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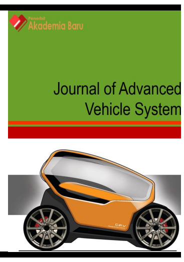

Application of IR 4.0 Technologies in Automated Vehicles (AV): A Review on Trends

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ABSTRACT

Autonomous vehicles (AVs) may provide more efficient logistical and passenger transportation methods. In the age of IOT, AVs provide the litmus test on the IOT system's reliability and the trust that it may inspire in road users. Understanding public acceptance of AVs is crucial for forecasting and altering adoption behaviour. The current research trend is on how to gain widespread use, however, this article examines the research topic about the future tendencies of IR 4.0 in the context of autonomous electric cars. In analysing the content of scientific literature, most are toward engineering, where breakthroughs in automobile technology are generated. However, innovations in automobile technology are often expensive and are typically implemented first in luxury cars. Early adopters who can afford large product premiums are often motivated to purchase by "technological distinction." While fully autonomous driving is not yet commercially viable, or if viable only available to selected few within the realm of testing and sandboxing, the technologies in AV are growing rapidly. As battery technology continues to advance, its unit capacity cost is progressively declining, hence aiding the growth of the AV industry within the electric vehicle (EV) and alternative-fuel context of interest.

Keywords:
Automated vehicles, electric vehicles, IR 4.0, trends, IOT

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1. Introduction

Autonomous vehicles (AVs) may provide more efficient logistical and passenger transportation methods. Intelligent sensors, cognitive computing, and the Internet of Things (IoT) characterise an autonomous vehicle (AV) as a cyber-physical system (CPS) in which data from all connected perspectives is carefully monitored and synchronised between physical devices and the cyber computational environment [26]. If autonomous vehicles apply advanced information analytics, they will be able to function more efficiently, collaboratively, and robustly.

According to Rymarczyk [26], AV is one of the industrial revolutions 4.0 (IR 4.0)'s applied technologies, and it offers a variety of risks, characteristics, and advantages. As seen in Figure 1, the concerns associated with AV include high investment costs and technical immaturity, while the characteristics and advantages include automation and digitization. Consequently, deploying IR 4.0 technologies in AV presents risks and opportunities, and its patterns and future growth are contingent upon these intrinsic qualities.

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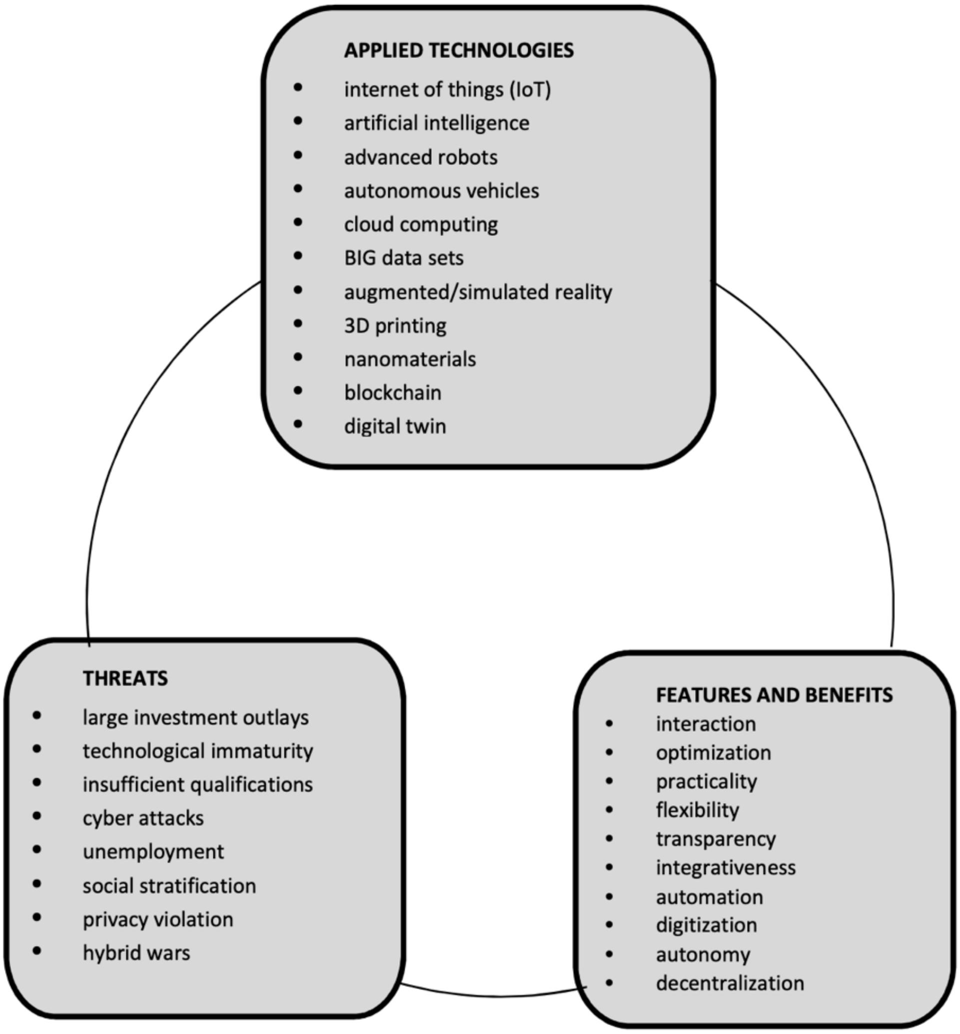

Fig. 1. Industrial revolution 4.0 and its threats, benefits, and technologies [26]

According to a 2022 assessment by Deloitte [7], customer interest in alternative-fuel engines differs by country. It is both intriguing and logical to observe that in nations that produce oil and gas (such as the United States), consumer interest in gas or diesel internal combustion engines (ICE) is greater than in countries that import oil (such as Japan). The following graph illustrates consumer interest in graphic formats as shown in Figure 2.

This paper examines the future research trends of IR 4.0 as they pertain to autonomous electric cars. This research issue is essential given that IR 4.0 is a rapidly evolving subject. Similarly, driverless automobiles and electric cars are also emerging research disciplines whose near-future patterns need additional consideration.

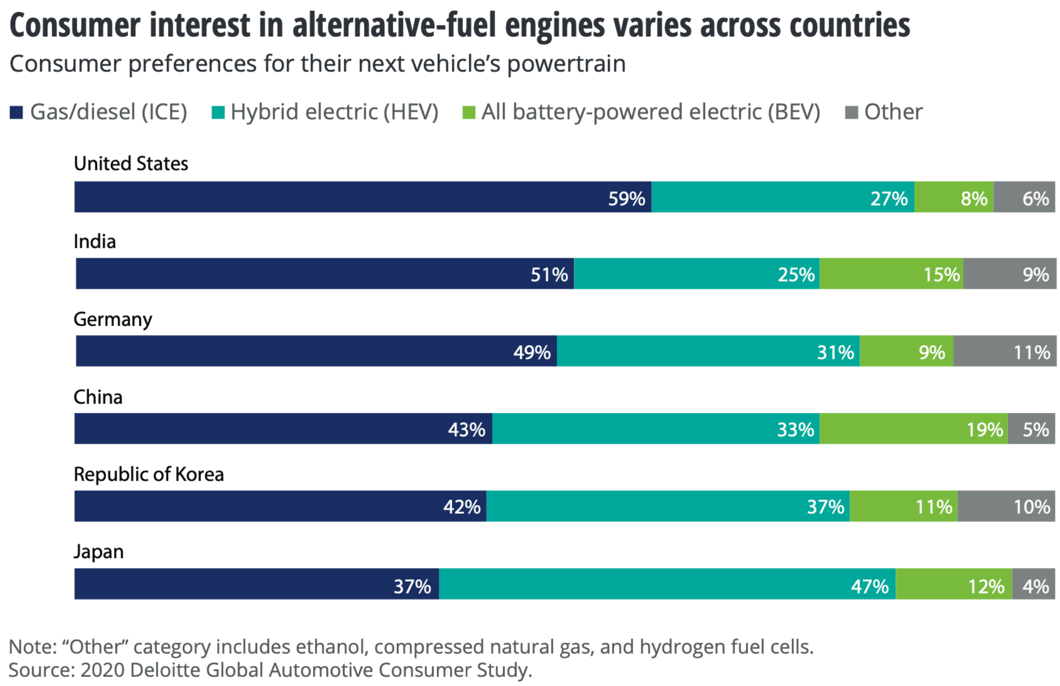

Fig. 2. Consumer interest in an alternative-fuel engines varies across countries

2. Related Studies

This section provides an analysis of the research on autonomous cars and IR 4.0. It is projected that the fourth industrial revolution would spur AV development, making AV manufacturing feasible. We reviewed a number of review articles and primary research. Work connected to review articles is given next.

Autonomous vehicles (AVs) are mobile cyber-physical devices, according to Rymarczyk [26]. They are used for intra-company travel, transportation between warehouses and production sites, as well as manufacturing and distribution. In the future, they will be used widely in public and intercity transportation. The probability of breakdowns and accidents caused by driver error and fatigue will reduce. The transportation industry will no longer be among the top contributors to air pollution and climate change, and its costs will also decrease. As a consequence of decongestion induced by the availability, affordability, and convenience of transportation, the mobility of persons, particularly the disabled, will increase, and living conditions in cities will also improve. Automobiles, drones, air taxis, and autonomous boats will also be used widely in manufacturing, agriculture, environmental protection, medicine, and the service industry.

The Society of Automotive Engineers (SAE) classifies autos into six separate levels of automation, according to Ahangar *et al.,* [1] (2021). Levels 0–2 are driver-assisted, Levels 3 and 4 are semi-autonomous, while Level 5 is fully automated. Following are detailed summaries of each level's characteristics:

i. Level 0 is completely manual, with the driver doing all duties.
ii. Level 1 offers driving assistance with features such as ACC and TSR, but the driver controls the accelerator and brakes while monitoring the surrounding environment.
iii. Level 2 gives little help to the driver, and the vehicle may execute steering and acceleration. Nevertheless, the driver is accountable for several safety-critical activities.
iv. Level 3 offers conditional driving automation in which the vehicle does all environmental monitoring. No longer is the driver accountable for safety-critical concerns.

v. Level 4 offers a high degree of driving automation, with the driver regaining control only if an automated scenario becomes risky. The vehicle performs steering, braking, acceleration, and a check of its immediate surroundings.
vi. Level 5 automation eliminates the need for human interaction and transforms the driver into a passenger.

Kovačić *et al.,* [19] stated that the need to build new paradigms and forms of urban mobility is developing as society's worries about sustainability increase and an increasing number of urban and suburban residents utilise fossil fuel automobiles without car sharing. This results in greenhouse gas emissions and climate change, which may be catastrophic for urban populations. Kovačić *et al.,* [19] also suggested that introducing and developing technologies under IR 4.0, such as artificial intelligence, permits the manufacture of autonomous cars. An autonomous vehicle is a vehicle that functions without human assistance.

Othman [25] emphasises this concept by tracing its evolution over the past century, beginning with the vehicle-to-vehicle communication system using radio waves in the 1920s, followed by the development of the vehicle's electromagnetic guidance in the 1930s and 1940s, and concluding with the addition of magnets to vehicles for the testing of smart highways in the 1950s. Mercedes-Benz collaborated with Bundeswehr University in Munich to create the world's first autonomous car in 1980, paving the path for law adaption and autonomous vehicle as a business.

Understanding the mental process of public acceptance of autonomous vehicles (AVs) is crucial for forecasting and altering adoption behaviour, according to Xiao *et al.,* [29], who represent the behavioural side of autonomous vehicle research. Clearly, current research is on the route to widespread use, although only when technology catches up. The California research by Xiao *et al.,* [29] demonstrates that perceived usefulness is a significant driver of behavioural intention. Young, well-educated, and male homeowners see AVs as more valuable than other sectors of the population. Households with telecommuters, transit users, riders of transportation network companies (e.g., Uber and Lyft), owners of electric vehicles (EVs), and households who possess or intend to install photovoltaic cell (solar) panels expect significant advantages from autonomous vehicles (AVs). Living or working in locations with infrastructure such as EV charging stations and hydrogen fuelling stations contributes to a favourable opinion of the benefits of autonomous vehicles. Households with a higher yearly income and EVs exhibit a greater interest in purchasing an AV, but not in ridesharing, when perceived utility is controlled for.

Dudziak *et al.,* [9] examine the commercial side of the case for AV. Due to the convergence of technical, IT, information, and measurement sciences, the researchers contend that the development of electric drives in motor vehicles is crucial for the development of autonomous cars. The automobile industry is experiencing massive alterations at now. Dudziak *et al.,* [9] explain that numerous trends in the development of motor vehicles may be noticed, the primary goal of which is to lessen the negative environmental effect of the automotive sector. Unfortunately, even the greatest efforts of designers and technological advancement cannot guarantee success if their ideas are not socially accepted.

Silva *et al.,* [27] believe, from an environmental standpoint, that current research on AVs may have major environmental implications, despite the fact that there are few studies concentrating only on these effects. According to the researchers, the great majority of papers address environmental concerns as a secondary result, whereas emissions are the primary subject. As environmental consequences include more than simply air pollution, the scope should be expanded to include land, water, noise, and light pollution in addition to air pollution.

Authors and researchers have worked on the electrification of cars paired with autonomous systems inside the IR 4.0 framework using the aforementioned works of literature. Nonetheless, the integration of all three is not yet scalable for the general market.

3. Research Methodology

Comparing the varied research methods and approaches of multiple authors allowed for a thorough analysis of the study's methodology and findings. Based on the examined publications, we formed our study subject before exploring many databases for associated keywords. Using criteria for exclusion and evaluation, only relevant publications were reviewed. Then, we assessed the quality of the articles and retrieved their essential characteristics.

The study issue of detecting the AV trend in the IR 4.0 sector inspired the review's layout. AVs were analysed to reveal their increasing occurrence. It is essential to develop a comprehensive review article in this topic to illustrate future directions, especially with driverless cars (AVs). As a consequence, we developed a search strategy, search strings, inclusion/exclusion criteria, and quality rating criteria for the articles retrieved from multiple sources.

The fundamental objective of this research is to determine the prevailing trend of autonomous cars in Industry 4.0. In addition, the research gap and limitations of current work in these areas allowed us to suggest growth opportunities; we also analysed prospective future pathways and outcomes. To get a "comprehensive understanding" of the research concerns, it was deemed necessary to investigate science/engineering databases. Following the creation of study themes, we combed the Science Direct collection for research articles. This SLR focuses on a single domain: AV within the 4.0 Industrial Revolution; hence, the search terms were relevant to the domain and its applications within Industry 4.0. On the mentioned subject, several IR 4.0 and AV-related research articles were discovered. To extract the most relevant and straightforward information from these articles, the criteria in Table 1 were used. The English-language, publicly available publications published between 2022 and 2023 that were pertinent to the search criteria and study objectives for IR 4.0 and autonomous cars were examined for further SLR tracking.

Table 1
Criteria and search string

Criteria	Search string
2023, 2022	Industrial revolution 4.0, IR 4.0
Research articles	Autonomous vehicle
All subject areas	Electric car

The downloaded papers were identified using first screening procedures based on inclusion criteria. On the above given topics, around 235 articles were found. After applying a year filter for just 2023 and 2022 and exclusion criteria (only research papers, subject categories engineering and business, management, and accounting), 209 items were discarded, leaving 36 articles to be reviewed based on the exclusion criteria. The remaining 36 articles were evaluated for quality. After the quality assessment, 22 articles were reviewed. The papers that were deleted included important information, but they were not studied because they did not meet the screening criteria. After collecting relevant papers, we did an SLR based on many characteristics, including topic, nation, and study area. Next a comprehensive literature review, the following part addresses and discusses the research questions.

4. Results

Only one of the 22 analysed publications is dated 2023. According to the filter, all other papers are in 2022. This filter is in place because the question to be answered relates to the forthcoming trend of IR4.0 addressing autonomous electric cars. Thus, it is worthwhile to anticipate utilising recently released studies.

India is the nation that has published the most papers out of the 22 total. France is the second most prolific source of papers. Others from Italy, the Czech Republic, the United States, and Russia show promise as well. In terms of topic matter or study field, Engineering leads the list, with fifty percent of the analysed publications pertaining to this discipline. The second most popular topic is Computer Science.

Additionally, the literature was evaluated based on the Title and Objective (s). On the basis of this information, the publications were further divided into more precise subfields within each study topic. The autonomous car industry/implementation/issues comprised the second biggest number of publications (12). (4). Other specialised disciplines include digital platforms (3), networks (2), and electrification (one study). If the filter had been expanded to include articles from earlier years (for instance, 2013 to 2023), the nation with the most published papers may not be India.

This sample is supposed to be typical, however, of the subject matter and its defined areas. This is due to the fact that driverless vehicles, electric automobiles, and IR 4.0 are fairly fresh study disciplines, despite the possibility that the notion was conceived decades ago. Table 2 displays the list of articles evaluated for this research.

Table 2
Systematic literature review based on the outlined in Table 1

Author	Year	Title	Objective	Country	Subject area
Manuguerra *et al.,* [21]	2023	A predictive eco-design method and tool for electric vehicles of Industry 4.0.	To make the designer more aware of the consumption of material resources and able to configure a use phase more efficiently in energy resource consumption.	Italy	Computer science
Jain *et al.,* [14]	2022	A vision towards integrated 6G communication networks: Promising technologies, architecture, and use-cases.	An exhaustive review of the 6G wireless communication network	India	Communication
Slanina *et al.,* [28]	2022	Automated guided vehicle control system for automated parking purposes	To focus on the design of the chassis with a moving mechanism.	Czech Republic	Engineering
Lakshmanan *et al.,* [20]	2022	Cooperative control in eco-driving of electric connected and autonomous vehicles in an un-signalized urban intersection	To obtain analytical solutions to the ED problem of an electric connected autonomous vehicles (CAV) crossing an un-signalized intersection subject to safety constraints, and to explore the benefits of cooperation.	France	Engineering
Khan *et al.,* [16]	2022	Cooperative navigation strategy for connected autonomous vehicle operating at smart intersection	To consider cooperative connected autonomous vehicles operating simultaneously with non-cooperative autonomous vehicles.	USA	Engineering
Gaponenko *et al.,* [10]	2022	Digital transport platforms: reality and prospects	To substantiate the architecture of building digital platforms and ecosystems focused on the transport environment, in which any service can be easily included with the full preservation of existing functionality and the potential for its development, without losing its identity and subscriber base.	Russia	Transportation
Zhen *et al.,* [30]	2022	Eco-driving trajectory planning of a heterogeneous platoon in urban environments	To present an eco-driving trajectory planning approach for a platoon of heterogeneous electric vehicles (EVs) in urban environments.	USA	Engineering
Kumar *et al.,* [18]	2022	Investigation and analysis of implementation challenges for autonomous vehicles in developing countries using hybrid structural modeling	To identify a variety of challenges which are then modeled using a hybrid approach that incorporates both ISM (Interpretive Structural Modeling) and MICMAC (Matrice d’impacts crois’es multiplication appliqu’ee ́a un classment) techniques	India	Social science
Amouzadi *et al.,* [2]	2022	Lane-free crossing of CAVs through Intersections as a minimum-time optimal control problem	To present a minimum-time optimal control problem to centrally control the CAVs to simultaneously cross an intersection in the shortest possible time.	UK	Engineering

Boissie *et al.,* [5]	2022	Obsolescence management practices overview in automotive industry	To present a documented reminder of what obsolescence is and subsequently analyse today's practices of its management in the automotive sector.	France	Engineering
Kibalama *et al.,* [17]	2022	Route generation methodology for energy efficiency evaluation of connected and automated vehicles	To provide a novel route generation process utilizing a driving data pool to produce representative missions for the evaluation of potential energy savings of CAVs.	Italy	Engineering
Iyer *et al.,* [13]	2022	Sliding mode control using power rate exponential reaching law for urban platooning	To develop platooning (method for preventing traffic congestion) for autonomous vehicle (autonomous platooning).	India	Engineering
Jandásek *et al.,* [15]	2022	Smart grid and electromobility	To outline the application of Smart Grid for electric vehicle use.	Czech Republic	Engineering
Moreno-Gonzalez *et al.,* [22]	2022	Speed-adaptive model-free lateral control for automated cars	To present a strategy framed in the Model-Free Control paradigm for the lateral control of the vehicle over a wide speed range.	Spain, France	Engineering
Ijemaru *et al.,* [12]	2022	Transformation from IoT to IoV for waste management in smart cities	To propose a novel IoV-based model for SC waste management strategies.	Australia	Computer science
Guo *et al.,* [11]	2022	Vehicular intelligence in 6G: networking, communications, and computing	To discuss fully-autonomous vehicle networking, communications, computing and intelligence, future technological developments and applications, and identify forthcoming challenges and research directions.	China	Telecommunications
Bathla *et al.,* [3]	2022	Autonomous vehicles and intelligent automation: applications, challenges, and opportunities	To survey the safety standards and challenges associated with autonomous vehicles in context of object detection, cybersecurity, and V2X privacy.	India	Information systems
Costa *et al.,* [6]	2022	Strategy for the introduction of autonomous driving technologies: case study in the logistics area of an automotive company	To answer the questions of "What requirements must be met to use autonomous transportation to move materials in the shopfloor?" and "What steps must be followed to introduce autonomous driving technologies, in an industrial environment?".	Portugal	Computer science
Begishev *et al.,* [4]	2022	Regulation of highly automated vehicles in the Russian Federation: problems, state and development prospects	To determine the features of the regulation of highly automated vehicles in the Russian Federation, taking into account its problems, state and development prospects.	Russia	Transportation
Dixit *et al.,* [8]	2022	Anomaly detection in autonomous electric vehicles using AI techniques: a comprehensive survey	To present a systematic outlook of AI techniques in anomaly detection of Automated Electric Vehicles (AEVs).	India	Computer science

Parekh *et al.*, [23]	2022	A Review on autonomous vehicles: progress, methods and challenges	To study the different proposed technologies and compare their approaches	India	Computer science
Piromalis and Kantaros [24]	2022	Digital twins in the automotive industry: the road toward physical-digital convergence	To delve into understanding Digital Twins.	Greece	Engineering
Frequency		Subject matter AV systems: 12 AV industry, implementation: 4		Country India:11 France:3	Research area Engineering: 11 Computer science: 5

5. Conclusions

This article examines the research topic about the future tendencies of IR 4.0 in the context of autonomous electric cars. The tendency in analysing the content of scientific literature is toward engineering, where breakthroughs in automobile technology are generated. Innovations in automobile technology are often expensive and are typically implemented first in luxury cars. Early adopters who can afford large product premiums are often motivated to purchase by "technological distinction." These customers anticipate manufacturers to implement as many innovations as feasible, including electric drive and autonomous driving technology. The initial product demand of early adopters will be expanded to the mainstream market when these items become cheaper as a result of the falling costs of innovations.

In this research, the majority of the scholarly literature studied focuses on autonomous vehicle systems. Since autonomous driving technology incorporates many onboard sensors and high-performance processing systems, it increases the electrical subsystem's requirements. Lead-acid batteries often power the 12V electrical system of conventional ICE engines. In contrast, EV battery packs can unquestionably offer a sufficient power supply and more variable voltage control, which means EVs will allow more latitude to install autonomous driving technologies. ICE-powered autonomous cars have difficulty refuelling and need the assistance of drivers, services, or intelligent robots. In contrast, wireless charging solutions that are now commercially available from a variety of firms will provide an ideal solution. Autonomous cars can navigate to accessible parking places and adapt to the appropriate angle to ensure the charging receiver is properly aligned with the pre-set wireless charging transmitter, maximising the effectiveness of wireless charging. In addition, autonomous cars will be capable of "opportunistic charging," which is charging between driving behaviours to keep a high battery level rather of waiting until the battery is exhausted.

Electric vehicles and accompanying infrastructure are not yet as widely accessible. Based on a comprehensive study of scientific literature, Asia, and India in particular, are poised to produce an IR 4.0-ready autonomous and electrified vehicle by leveraging their strengths in computer sciences and software development. Fully autonomous driving is not yet commercially viable, but both technologies are growing rapidly. As battery technology continues to advance, its unit capacity cost is progressively declining, hence aiding the growth of the EV industry. The iterations of sensors and software algorithms enable the cost-effective optimization of the autonomous driving experience and the incremental advancement toward fully autonomous driving. Therefore, the temporal synchronisation of the progress of the two technologies will push their integration and mutual promotion.

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