It therefore addresses both functional variability over time and a service-oriented software model.
2	A, B, C	The paper discusses on-demand safety features as functionality that can be introduced dynamically. It further addresses remote feature requests and downloading from the cloud, while focusing on the safe deployment of features and their interaction with the existing vehicle system.
3	A, C	The paper describes vehicles that can be configured after delivery, including the subsequent download and activation of functionality. This represents functional variability over the vehicle lifecycle and remote deployment of features.
4	A, B, C	Function on Demand is described as a means of extending or adapting vehicle functionality. The paper addresses ECU-based activation and configuration mechanisms as well as dynamic and remote activation in the field without requiring a workshop intervention.
5	A, C	The paper discusses the subsequent purchase and download of additional software functions, enabling the vehicle to be continuously adapted to changing user requirements. This represents lifecycle-based functional extension enabled through remote software delivery.
6	A, C	The paper describes the activation of additional functions after vehicle delivery and explicitly addresses OTA update-driven feature activation. It therefore combines lifecycle-based functional extension with OTA-enabled deployment.
7	A, B, C	The paper addresses after-sale upgrades and Function-on-Demand in combination with Over-the-Air Updates. Its main technical focus is the compatibility of different vehicle configurations when new functionality is introduced into an existing vehicle system.
8	A	The paper describes the subsequent purchase of new ECU features as Feature on Demand. The relevant passage supports a lifecycle-based extension of vehicle functionality but does not provide sufficient evidence for an explicit OTA, system-integration, or service-oriented perspective.

Table A4. *Cont.*

ID	Clusters	Justification for Cluster Assignment
9	A	The paper explicitly discusses function on demand and OTA in the context of increasing numbers of variants and configurations over time. The central perspective is therefore the increasing dynamism of vehicle configuration after production.
10	A, C, D	The paper discusses post-purchase customization and the introduction of new functions after purchase, including explicit over-the-air software upgrades. It further describes premium functions for which the required hardware is already available and which are subsequently enabled through software.
11	A, C, E	The paper describes the continuous provision of new software and functions after vehicle delivery, with OTA upgrades serving as the enabling mechanism. It additionally discusses subscription services and new revenue models, linking lifecycle-based functionality with service-oriented business models.
12	A, C, E	The paper defines on-demand features (ODFs) as additional functionalities made available after purchase, including time-limited access. It discusses over-the-air updates as an enabling mechanism and explicitly relates ODFs to servitization, the sharing economy, and recurring revenues.
13	A, C, E	The paper addresses the subsequent extension of vehicle functionality through remote configuration and OTA. It additionally discusses subscription-based and time-limited features as well as new business models, thereby connecting lifecycle functionality with service-oriented approaches.
14	A, B, C	The paper describes the installation of new features after vehicle delivery using OTA. Its main focus is the technical infrastructure required for secure OTA software deployment, linking lifecycle-based feature extension with system deployment and integration.
15	A, C, D, E	The paper explicitly addresses Functions on Demand and Preinstalled functionality as a service, including after-purchase add-ons and over-the-internet enablement. Functionality is already installed or supported by the existing hardware and is subsequently unlocked, while the paper also adopts a clear subscription and as-a-service perspective.
16	A, D	The paper explicitly defines internal product upgrades as the subsequent activation of originally built-in but deliberately restricted optional features. The focus is therefore on lifecycle-based functional extension through the unlocking of already available capabilities.
17	A	The paper discusses the dynamic configuration of digital features after product deployment and digital add-ons. The relevant passage supports a perspective of functional variability over time, but does not provide sufficient explicit evidence for OTA-based activation or preinstalled capabilities.
18	A, C, D, E	The paper describes features that are activated after purchase, including seat-heating-on-demand, where the required functionality is already available in the vehicle. Activation takes place through the vehicle app and is associated with subscription, micropayment, and feature-as-a-service models.
19	A	The paper describes on-demand feature activation as introducing an additional dimension of variability over time. Different software states of the same ECU result from the activation or deactivation of software modules, directly supporting the perspective of functional variability over time.
20	A, C, E	The paper describes functions that can be installed after purchase or switched on and off in real time. OTA and connectivity enable this functionality, while time- or usage-dependent payment and digital services introduce a service-oriented and business-model perspective.

Table A4. *Cont.*

ID	Clusters	Justification for Cluster Assignment
21	A, C	The paper discusses the on-demand upgrade and modification of vehicle functionality as well as continuous vehicle improvement through over-the-air updates. It therefore addresses both lifecycle-based functional extension and OTA-enabled deployment.
22	A, B, C	Function-on-demand is described as a mechanism for extending functionality after the initial vehicle configuration. The paper also addresses over-the-air software updates and the associated safety challenges arising from the interaction of software, hardware, and highly configurable vehicle systems.
23	A, B, E	The paper discusses Features on Demand and the unlocking of existing customer features. It further emphasizes the interaction of the vehicle, communication infrastructure, backend, and third-party systems, as well as subscription models, thereby covering system integration and service-oriented perspectives.
24	A, C, E	The paper discusses on-demand capabilities throughout the vehicle lifecycle and considers OTA delivery as an enabling mechanism. It explicitly addresses Feature-as-a-Service (FaaS), subscription-based enhancements, usage-based pricing, and context-aware feature activation.
25	A, B, C, D	The paper describes the continuous evolution of vehicles during their use phase, including new functionality enabled through OTA Updates. It also discusses pre-embedded hardware that can subsequently be activated and the integration of new functionality without physical access to the vehicle.
26	A, E	The paper discusses Features-on-Demand (FoD) as a lifecycle strategy and places strong emphasis on Software-as-a-Service (SaaS), subscription-based services, flexible pricing, recurring revenue streams, and vehicle lifecycle monetization. The relevant passage does not provide explicit evidence for OTA-based activation.
27	A	The paper describes Features on Demand and Functions on Demand as mechanisms for activating or renting specific functionalities. This extends the functional variability of the vehicle, while the relevant passage does not provide sufficient evidence for the other cluster perspectives.
28	A, C, D	The paper discusses post-purchase upgrades and an upgradeable add-on strategy, in which the necessary hardware is pre-embedded in the vehicle. Functions can subsequently be unlocked through OTA upgrades, directly linking functional variability, OTA deployment, and preinstalled capabilities.
29	A, C, E	The paper describes the post-sale modification and enhancement of vehicles through software. Digital features can be downloaded, activated, or subscribed to, including through an in-vehicle App Store, while subscription-based services, function-on-demand, and lifecycle monetization provide the service-oriented perspective.

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