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A Comparative Study of Factors Influencing ADAS Acceptance in Belgium and Vietnam

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Abstract: This paper focuses on the acceptance of ADASs in the traffic safety and human factor domain. More specifically, it examines the predictive validity of the Unified Model of Driver Acceptance (UMDA) for an ADAS bundle that includes forward collision warning, headway monitoring and warning, and lane-keeping assistance in Belgium and Vietnam, two substantially different geographical, socio-cultural, and macroeconomic settings. All systems in the studied ADAS bundle are located at the Society of Automotive Engineer (SAE)-level 0 of automation. We found moderate acceptance towards such an ADAS bundle in both countries, and respondents held rather positive opinions about system-specific characteristics. In terms of predictive validity, the UMDA scored quite well in both countries, though better in Belgium than in Vietnam. Macroeconomic factors and socio-cultural characteristics could explain these differences between the two countries. Policymakers are encouraged to prioritise initiatives that stimulate the purchase and use of the ADAS, rather than on measures meant to influence the underlying decisional balance.

Keywords: ADAS; user acceptance; UMDA; cross-national comparison; Belgium; Vietnam

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1. Introduction

1.1. Background

Road safety remains a major public health concern, with organisations like the United Nations, the World Health Organization, and the European Commission working to reduce traffic deaths and injuries. Consequently, their safety measures have led to a decrease in road fatalities in developed countries despite having a substantial share of world vehicles. For instance, the European Commission reports a 22% decrease in traffic deaths in Europe from 2012 to 2022, totalling 20,634 [1]. Belgium, a Western European country, has also seen substantial improvements, with a 43% reduction in traffic fatalities and a 36% reduction in serious injuries over the past decade, aligning its mortality rate at 42 per million inhabitants to the EU average. However, car-involved crashes still account for nearly 50% of fatalities in Belgium, with 38% of fatalities among unprotected road users (i.e., pedestrians, cyclists, powered two-wheelers) due to collisions with cars, declining only 9% in the last ten years [2].

While the number of road crashes has decreased in high-income countries, low and middle-income countries report an increase, contributing to over 90% of global road traffic fatalities [3,4]. In particular, rapid motorisation in Southeast Asian countries has led to a surge in crashes [3]. Vietnam, situated in Southeast Asia, has a road traffic fatality rate of 26.4 per 100,000 people, surpassing the regional average of 20.7 [5]. Road crashes cost Vietnam about 2.5% of its GDP annually, according to the National Traffic Safety Committee [5]. Motorcycles, the most common transport mode in the country (74%) [6], account for most fatalities and injuries [7]. However, car ownership has significantly increased in recent years [7], exacerbating safety risks due to increased interactions between cars and unprotected road users such as motorcyclists, cyclists, and pedestrians [8]. Risky driving behaviours, including speeding, unsafe overtaking, drunk driving, poor road observation, the misuse of lanes, and pedestrian behaviour, are the primary causes of crashes in Vietnam [9]. According to the World Bank, the male-to-female fatality ratio in crashes is three to one, and the most vulnerable age group is 15–49 years [10]. Regarding road type, the highest fatalities—36% of the total—occur on national highways, which comprise only 15.4% of the total kilometres of roads [11]. Urban roads are also hazardous, contributing to 34% of fatalities, many occurring at intersections with national highways.

Human factors play an important role in the causation of road crashes. For instance, Fagnant and Kockelman [12] mentioned that human errors alone or in conjunction with other factors contribute to more than 90% of crashes. Advanced Driver Assistance Systems (ADASs) are meant to support drivers in safely operating their vehicles while travelling [13–16], by offering various functionalities, levels of automation, situational adaptivity, interface design and sensory modalities (visual, auditory, haptic) [17–20]. Research shows that both the ADAS and Intelligent Connected Vehicles (ICVs) improve road safety and operational efficiency [21,22]. For instance, Morando et al. [23] found that ICVs could increase highway capacity and significantly reduce travel times by allowing shorter headways, while Maryam Mousavi et al. [24] showed that ICVs offer mobility benefits to specific groups, including the elderly and disabled individuals, while Bifulco et al. [25] highlighted the ADAS's role in promoting eco-efficient driving. However, most research has primarily focused on road safety.

1.2. ADAS: Road Safety Effects

The overall picture is that ADAS/ICV technologies have the potential to reduce crashes caused by human error significantly [14,26–31], albeit findings are not always consistent (see, for instance, [32]). Studies predict that Connected and Automated Vehicles (CAVs) will greatly decrease crash frequency and severity due to improved environmental sensing and hazard anticipation [33,34]. Scholliers et al. [35] studied the feasibility, costs, and benefits of retrofitting ADASs in the EU and estimated that the full penetration of an ADAS bundle, including forward collision warning, speed limit information, and lane departure warning, could potentially reduce between 12.9% to 27.2% of road-related fatalities and 8.4% to 23.4% of road-related injuries. Similarly, Masello et al. [18] found that deploying common ADASs could decrease road crash frequency by 23.8% or 18,925 crashes annually in the UK. Wang et al. [36] used meta-analysis to evaluate the safety effectiveness of various CV or AV technologies on a geographically broader scale (considering New Zealand, Australia, the UK, the USA, Canada, and India) and found that implementing these technologies could reduce crashes by 3.40 million. Despite such promising data, the ADAS is criticised for being an assistance system that only has a limited effect if drivers continuously disregard traffic laws. Concerning this criticism, Gouribhatla and Pulugurtha [37] reported that the ADAS's presence (and use) affects driving behaviour and correlates with more compliant and less aggressive driving than when the ADAS is not present. Furthermore, ADASs are often part of a broader suite of safety technologies, such as collision avoidance systems, automatic emergency braking, etc., which collectively work to prevent accidents and mitigate the consequences of traffic law violations. Naumann et al. [38] demonstrated that even underutilised ADASs could prevent about 22% of deaths and 16–17% of injuries by 2050, saving over 150,000 lives and preventing nearly 8.7 million injuries.

The proven benefits of ADASs in enhancing road safety and driving comfort have led policymakers to push for widespread adoption in modern vehicles [18]. However, the safety impact of these technologies depends on market penetration rates [32]. This finding was also confirmed recently by Xiao et al. [39], who estimated ICVs' safety effects using the market penetration rate (MPR) by adopting a meta-analysis approach. They projected significant reductions in traffic conflicts correlating with increases in market penetration rates (MPRs). In a U.S. case study, it was projected that, with an MPR of 17–20% by 2025 and 40–48% by 2035, fatal crashes could be reduced by 5% and 13%, respectively.

1.3. ADAS: Market Penetration Rates

The ADAS market is poised for substantial growth worldwide. A report by Global Industry Analysts Inc. suggests the global ADAS market could reach $77.8 billion by 2027, growing at a Compound Annual Growth Rate (CAGR) of 18.8% from 2021 to 2027 [40]. The passenger car segment is expected to dominate due to a substantial rise in sales in the context of increasing urbanisation, demographic growth, and rising disposable incomes. In Europe, Triton Market Research forecasted the ADAS market to expand at a CAGR of 20.73% in revenue and 23.11% in volume through 2019–2027 [41]. In line with that, Waas et al. predicted that, by 2030, 54% of European vehicles will be equipped with ADAS, significantly higher than the 34% expected by 2025 and quadruple the 14% at the end of 2019 [42]. This growth is supported by EU safety initiatives, including Regulation (EU) 2019/2144, which mandates certain ADASs in new vehicle models from June 2022 and all new vehicles by June 2024. As a country, Belgium was one of the early adopters of the ADAS in vehicles. For instance, 39% of new cars had an automatic emergency braking system in Belgium (and the Netherlands) as early as 2016—the highest proportion in Europe [43]. Moreover, it was reported that Belgium's adoption of the ADAS aligns with the EU's mandate of all new vehicles equipped with the mandatory ADAS.

Turning to the Asia-Pacific Region, research projected fast progress of the ADAS market at a CAGR of 20.04% in revenue and 22.16% in volume from 2019 to 2027 [44]. Accordingly, Asia-Pacific is expected to witness the largest market share, driven by robust automotive sales and production alongside the increased adoption of electric vehicles, particularly in China and Japan. Moreover, the presence of key players in the region and the entry of international players are expected to stimulate investment. In Vietnam, rising disposable incomes and new government policies are propelling the automotive market [45]. Car purchases in Vietnam rose by 5.8% from 2016 to 2018 [46], and they are expected to reach 3.5–4.0 million by 2020 and 11–17 million by 2030 [47]. In 2019, Ho Chi Minh City, the biggest city in Vietnam, recorded the largest car ownership, accounting for 17.4% [7]. The European–Vietnam Free Trade Agreement (EVFTA), effective from 2019, decreased tariffs on automobiles, enhancing ADAS market opportunities in Vietnam [48]. Regarding the ADAS, the Vietnamese market is valued at USD 810 million as of 2023 and is projected to reach USD 1617 million by 2029, growing at a CAGR of 12.10% during the forecast period [49].

However, as Viktorová and Šucha [50] noted, the safety benefits of ADASs hinge on driver acceptance, a sentiment echoed by Rahman et al. [51], who highlighted that accepting these systems is critical to their adoption rate and realising safety benefits.

1.4. ADAS: User Acceptance

This study adopted the *acceptance* definition as provided by Adell [52], namely, as '*the degree to which an individual incorporates the system in his/her driving, or, if the system is not available, intends to use it*'. This definition implies that our study is interested in what Pianelli et al. [53] labelled as a priori acceptability, which represents acceptance formed before any experience with ADASs. On the other hand, acceptance formed after using an ADAS is called posteriori acceptability. A priori acceptability typically concerns future intentions to purchase and try an ADAS, whereas a posteriori acceptability deals with whether users correctly employ the ADAS post-purchase as intended [54]. Both forms of acceptability are crucial to consider in the context of the market penetration of ADASs.

Numerous studies on acceptance in a posterior context, employing different methods (e.g., driving simulations, test tracks, instrumented vehicles, field tests, and surveys), showed that drivers do not always adapt positively to ADASs and may even ignore or deactivate the technology after a period of use [55–62]. Sullivan et al. [19] referred to this phenomenon as 'negative behavioural adaptation', which the [63] formally defined as '*[. . .] behaviours which may occur following the introduction of changes to the road-vehicle-user system which were not intended by the initiators of the change*'. Negative behavioural adaptation can significantly undermine the safety benefits of ADASs, which is why the topic received considerable research interest since these systems were introduced. Sullivan et al. [19] noted how drivers adapt to ADASs largely depends on their mental model of the system's function and their confidence in this understanding. Consequently, many researchers stress the necessity of accurate system knowledge and proper training to foster trust and adequate use of these emerging technologies (e.g., [64–67]).

Successful market penetration also depends on the disposition of potential future consumers towards technology before actual user experience (i.e., a priori acceptance). As for acceptance in an a priori setting, Rahman et al. [51] conducted an online survey among 387 respondents with very low system familiarity and without actual user experience and found a generally neutral intent to use the systems. Similarly, Al Haddad et al. [68] assessed user acceptance of a novel ADAS (warning–monitoring system) through driving simulations and questionnaires with 122 drivers across various transport modes, noting that acceptance was influenced by the system's perceived ease of use and usefulness. The authors further stated that some findings are applicable across vehicle types, and others are more mode-specific. Likewise, the Eurobarometer study on Intelligent Systems, which surveyed 24,796 EU citizens, reported a lower willingness to adopt ADASs not yet available [69]. The authors continued, '*It is worth noting that there are still a reasonable number of respondents who do not want to have some of these systems* (e.g., *lane departure warning system, speed alert or real time traffic and travel information) in their car or do not recognise them as an improvement to the security or comfort of driving. This could be due to the fact that these systems are not yet on the market* [69]'. More recently, a study conducted a cross-sectional survey in the US and found that understanding, awareness, and trust in a (given) ADAS, including crash avoidance systems and Adaptive Cruise Control (ACC), varied significantly between owners who purchased new versus used vehicles and emphasised the importance of early education on ADAS functionalities for all owners [67].

To summarise, before actual user experience with ADAS, acceptance is typically lower when system awareness and familiarity are limited or lacking. This finding poses a potential barrier to the successful market penetration of such technologies. It is, therefore, essential to gain a deeper understanding of the specific factors that influence acceptance when potential future consumers are unfamiliar with emerging technologies and lack of user experience. Furthermore, from a post-purchase standpoint (i.e., a posteriori perspective), it is equally important to identify the factors that lead drivers to negatively adapt their behaviour in response to full or partial automation.

1.5. ADAS: Determinants of User Acceptance

The determinants of user acceptance towards assistive vehicle technology were studied at different levels of automation for more than a decade, leading to the development of several theoretical models (for reviews, see: [51,70–73]). The Technology Acceptance Model (TAM: see [74,75]), rooted in the Theory of Reasoned Action [76], is generally seen as one of the first influential theories. The TAM assumes that the behavioural intention to use and accept a system is mainly influenced by the individual's *attitude* (i.e., a person's overall evaluation) towards the system, which is shaped by two key factors: *perceived usefulness* (i.e., the belief that the system will improve driving performance), and *perceived ease of use* (i.e., how effortless the system is to operate). A second version, called the TAM2 [77], was proposed that incorporates additional elements from the Theory of Planned Behaviour [78]. These additional elements account for social influences and the ability to handle instrumental challenges and include a *subjective norm* (i.e., the belief that important others support the use of a system) and *perceived behavioural control* (i.e., the belief in how easy or difficult it is to use the system effectively) as predictors of technology acceptance. The TAM2 also integrated elements from the Innovation Diffusion Theory [79], considering *personal innovativeness* (i.e., the extent to which an individual is inclined to adopt new technologies ahead of others) as a determinant of technology acceptance.

In the next stage, Venkatesh et al. [80] advanced the study of the acceptance of technology by introducing the Unified Theory of Acceptance and Use of Technology (UTAUT), which added *facilitating conditions* (i.e., the belief that adequate organisational and technical support exists to assist the use of a certain system) as a direct predictor of technology usage. They expanded this framework into the UTAUT2 [81], adding *hedonic motivation* (i.e., the enjoyment derived from using a system) and *price value* (i.e., the cognitive trade-off between perceived benefits and monetary costs of system usage) as supplementary predictors. Following this progress, Ghazizadeh et al. [70] proposed the Automation Acceptance Model (AAM), focusing on *compatibility* (i.e., the system's alignment with adopters' values, needs, and experiences) from the Task-Technology Fit model [82] and *trust* (i.e., the belief that a system will perform its intended task with high effectiveness and comes from e-commerce and e-government). Rahman et al. [51] proposed the Unified Model of Driver Acceptance (UMDA), which incorporates the abovementioned variables and adds *endorsement* (willingness to recommend a system) as a predictor of the intention to use automotive technologies.

In their final step of theorising on technology acceptance in vehicle automation, Venkatesh et al. [83] introduced a more holistic version of the UTAUT2 model, termed the UTAUT3. This model incorporates not only individual-level factors (such as individual characteristics, technology, task attributes, and specific events) but also higher-level contextual factors (i.e., environmental, organisational, and locational attributes). Alongside the Car Technology Acceptance Model (CTAM: see [84]), which emphasises moral-normative aspects of system evaluation (such as the perceived benefits and risks of vehicle automation), these models form the basis of the Multi-level Model of Automated Vehicle Acceptance (MAVA: see [73]). The MAVA adopts a process-oriented approach to understanding vehicle automation acceptance. It integrates micro-level individual differences (e.g., socio-demographics, travel behaviour, personality traits) with meso-level factors, including domain-specific aspects (e.g., performance expectancy, effort expectancy), symbolic-affective aspects (e.g., social influence, hedonic motivation), and moral-normative aspects (e.g., perceived benefits and risks). These meso-level factors are considered interrelated and connected to the micro-level factors.

Turning to empirical studies on the predictive validity of the abovementioned models, Rahman [85] conducted a review focusing on the lower levels of vehicle automation (i.e., SAE levels 0 to 2). Out of 33 included studies, three did not assess acceptance-related factors, eleven relied on unstructured interviews or questionnaires created without a theoretical framework for technology acceptance, two measured acceptance with only one or two items, and ten utilised the Driver Acceptance Scale (DAS) by van der Laan et al. [86] to assess ADAS acceptance. Although the DAS is widely applied, it only contains nine items capturing two aspects of system evaluation, i.e., usefulness and pleasantness or satisfaction. Other studies reviewed the acceptance of higher vehicle automation levels, i.e., SAE levels 4 and 5 [71–73]. For a detailed overview of the major findings from these studies, please refer to Table 1.

In sum, theoretical as well as empirical studies on the determinants of ADAS acceptance have proliferated over the last ten years. Extended models of extended versions of the TAM (e.g., TAM2, UTAUT, UTAUT2, CTAM, AAM) have been pivotal in identifying key determinants influencing the intention to use ADASs. The UMDA serves as a synthesis model amalgamating the most important variables, like attitude, perceived usefulness, the perceived ease of use, subjective norm, perceived behavioural control, compatibility, trust, endorsement, and affordability. While these models effectively predict intentions to use an ADAS, the influence of specific variables can vary widely across different studies. Also, the most recent theoretical frameworks (i.e., UTAUT3, MAVA) adopt a systemic perspective and introduce a process orientation towards the acceptance of vehicle automation, yet the focus of these theories is more towards the higher levels of automation, i.e., SAE levels 4 and 5.

Table 1. Overview of review studies on the acceptance of vehicle automation.

Study	N	Objective	Focus (SAE Level)	Variables	Major Results
Golbabaei et al. [71]	80	Acceptance of and intention to use AVs	4 and 5	Three levels of factors - Demographic factors - Psychological factors - Mobility-related factors	**Psychological factors** - Personal innovativeness: 25 studies - Awareness of avs: 18 studies - Environmental concerns: 5 studies - Facilitating conditions: 27 studies - Subjective norm: 16 studies - Hedonic motivation: 6 studies - Perceived usefulness: 18 studies - Perceived ease of use: 9 studies - Perceived benefits: 31 studies - Perceived risks: 57 studies
Gkartzonikas and Gkritza [72]	28	Intention to use AVs	4 and 5	Psychological factors	**Psychological factors** - Level of awareness: 6 studies - Consumer innovativeness: 7 studies - Trust of strangers: 8 studies - Relative advantage/compatibility/complexity: 19 studies - Subjective norm: 6 studies - Self-efficacy: 6 studies - Driving-related sensation seeking: 8 studies - Safety concerns: 11 studies - Environmental concerns: 8 studies
Nordhoff et al. [73]	124	Acceptance of vehicle automation	4 and 5	Divided into two levels - Meso-level - Micro-level	Acceptance factors were divided into seven main acceptance classes at two levels **Meso-level** - Exposure to AVs: 6% of the studies - Domain-specific: 22% of the studies - Symbolic-affective system evaluation: 4% of the studies - Moral-normative system evaluation: 12% of the studies **Micro-level** - Socio-demographics: 28% of the studies - Personality: 14% of the studies - Travel behaviour: 15% of the studies

2. Problem Statement

The previous section highlights that it is much less clear which factors are the underlying determinants of acceptance towards lower-level ADASs (SAE levels 0–2) compared to higher levels (SAE levels 3–5). Indeed, to the best of our knowledge, there is only one systematic review focusing on SAE levels 0 to 2, and this study identified several limitations to the available empirical research on the topic, bringing the author to a conclusion that '*[. . .] much of the focus in the media and scientific endeavors has been on the technology itself and far less attention has been devoted to user-centered aspects, such as acceptance and utilization* [85]'. This conclusion is a caveat that merits attention as lower-level ADASs are prominently present in the market [87]. Moreover, studies show inconsistent results regarding the psychological determinants of ADAS acceptance, which is why Rahman et al. [51] and Cunningham et al. [88] explicitly called for further investigation to corroborate already reported findings.

Additionally, despite the fact that empirical studies on the determinants of ADAS acceptance have adopted a broad geographic scope, covering several countries and world regions, there is little research where the primary focus is on the cross-national comparison of ADAS acceptance determinants. Most multi-national studies focus on countries belonging to one particular world region (see Nordhoff et al. [89] and Tennant et al. [90]

with a focus on European countries, and Cunningham et al. [88] with a focus on Australia and New Zealand) while comparisons of countries belonging to different continents or world regions are rather scarce and primarily oriented towards the impact of cross-country or cross-cultural differences on the use and design of ADASs (e.g., [91–93]), rather than addressing the deeper determinants of acceptance. Notable exceptions, however, include Jeon et al. [94], who ran a survey study and found attitudes towards in-vehicle technologies to vary across Austria, the US, and South Korea; Schoettle and Sivak [95] found public opinion about autonomous and self-driving vehicles to differ between China, India, Japan, the US, the UK, and Australia. Yerdon et al. [96] conducted an exploratory literature review and linked trust in automotive automation to cultural contexts (i.e., the level of individualism versus collectivism, etc.). More recently, Edelmann et al. [97] demonstrated that cultural background and driving decisions influence the acceptance of automated vehicles in a study involving China, Germany, Japan, and the US.

In conclusion, there is currently not much known about the underlying determinants of acceptance towards lower-level ADASs, and more research accounting for cross-continental differences is urgently required as these systems continue to expand rapidly into global markets.

3. Study Objectives and Research Questions

The main objectives of this study are twofold. Firstly, we are interested in what Nordhoff et al. [73] called domain-specific factors of system evaluation to examine which factors determine acceptance towards an ADAS at the lowest level of automation, SAE level 0, which includes providing warnings and momentary assistance with the vehicle operator maintaining full control and supervision (detailed features discussed in Section 5.1). Second, we seek to determine if the impact of these domain-specific factors on ADAS acceptance at SAE level 0 differs between Belgium and Vietnam, countries representing two substantially different world regions and car markets.

The focus on domain-specific factors in this study is motivated by their frequent investigation and supportive, though inconsistent, validation as predictors of ADAS acceptance in previous studies (e.g., [85]). Nordhoff et al. ([73]: see Figure 2), for example, found that domain-specific factors are the most extensively studied category of meso-level acceptance determinants, though their study focused on automation at SAE levels 4 and 5. We aim to investigate their predictive validity for SAE level 0 using the UMDA (see Section 4 for more details), which synthesises domain-specific evaluations [51]. Moreover, the UMDA incorporates potential indirect effects (i.e., mediation or moderation) between domain-specific and sociodemographic factors, aligning with theories like the UTAUT3 and MAVA [53]. The emphasis on investigating the acceptance of SAE level 0 is underscored by calls for more research on acceptance determinants of lower-level ADAS (e.g., [51,88]) and the continued prevalence of such systems in the market, as evidenced by their dominance in international ADAS sales in 2021, occupying 61.4% of the global ADAS market [98].

Belgium and Vietnam were chosen for this investigation due to several reasons. First and foremost, this study is a part of a project focused on studying the behavioural adaptation to ADASs in the two countries. These countries provide an exciting avenue of research for their substantial macroeconomic and sociocultural differences. Belgium, with a vastly stable economy, has a GDP per capita of EUR 53,475.3 and a national GDP of EUR 632.22 billion as of 2023, reflecting modest growth projections of 1.3% for 2024 [99]. In contrast, Vietnam, a rapidly developing nation, projects a (higher) 5.5% growth rate for 2024, with current GDP figures at VND 429.72 billion and a GDP per capita of VND 4346.8 [99]. Recently, Vietnam has seen significant economic improvements, with some estimates stating that its GDP per capita increased 3.6 times from 2002 to 2022, and poverty rates dropped from 14% to 5.7% in 2022 compared to 2010 [100]. These economic differences play a significant role in shaping the share of various transport modes in each country. Belgium remains a car-centric society, while motorcycles dominate in Vietnam. For every 1000 inhabitants, there are approximately 509 and 61 passenger cars in Belgium [101] and Vietnam [102], respectively. Recent market surveys, however, predict a significant increase in car usage in Vietnam, as seen in Section 1.3, which could also be the reason for the lower mean age of automobiles in Vietnam compared to Belgium (5.7 years for Vietnam [103] vs. 9.5 years for Belgium [104]). Both countries actively integrate ADAS technologies into new vehicles, with Belgium aligning with EU safety regulations and Vietnam addressing challenges from its expanding car market. Moreover, cultural differences are pronounced between the two countries, with Belgium standing as individualistic and Vietnam as collectivistic on Hofstede's scale [105,106].

The more precise research questions addressed in this study are formulated as follows:

- RQ1: Which domain-specific factors of system evaluation contained by the UMDA statistically significantly predict Belgian and Vietnamese car drivers' acceptance towards ADAS features situated at SAE level 0? (cf. study objective 1)
- RQ2: Which (socio-demographic) factors mediate or moderate the effect of domain-specific factors of system evaluation contained by the UMDA on the acceptance of Belgian and Vietnamese car drivers towards ADAS features situated at SAE level 0? (cf. study objective 1)
- RQ3: Are there differences between Belgian and Vietnamese car drivers in terms of which domain-specific factors of system evaluation contained by the UMDA statistically significantly predict acceptance towards ADAS features situated at SAE level 0? (cf. study objective 2)
- RQ4: Are there differences between Belgian and Vietnamese car drivers in terms of which (socio-demographic) factors mediate or moderate the effect of domain-specific factors of system evaluation contained by the UMDA on the acceptance towards ADAS features situated at SAE level 0? (cf. study objective 2)

4. Conceptual Model and Hypotheses

As already mentioned, this study hinges upon the UMDA as proposed by Rahman et al. [51] (see Figure 1).

The UMDA assumes nine domain-specific factors of system evaluation to significantly predict driver acceptance, i.e., attitude, perceived usefulness, the perceived ease of use, subjective norm, perceived behavioural control, compatibility, trust, endorsement, and affordability (for formal definitions of these factors, see Section 1.5). Additionally, the socio-demographic factors of age, gender, system experience, and personal innovativeness are proposed as potential moderators, affecting the relationship between the independent variables and behavioural intention towards ADASs. Furthermore, Rahman et al. [51] proposed that attitude acts as a (partial) mediator between the other eight independent variables and driver acceptance. Based on the premises behind the UMDA, we propose the following hypotheses:

H1. *The attitude towards ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: a more positive attitude results in a higher use intention.*

H2. *The perceived usefulness of ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: the more useful such features are perceived, the higher the intention to use them.*

H3. *The perceived ease of use of ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: the more user-friendly such features are perceived, the higher the intention to use them.*

H4. *The subjective norm towards ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: a more positive subjective norm results in a higher use intention.*

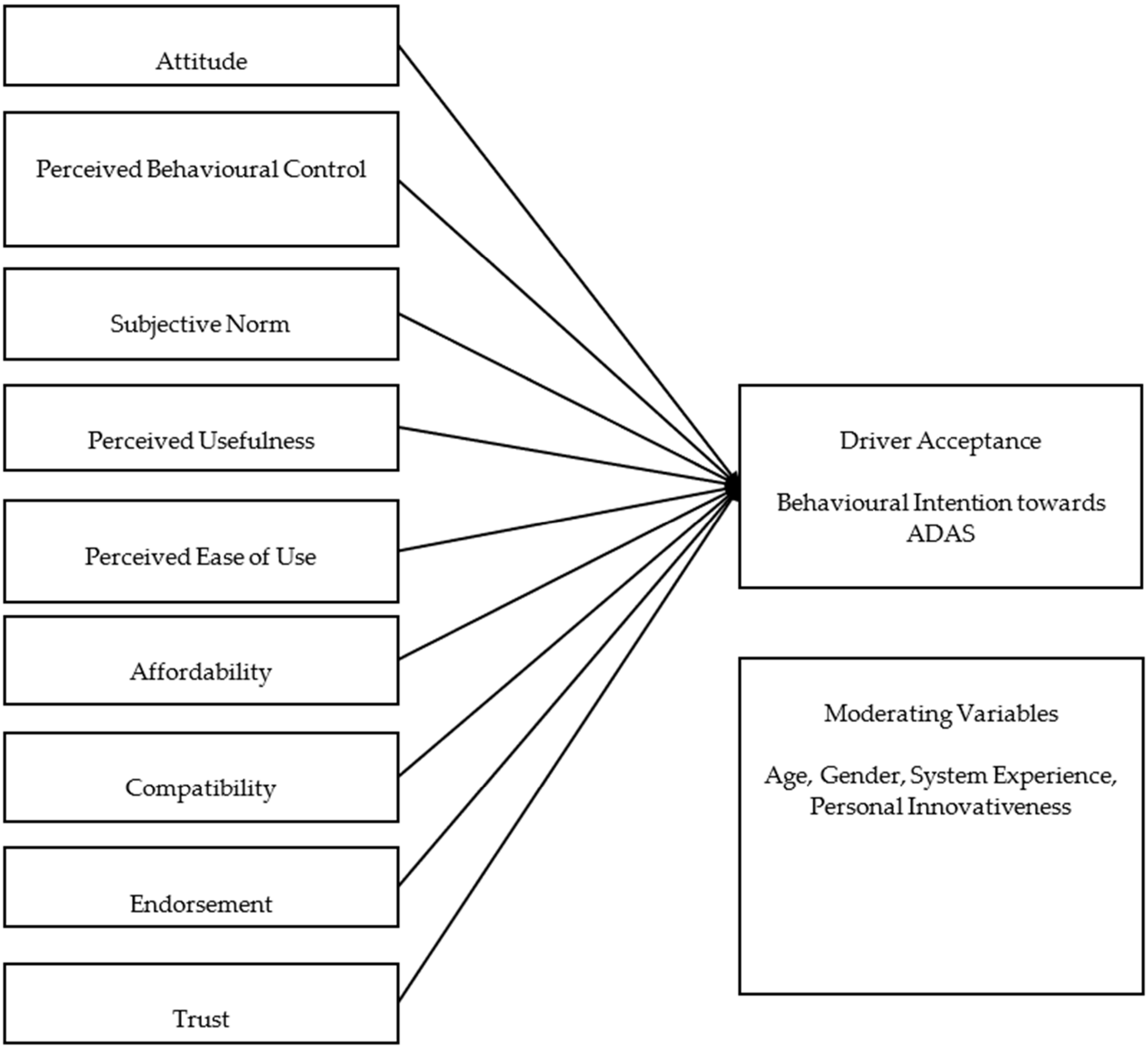

Figure 1. The unified model of driver acceptance (UMDA) as proposed by Rahman et al. [51].

H5. *The perceived behavioural control towards ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: the more users perceive to be in control over such features, the higher the intention to use them.*

H6. *The compatibility of ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: the more compatible they are perceived, the higher the intention to use them.*

H7. *Trust towards ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: the more such features are trusted, the higher the intention to use them.*

H8. *Endorsement towards ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: the more such features are endorsed, the higher the intention to use them.*

H9. *Affordability of ADAS features at SAE level 0 exerts a statistically significant positive effect on the acceptance towards such ADAS features: the more affordable such features are perceived, the higher the intention to use them.*

H10. *The effect of the domain-specific factors of system evaluation proposed by the UMDA is moderated by age, gender, system experience, and personal innovativeness.*

H11. *The effect of the domain-specific factors of system evaluation proposed by the UMDA is (partially) mediated by attitude.*

5. Methods

5.1. Study Design

This study is part of a larger research project on behavioural adaptation towards ADASs among Belgian and Vietnamese car drivers, conducted within a bilateral scientific collaboration between universities in Belgium and Vietnam. The project received ethical clearance from the Social-Societal Ethics Committee (SSEC) at Hasselt University, Belgium (registration number REC/SMEC/2021-22/3) and from the Ethics Committee at the Vietnamese–German University in Vietnam.

This study utilised a cross-sectional survey design to achieve its objectives, with participants from both countries completing a structured online questionnaire. The survey focused on an ADAS at SAE level 0, combining three specific features: (1) Forward Collision Warning, (2) Headway Monitoring and Warning, and (3) Lane Assist. Formal descriptions of these functionalities were provided to ensure participants understood them correctly. The questionnaire was divided into four sections: (1) socio-demographic background, (2) the perceived usefulness of the ADAS in supporting personal driving, (3) personal experience with and willingness to use the ADAS, and (4) the acceptance of ADASs and related determinants. Research teams in both countries worked with professionals fluent in the local languages and English to develop Dutch and Vietnamese versions of the questionnaire.

Prior to this main study, a pilot test with 20 participants from each country was conducted to evaluate the clarity and understanding of the concepts being assessed, the instructions provided, and the statements to be evaluated. The pilot also checked the appropriateness of the survey length and duration and tested the online administration format. After the pilot, a group discussion was held to collect feedback, leading to minor adjustments in wording.

This study reports findings from the socio-demographic background and the section on acceptance towards the ADAS and its related determinants.

5.2. Survey Instrument

The questionnaire consisted of 71 questions divided into four sections. Since this study is limited to sections one (socio-demographic background) and four (acceptance of ADAS and related determinants), we will only focus on operationalising those two sections here. The socio-demographic background section contained nine items probing for age, gender, level of education, driving experience, exposure in general (i.e., the average number of kilometres driven per week), road type-specific exposure (i.e., the average number of kilometres driven per week on urban roads, rural roads, and motorways), crash involvement during the last three years, and the level of personal innovativeness.

Section four focused on the determinants of acceptance, with emphasis on the ADAS under study. At the beginning of this section, the system's functionalities were explained to respondents, and they were clearly told to base their evaluations of all acceptance-related statements on this system description. Similar to the approach taken by Rahman et al. ([51]: see Appendix A), respondents were presented with a scenario description of driving conditions in which the ADAS would be used. They were asked to keep this scenario in mind when evaluating the acceptance-related statements in section four.

The acceptance-related statements were all based on the UMDA [51]. Various items derived from Rahman et al. [51] (see Appendix A (Only the survey section, which focused on acceptance and related determinants (that is, Section 4) is provided in Appendix A)) were included, measuring acceptance (i.e., the intention to use the ADAS examined in this study) as the dependent variable and nine independent variables hypothesised to predict system acceptance (i.e., attitude, perceived usefulness, the perceived ease of use, perceived behavioural control, compatibility, subjective norm, trust, endorsement, and affordability). For more details on the number of items per construct and the specific statements used, see the section about descriptive statistics. All items were rated on a unipolar seven-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). One item (related to the subjective norm) required reverse coding before analysis. Lastly, one additional item was added to assess the level of user experience with the features of the ADAS under study.

5.3. Sampling and Recruitment

Random sampling was used to select participants for this study, with the only requirements being that they hold a valid car driving licence and have Belgian or Vietnamese nationality. Actual user experience with ADAS features was no strict requirement for respondents to participate in the survey. In both countries, recruitment was conducted through various channels, including Facebook, official university social media accounts, student groups, local transportation and interest groups mailing lists, and personal networks such as colleagues, friends, and family. People willing to participate could easily access the questionnaire via a web link. In Belgium, a lottery with a few reward vouchers of EUR 50 was meant to incentivise participation, while in Vietnam, respondents who fully completed the questionnaire were compensated for their participation with a phone recharge card valued at approximately EUR 3. Only respondents who chose to participate in the lottery/phone recharge provided their email addresses, which were collected solely to administer and distribute rewards.

5.4. Data Collection

Data were collected in a GDPR-compliant manner via Qualtrics. Participant privacy was consistently maintained, and no personal details such as email addresses or IP addresses were collected except for those participating in the rewards. Participants were informed about this study's objectives, the voluntary nature of their participation, and their right to withdraw at any point. They were also briefed on data privacy protocols before providing formal consent to proceed with the survey.

Completing the questionnaire took around 15–20 min. Data were excluded if questionnaires were incomplete. In Belgium, the survey ran from 13 September to 22 October 2021, receiving 473 responses, with 322 deemed valid. In Vietnam, it was open from October 10 to 21 November 2021, with 303 of 614 responses complete. Overall, out of 1087 responses collected across both countries, 625 were included for statistical analysis. According to Hair et al. [107], a sample size of at least 100 is considered adequate for the generalisability of the empirical results. However, to be sure, we also determined the required minimum sample size using power calculation. Based on a power analysis conducted using G*Power software, version 3.1.9.7 [108], the sample size obtained for each country separately (i.e., N = 322 in Belgium and N = 303 in Vietnam) exceeded the minimum requirement of N = 114, which is needed to detect a medium effect size of 0.15 in a model with nine parameters, a power of 0.80, and an alpha level of 0.05. The selection of these parameters for the calculation of sample size in G*Power software was derived from previous studies in our research domain [109].

5.5. Data Analysis

The data analysis protocol was identical for both Belgian and Vietnamese data, and the procedure was replicated exactly as proposed by Rahman et al. [51] to maximise the comparability of results. First, composite variables were calculated by computing the mean of their respective measurement items. Next, internal reliability was verified using Cronbach's alpha (α), with coefficients above 0.70 considered acceptable [110,111]. Descriptive statistics focused on the central tendency (mean) and variability (standard deviation) for individual items and composite variables.

In exploring the hypotheses proposed in Section 4, we first conducted a Pearson's correlation analysis with 2-tailed tests to determine the strength of a linear relationship for each hypothesised pair of variables. Subsequently, simple linear regression models were developed to examine the explanatory power of individual predictors, with behavioural intention as the dependent variable and each of the nine variables serving as independent predictors. We then conducted hierarchical multiple regression to assess the combined effects of these predictors on ADAS acceptance, employing the forward selection approach to evaluate the contribution of each variable. Changes in R^2 during each step provided insights into the contribution of different factors to predict the dependent variable. Lastly, mediation and moderation analysis was carried out using the procedures introduced by Baron and Kenny [112], Kenny et al. [113], and Frazier et al. [114]. The statistical package IBM SPSS: Version 27 was used to perform all the above-mentioned analyses.

6. Results

6.1. Sample Composition

Table 2 presents the composition of both Belgian and Vietnamese samples for the various socio-demographic characteristics queried.

Table 2. Socio-demographic characteristics of study participants by country.

Factor	**Levels**	**Belgium**		**Vietnam**	
		N	**Percent (%)**	**N**	**Percent (%)**
Gender	Male	167	51.90%	234	77.23%
	Female	155	48.10%	68	22.44%
	X	-	-	1	0.33%
Age	30 years and below	121	37.60%	77	25.41%
	31–50 years	119	37.00%	193	63.70%
	51 years and above	82	25.50%	33	10.89%
Education level	Bachelor's, below, and all others	209	64.90%	198	65.35%
	Master's and above	113	35.10%	105	34.65%
Average weekly travelled distance	≤50 km	65	20.20%	131	43.23%
	51–100 km	57	17.70%	67	22.11%
	101–500 km	161	50.00%	81	26.73%
	>500 km	39	12.10%	24	7.92%
Obtained car driver's licence	< or = 10 years	124	38.50%	210	69.31%
	>10 years	198	61.50%	93	30.69%
Crash history	No crash	275	85.40%	265	87.46%
	Yes, once	41	12.70%	33	10.89%
	Yes, 2 times	6	1.90%	2	0.66%
	Yes, 3 or more	-	-	3	0.99%
Users' ADAS experience	Yes	113	35.09%	89	29.37%
	No	209	64.91%	214	70.63%
Users' personal innovativeness	Yes	185	57.5%	225	74.3%
	No	137	42.5%	78	25.7%

	Belgium			Vietnam		
Share of weekly travel by road type *	Mean	SD	Range	Mean	SD	Range
Urban roads	36.18	19.12	0–100	61.65	27.43	0–100
Roads outside built-up areas	38.28	18.27	0–90	21.02	20.54	0–90
Motorways	25.54	20.45	0–90	14.06	16.45	0–85

* The amount of time (expressed in percentages) the participants spend on different types of roads during a typical working week.

The Belgian sample was almost equally divided between genders and across different age groups, whereas the Vietnamese sample showed a male majority, and mature adults (31–50 years of age) formed the highest proportion of survey participants (63.7%, N = 193). The gender discrepancy might be explained by broader cultural and societal tendencies in Vietnamese society. In particular, Vietnam is known to have a masculine culture [115], in which males are typically income-earning breadwinners [116] (and have a more significant influence on purchasing decisions about male-dominated technical items such as cars). In contrast, Vietnamese women tend to prefer public transportation due to complex travel patterns and safety concerns [117]. This finding aligns with data from the Department for Roads of Vietnam (personal communication, 2023), which show that the rate of valid driver's licences for males and females is 80.4% versus 19.6%, respectively. Both samples had relatively similar educational backgrounds. The average weekly travelled distance for most Belgian respondents (50.00%, N = 161) was between 101 and 500 km, while for most Vietnamese respondents, it was equal to or less than 50 km (43.23%, N = 131). The Belgian sample consisted of more experienced drivers than the Vietnamese sample (B: 61.50%, N = 198 vs. V: 30.69%, N = 93 with 10 plus years of driving experience). The crash history of the two countries was approximately similar. Belgian respondents had more experience with ADAS technologies than Vietnamese respondents. However, Belgians appeared less personally innovative than the Vietnamese respondents. On average, the Belgian sample exhibited equal exposure to both urban roads and roads outside built-up areas and a relatively low exposure to motorways. Unlike that, the exposure to urban roads was highest in the Vietnamese sample (three to four times more than exposure reported for roads outside built-up areas and motorways).

6.2. Descriptive Statistics

Table 3 presents the means and standard deviations for both countries at the item and composite variable levels. It also includes Cronbach's alpha coefficients for the composite variables.

Table 3. Descriptive statistics for scales and individual items (adopted from Rahman et al. [51]).

Items	Belgium			Vietnam		
	Mean	**SD**	**α**	**Mean**	**SD**	**α**
Attitude (4 items)	5.37	1.18	0.85	5.67	1.41	0.9
The use of the system when I am driving would be a. Useless: Useful	5.65	1.39		5.83	1.69	
b. Ineffective: Effective	5.53	1.31		5.73	1.66	
c. Sleep-inducing: Alerting	5.40	1.47		5.60	1.55	
d. Extremely annoying: Not Annoying	4.89	1.51		5.52	1.56	
Perceived Usefulness (2 items)	4.98	1.05	0.73	5.43	1.93	0.93
a. Using the system in driving increases my safety	5.33	1.08		5.46	2.05	
b. Using the system would improve my driving performance	4.62	1.28		5.41	1.95	
Compatibility (3 items)	5.16	1.09	0.83	5.31	1.76	0.97
a. The system is compatible with all aspects of my driving	5.12	1.22		5.27	1.8	
b. I think that using the system fits well with the way I like to drive	5.15	1.3		5.35	1.84	
c. Using the system would complement my driving style	5.2	1.25		5.31	1.81	

Table 3. *Cont.*

Items	Belgium			Vietnam		
	Mean	**SD**	**α**	**Mean**	**SD**	**α**
Endorsement (2 items)	5.18	1.28	0.92	5.65	1.77	0.97
a. I would recommend that my family and friends buy vehicles equipped with the system	5.09	1.36		5.65	1.79	
b. I would recommend that my child, spouse, parents—or other loved ones—use the system	5.27	1.31		5.65	1.8	
Affordability (2 items)	2.64	1.38	0.84	2.54	1.71	0.96
a. How much would you be willing to pay for the system if it were an optional feature in a new car?	2.85	1.5		2.61	1.75	
b. How much would you be willing to pay the system if it could be retrofitted to an existing car?	2.43	1.47		2.47	1.73	
Trust (2 items)	5.1	1.26	0.83	5.61	1.72	0.91
a. I think I can depend on the system for safe driving	4.95	1.4		5.55	1.78	
b. I would feel comfortable if my child, spouse, parents—or other loved ones—drove a vehicle equipped with the system	5.24	1.33		5.67	1.81	
Perceived Ease of Use (3 items)	4.74	1	0.81	5.21	1.77	0.93
a. My interaction with the system would be clear and understandable	4.85	1.05		5.32	1.89	
b. I would find the system user-friendly	4.77	1.15		5.26	1.83	
c. Interacting with the system would not require a lot of mental effort	4.59	1.31		5.05	1.94	
Subjective Norm (2 items)	4.44	1.07	0.28	5.34	1.78	0.9
a. People who influence my behaviour would think that I should use the system	4.39	1.35		5.25	1.89	
b. People who are important to me would not think that I should use the system (reverse-scaled item)	4.48	1.45		5.43	1.85	
Perceived Behavioural Control (3 items)	5.18	1.01	0.76	5.24	1.66	0.89
a. I have control over using the system	4.98	1.2		5.31	1.8	
b. I have the resources necessary to use the system	5.28	1.14		5.08	1.83	
c. I have the knowledge necessary to use the system	5.3	1.32		5.33	1.85	
Behavioural Intention (3 items)	5.37	1.18	0.89	5.67	1.72	0.96
a. If the system is available in the market at an affordable price, I intend to purchase the system	4.95	1.42		5.6	1.75	
b. If my car is equipped with a similar system, I predict that I would use the system when driving	5.63	1.2		5.72	1.82	
c. Assuming that the system is available, I intend to use the system regularly when I am driving	5.52	1.28		5.68	1.8	

Overall, the samples investigated in both countries seemed favourably disposed towards the ADAS examined in this study. However, the 'affordability' subscale stood out, with significantly lower scores than acceptance and its eight hypothesised predictors. Furthermore, Vietnamese respondents' mean values were higher than those obtained in Belgium. In the Belgian sample, Cronbach's α values indicated that most subscales were within the acceptable range, except for subjective norm (SN) (α = 0.278). The Vietnamese sample demonstrated high internal reliability for all subscales based on Cronbach's alpha values.

6.3. Correlation Analysis

Figure 2 presents the results of the Pearson's correlation test for Belgium.

Figure 2. Correlation analysis of subscales (Belgium). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Correlation analysis revealed statistically significant and notably strong associations between the intention to use the ADAS and its predictors (Please check the list of abbreviations for subscale), as outlined by the UMDA. In the Belgian sample, the strongest predictors of acceptance were endorsement (r = 0.765, p = 0.01), compatibility (r = 0.701, p = 0.01), and trust (r = 0.647, p = 0.01). The weakest associations were with the subjective norm (r = 0.385, p = 0.01) and affordability (r = 0.405, p = 0.01).

Figure 3 contains the results of Pearson's correlation test for Vietnam.

In the Vietnamese sample, all variables hypothesised by the UMDA to predict acceptance showed statistically significant and strong correlations with the intention to use the ADAS. Highest values were found for endorsement (r = 0.730, p = 0.01), trust (r = 0.706, p = 0.01), and perceived behavioural control (r = 0.706, p = 0.01). Interestingly, the subjective norm (r = 0.703, p = 0.01) was also strongly associated with behavioural intention in the Vietnamese sample, in contrast to what was found for Belgium. The lowest values were established for affordability (r = 0.183, p = 0.01), and attitude (r = 0.280, p = 0.01).

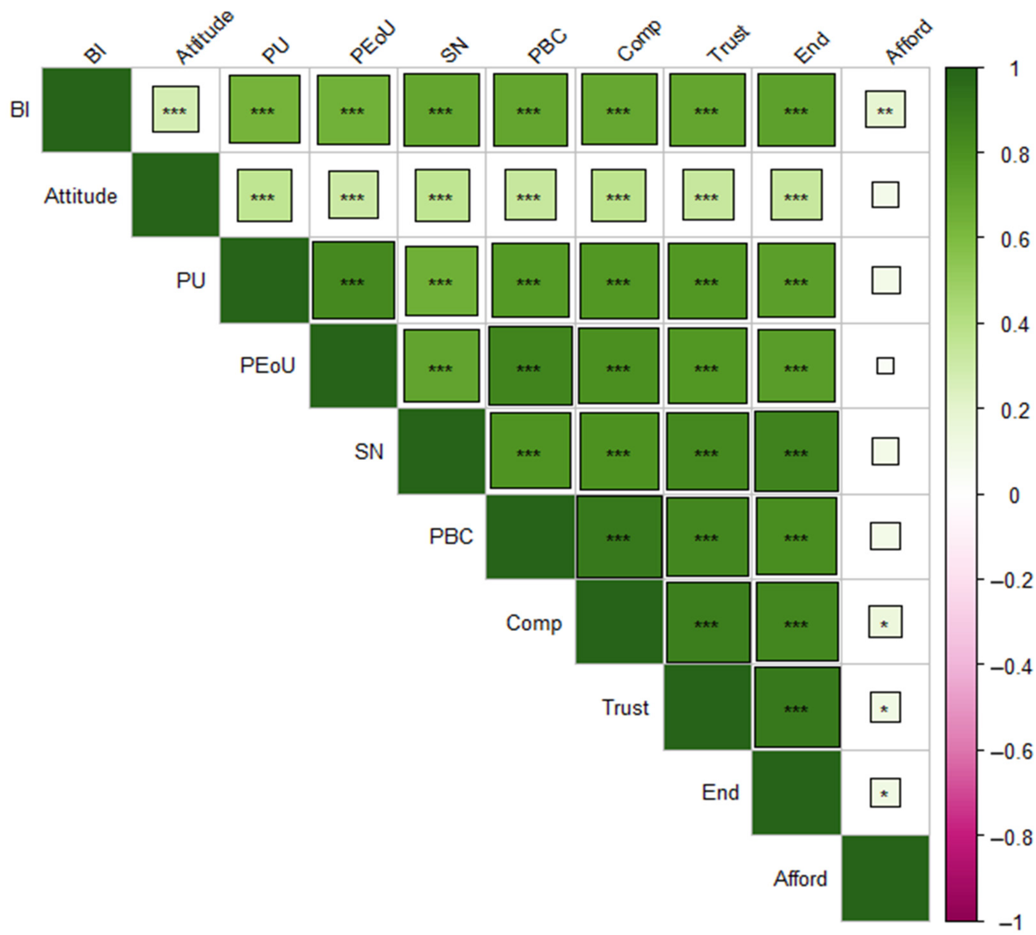

Figure 3. Correlation analysis of subscales (Vietnam). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6.4. Simple Linear Regression Analysis

Simple linear regression analysis was performed to examine whether each hypothesised predictor individually contributes to the variance explained in behavioural intention. The results for Belgium are shown in Table 4.

All independent variables had a statistically significant association with the behavioural intention to use the studied ADAS. Largest effects were found for endorsement (Adj. R^2 = 0.584), compatibility (Adj. R^2 = 0.490), and trust (Adj. R^2 = 0.471), and lowest for the subjective norm (Adj. R^2 = 0.145) and affordability (Adj. R^2 = 0.161).

Table 5 contains results for the Vietnamese sample.

In the Vietnamese sample, all hypothesised predictors from the UMDA showed statistically significant contributions to the variance explained in behavioural intention to use the ADAS. Factors contributing most were endorsement (Adj. R^2 = 0.531), perceived behavioural control (Adj. R^2 = 0.497), and trust (Adj. R^2 = 0.496). Also, in this case, the subjective norm (Adj. R^2 = 0.493) was substantially more influential compared to what was found for Belgian respondents. The lowest effects were obtained for affordability (Adj. R^2 = 0.03) and attitude (Adj. R^2 = 0.075).

Table 4. Simple linear regression (Belgium).

Models	Adj. R^2	B	SE B	β
1. Model: BI = Att Predictor: Attitude	0.313	0.563	0.046	0.562 ***
2. Model: BI = PU Predictor: Perceived Usefulness	0.396	0.708	0.049	0.630 ***
3. Model: BI = PEoU Predictor: Perceived Ease of Use	0.343	0.695	0.054	0.587 ***
4. Model: BI = SN Predictor: Subjective Norm	0.145	0.426	0.057	0.385 ***
5. Model: BI = PBC Predictor: Perceived Behavioural Control	0.176	0.496	0.059	0.422 ***
6. Model: BI = Com Predictor: Compatibility	0.490	0.760	0.043	0.701 ***
7. Model: BI = T Predictor: Trust	0.417	0.607	0.04	0.647 ***
8. Model: BI = End Predictor: Endorsement	0.584	0.703	0.033	0.765 ***
9. Model: BI = Aff Predictor: Affordability	0.161	0.347	0.044	0.405 ***

*** $p < 0.01$; B—regression coefficient, SE B—standard error of B, β—standardised regression coefficient.

Table 5. Simple linear regression (Vietnam).

Models	Adj. R^2	B	SE B	β
1. Model: BI = Att Predictor: Attitude	0.075	0.34	0.067	0.280 ***
2. Model: BI = PU Predictor: Perceived Usefulness	0.399	0.563	0.04	0.634 ***
3. Model: BI = PEoU Predictor: Perceived Ease of Use	0.412	0.625	0.043	0.643 ***
4. Model: BI = SN Predictor: Subjective Norm	0.493	0.679	0.04	0.703 ***
5. Model: BI = PBC Predictor: Perceived Behavioural Control	0.497	0.731	0.042	0.706 ***
6. Model: BI = Com Predictor: Compatibility	0.477	0.675	0.041	0.692 ***
7. Model: BI = T Predictor: Trust	0.496	0.705	0.041	0.706 ***
8. Model: BI = End Predictor: Endorsement	0.531	0.708	0.038	0.730 ***
9. Model: BI = Aff Predictor: Affordability	0.03	0.185	0.057	0.183 ***

*** $p < 0.01$; B—regression coefficient, SE B—standard error of B, β—standardised regression coefficient.

6.5. Hierarchical Multiple Regression Analysis

Since the bivariate correlation analysis indicated strong correlations between pairs of different factors, we checked for multicollinearity between the independent variables using variance inflation factors (VIFs) before carrying out hierarchical multiple regression analysis. In the Belgian data, all variables were found to have VIFs less than 5, which is a recommended threshold [107]. In the Vietnamese data, a few independent variables showed multicollinearity and were, therefore, not included. Accordingly, the final modelling was based on attitude, perceived usefulness, subjective norm, affordability, the perceived ease of use, and compatibility. In each step, variables were added to the regression analysis based on the descending order of their predictive ability (as shown by R^2 in Tables 6 and 7).

Table 6. Hierarchical multiple regression model with forward selection (Belgium).

Model							
Tests		**Adj. R^2**	**B**	**SE B**	**β**	**F-Change**	***p*-Value**
Step 1	Model: BI = End	0.584					
	Predictor: Endorsement		0.703	0.033	0.765 ***		
Step 2	Model: BI = End + Com	0.651				61.804	0.000
	Predictor: Endorsement		0.493	0.040	0.536 ***		
	Predictor: Compatibility		0.375	0.048	0.346 ***		
Step 3	Model: BI = End + Com + PU	0.670				19.820	0.000
	Predictor: Endorsement		0.432	0.042	0.470 ***		
	Predictor: Compatibility		0.301	0.049	0.278 ***		
	Predictor: Perceived Usefulness		0.211	0.047	0.188 ***		
Step 4	Model: BI = End + Com + PU + Aff	0.679				9.738	0.002
	Predictor: Endorsement		0.409	0.042	0.445 ***		
	Predictor: Compatibility		0.294	0.049	0.271 ***		
	Predictor: Perceived Usefulness		0.194	0.047	0.173 ***		
	Predictor: Affordability		0.092	0.029	0.107 ***		
Step 5	Model: BI = End + Com + PU + Aff + PEoU	0.679				1.410	0.236
	Predictor: Endorsement		0.403	0.042	0.438 ***		
	Predictor: Compatibility		0.278	0.050	0.257 ***		
	Predictor: Perceived Usefulness		0.170	0.051	0.152 ***		
	Predictor: Affordability		0.089	0.029	0.104 **		
	Predictor: Perceived Ease of Use		0.064	0.054	0.054		
Step 6	Model: BI = End + Com + PU + Aff + Att	0.682				3.913	0.049
	Predictor: Endorsement		0.397	0.042	0.432 ***		
	Predictor: Compatibility		0.275	0.049	0.253 ***		
	Predictor: Perceived Usefulness		0.163	0.049	0.145 ***		
	Predictor: Affordability		0.087	0.029	0.101 ***		
	Predictor: Attitude		0.082	0.041	0.082 ***		
Step 7	Model: BI = End + Com + PU + Aff + Att + PBC	0.681				0.221	0.639
	Predictor: Endorsement		0.396	0.042	0.431 ***		
	Predictor: Compatibility		0.267	0.052	0.246 ***		
	Predictor: Perceived Usefulness		0.163	0.049	0.145 ***		
	Predictor: Affordability		0.084	0.030	0.098 **		
	Predictor: Attitude		0.083	0.042	0.083 *		
	Predictor: Perceived Behavioural Control		0.021	0.044	0.018		
Step 8	Model: BI = End + Com + PU + Aff + Att + SN	0.682				1.545	0.215
	Predictor: Endorsement		0.415	0.044	0.451 ***		
	Predictor: Compatibility		0.281	0.050	0.259 ***		
	Predictor: Perceived Usefulness		0.162	0.049	0.144 ***		
	Predictor: Affordability		0.087	0.029	0.102 **		
	Predictor: Attitude		0.083	0.041	0.083 *		
	Predictor: Subjective Norm		−0.051	0.041	−0.046		
Step 9	Model: BI = End + Com + PU + Aff + Att + T	0.681				0.045	0.833
	Predictor: Endorsement		0.404	0.052	0.439 ***		
	Predictor: Compatibility		0.277	0.050	0.255 ***		
	Predictor: Perceived Usefulness		0.164	0.050	0.146 ***		
	Predictor: Affordability		0.087	0.029	0.102 **		
	Predictor: Attitude		0.081	0.042	0.081		
	Predictor: Trust		−0.011	0.050	−0.011		

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7. Hierarchical multiple regression model with forward selection (Vietnam).

Model							
Tests		**Adj. R^2**	**B**	**SE B**	**β**	**F-Change**	
Step 1	Model: BI = SN	0.493					
	Predictor: Subjective Norm		0.679	0.040	0.703 ***		
Step 2	Model: BI = SN + PU	0.543				34.193	0.000
	Predictor: Subjective Norm		0.488	0.050	0.505 ***		
	Predictor: Perceived Usefulness		0.268	0.046	0.302 ***		
Step 3	Model: BI = SN + PU + Com	0.555				9.227	0.003
	Predictor: Subjective Norm		0.378	0.061	0.391 ***		
	Predictor: Perceived Usefulness		0.179	0.054	0.201 ***		
	Predictor: Compatibility		0.222	0.073	0.227 ***		
Step 4	Model: BI = SN + PU + Com + PEoU	0.554				0.434	0.510
	Predictor: Subjective Norm		0.371	0.062	0.384 ***		
	Predictor: Perceived Usefulness		0.155	0.065	0.174 ***		
	Predictor: Compatibility		0.206	0.077	0.211 ***		
	Predictor: Perceived Ease of Use		0.051	0.078	0.053		
Step 5	Model: BI = SN + PU + Com + Aff	0.563				6.382	0.012
	Predictor: Subjective Norm		0.383	0.061	0.396 ***		
	Predictor: Perceived Usefulness		0.181	0.054	0.203 ***		
	Predictor: Compatibility		0.203	0.073	0.208 ***		
	Predictor: Affordability		0.098	0.039	0.097 ***		
Step 6	Model: BI = SN + PU + Com + Att	0.554				0.376	0.540
	Predictor: Subjective Norm		0.382	0.062	0.396 ***		
	Predictor: Perceived Usefulness		0.182	0.054	0.205 ***		
	Predictor: Compatibility		0.225	0.073	0.230 **		
	Predictor: Attitude		−0.031	0.051	−0.026		
Step 7	Model:BI = SN + PU + Com + Aff + Att	0.562				0.544	0.461
	Predictor: Subjective Norm		0.388	0.061	0.402 ***		
	Predictor: Perceived Usefulness		0.185	0.054	0.208 ***		
	Predictor: Compatibility		0.206	0.073	0.211 **		
	Predictor: Affordability		0.099	0.039	0.098 **		
	Predictor: Attitude		−0.037	0.051	−0.031		

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6 presents the outcome for the Belgian sample.

The final model for Belgium was obtained after six steps. It included endorsement, compatibility, perceived usefulness, affordability, and attitude as statistically significant predictors of the behavioural intention to use the ADAS examined in this study. Together, these five variables explained 68.2% of the variance in behavioural intention. This means that empirical support was found for hypotheses 1, 2, 6, 8, and 9, while hypotheses 3, 4, 5, and 7 could not be confirmed.

Table 7 shows the results for the Vietnamese sample.

The final model for the Vietnamese data was obtained after five steps. It retained the subjective norm, perceived usefulness, compatibility, and affordability as the predictors of the behavioural intention to use the ADAS studied here. These four predictors explained 56.3% of the variance in behavioural intention. Thus, empirical support was provided for hypotheses 2, 4, 6, and 9, while hypotheses 1, 3, 5, 7, and 8 were not confirmed.

6.6. Mediation and Moderation Analysis

Following the Rahman et al. [51] methodological protocol, mediation and moderation analyses were conducted as the final steps of this analysis. In line with the reasoning proposed by Rahman et al. [51] (p. 138), the attitude was examined as a potential mediator between various factors hypothesised by the UMDA and behavioural intention to use the ADAS. For more detailed statistical outputs, we refer to 'Supplementary Materials: Mediation Analyses' for mediation (Tables S1–S5) and 'Supplementary Materials: Moderation Analyses' for moderation (Tables S6–11), where only the results for significant mediation and moderation effects are presented. For Belgium, the results indicated that attitude partially mediated the effects of endorsement, compatibility, perceived usefulness, and affordability on behavioural intention. This finding implies that these factors not only have a direct influence on behavioural intention but also shape attitude, which in turn affects behavioural intention indirectly. Taking endorsement as an illustrative example, partial mediation by the attitude in simpler terms implies that more endorsement towards the studied ADAS results in an increased intention to use it, with part of this effect dependent on how favourable people's attitudes are towards the ADAS; more endorsement leads to a more favourable attitude, and a more favourable attitude results in an increased intention to use the ADAS. In the Vietnamese sample, only the influence of affordability on behavioural intention was partially mediated by attitude, meaning that the more affordable the investigated ADAS is perceived, the more favourably Vietnamese respondents are disposed towards the system, making it more likely that the ADAS will be used. These findings offer partial support for hypothesis 10 in both countries.

The socio-demographic variables, including age, gender, level of education, driving experience, level of experience with the ADAS studied, and personal innovativeness, were tested as candidate moderators of the effects of the nine hypothesised predictors on behavioural intention to use the ADAS. For Belgium and Vietnam, no moderating effects were found for age, gender, or driving experience. However, in Belgium, education level significantly moderated the effects: higher education levels were associated with a weaker influence of perceived usefulness ($\beta = -0.09$, $p < 0.1$) and endorsement ($\beta = -0.11$, $p < 0.05$) on behavioural intention to use the examined ADAS (as indicated by the β-coefficient for the interaction term (see Supplementary Materials: Moderation Analyses). To put it simply, compared to people with a lower level of education, for people with a higher level of education, the intention to use the ADAS is less dependent on how useful it is perceived or how strongly it is endorsed. The level of user experience with the ADAS also negatively moderated the effect of endorsement ($\beta = -0.09$, $p < 0.1$) on behavioural intention in the Belgian sample: compared to people without actual user experience, for people who already experienced it, the intention to use the system is less dependent on how much it is endorsed. For Belgian respondents, personal innovativeness was another negative moderator of the effect of perceived usefulness ($\beta = -0.16$, $p < 0.05$) and compatibility ($\beta = -0.11$, $p < 0.1$) on the behavioural intention to use the ADAS: compared to people who are less open towards new technology, for people who are more open towards new technology, the intention to use the ADAS is less dependent on how useful or compatible it is perceived.

Interestingly, in the Vietnamese sample, the level of education was also identified as a significant moderator, but contrary to the Belgian sample, it strengthened the relationship between perceived usefulness ($\beta = 0.14$, $p < 0.05$) and the behavioural intention to use the ADAS. This finding indicates that higher-educated individuals place greater reliance on perceived usefulness compared to their less-educated counterparts. In line with Belgian data, the level of user experience had a weakening effect, but moderated effects were generated by another selection of predictors, i.e., the subjective norm ($\beta = -0.14$, $p < 0.01$), perceived usefulness ($\beta = -0.18$, $p < 0.01$), and compatibility ($\beta = -0.16$, $p < 0.1$). Put differently, compared to people without user experience, for people who experienced the studied ADAS, the intention to use it is less dependent on how people important to them think about using or not using the system or how useful or compatible they perceive it. Finally, personal innovativeness was also found to weaken the effects of the subjective norm ($\beta = -0.16$, $p < 0.01$), perceived usefulness ($\beta = -0.29$, $p < 0.01$), compatibility ($\beta = -0.15$, $p < 0.01$), and attitude ($\beta = -0.30$, $p < 0.1$) among Vietnamese respondents. In other words, compared to people who are less open towards new technology, for people who are more open towards new technology, the intention to use the ADAS is less dependent on how peers/people important to them think about using or not using the system, how useful or compatible they perceive it, or how favourably they are personally disposed towards it. Together, the above-mentioned results provide partial support for hypothesis 11 in both Belgium and Vietnam.

7. Discussion

7.1. Descriptive Findings

The mean values for the behavioural intention to use ADASs and the nine predictors proposed by the UMDA show that Belgian and Vietnamese drivers are generally positive towards supportive car technology at SAE level 0, combining forward collision warning, headway monitoring and warning, and lane assistance. In qualitative terms, respondents from both countries somewhat to moderately agree on their willingness to use systems with these features. Our results align with the only other study where the complete UMDA was implemented (see [51]: Table 2), which also examined lower SAE level ADAS features. More specifically, they examined driver fatigue monitoring and warning systems, which are situated at SAE level 0, and adaptive cruise control and lane-keeping systems, which are situated at SAE level 2. Similar results were found in another study by Rahman et al. ([118], see Table 3), which explored the predictive validity of two versions of the TAM, TPB, and UTAUT for the same two systems using both questionnaires and simulator data. Comparable findings were also reported for higher levels of automation. Nordhoff et al. ([89]: see Table 2), for example, applied the UTAUT2 to assess the acceptance of conditionally automated cars (SAE level 3) and found mean values reflecting responses ranging from neutral to positive on a 5-point Likert scale, exploring acceptance and its underlying factors. Similarly, Buckley et al. ([119], see Table 1) conducted a simulator study that combined ‘trust’ with constructs from the TAM and TPB to investigate conditional automation (SAE level 3) and reported descriptive statistics consistent with the aforementioned studies.

A noteworthy finding across both Belgian and Vietnamese samples was the relatively lower scores for ‘affordability’ compared to other predictors of acceptance. Despite a generally favourable disposition towards the ADAS, affordability is understood here as the willingness to pay for the ADAS features [51] was less supported with mean values of 2.64 and 2.54, respectively, suggesting a willingness to pay between EUR 200 and EUR 600 for the system either as an option in new cars or as a retrofit. This finding aligns with Rahman et al. [51], where respondents indicated a willingness to spend USD 250 to USD 750 for systems monitoring driver fatigue (SAE level 0) or offering advanced cruise control and lane-keeping assistance (SAE level 2), indicating consistent price sensitivity across different studies and settings.

7.2. Predictive Validity

Overall, this study’s findings provide empirical support for the UMDA in both Belgium and Vietnam, though not all hypotheses were fully confirmed. Hierarchical multiple regression analysis revealed that significant predictors from the UMDA accounted for 68% and 56% of the variance in the intention to use the studied ADAS features in Belgium and Vietnam, respectively.

Looking at the explanatory power of the UMDA, it is interesting to observe that the results align more closely with findings from other research on lower-level ADASs (SAE levels 0 to 2) than with studies on higher automation levels (SAE levels 3 to 5). For instance, Rahman et al. [118], Table 2 reviewed 12 studies utilising the TAM, TPB or UTAUT for ADAS acceptance, where the variance explained ranged from 20% to 73%, with most studies (nine total) showing a 50% to 70% variance explanation for lower-level ADAS features. One study also focused on SAE levels 0 to 2 (i.e., [118]) and found the predictive power of such models even to be higher. Using a mixed method approach with data from an online survey (N = 387) and simulator (N = 43), Rahman et al. [118] found that two versions of the TAM, TPB, and UTAUT explained between 71% and 82% of the variance in acceptance. Similarly, in the only study where the complete UMDA was applied to predict the acceptance of ADAS features at SAE levels 0 to 2 (i.e., [51]), the UMDA variables explained 85% of the variance in acceptance. The authors attributed the high level of explained variance to the comprehensive nature of the UMDA (i.e., nine predictors in total), including newly added components like endorsement, compatibility, and affordability.

A direct comparison with the only other study where a complete UMDA was empirically tested on lower-level ADAS (i.e., [51]) reveals both similarities and differences. Endorsement and compatibility were among the three strongest predictors in Belgium in correspondence with Rahman et al. [51]; however, these predictors were less influential in Vietnam. Perceived usefulness was also a significant predictor of ADAS acceptance in Rahman et al. [51], as it was for Belgian and Vietnamese respondents in this study. While affordability also predicted acceptance in this study and in Rahman et al. [51], it was not the most influential factor in their study. Conversely, attitude, which was the most influential factor in Rahman et al. [51], played a lesser role in our study, potentially due to our shorter, four-item measure compared to their nine-item measure, which might have captured more relevant aspects of attitude. The significance of a subjective norm, not retained in Rahman et al. [51], was particularly influential in this study for Vietnamese respondents and will be further discussed in Section 7.3.

From a theoretical perspective, this study underscores the importance of three newly added variables by Rahman et al. [51] in predicting the acceptance of lower-level ADASs. In Belgium, endorsement emerged as the strongest predictor of intention to use ADASs, while compatibility and affordability also made significant contributions to the explained variance in that intention in both Belgium and Vietnam. Worth noticing was a strong association between trust and acceptance established using correlation and simple regression analysis in both countries, which supports enhancements made to the TAM by the Automation Acceptance Model (see [70]). In the literature, compatibility, more specifically, was found relevant in higher-level automation contexts (e.g., [71–73]). Additions from the TPB—specifically the subjective norm and perceived behavioural control—were found to be particularly relevant in Vietnam (see Section 7.3 for further discussion). From the original TAM, perceived usefulness was the only significant predictor, while the roles of attitude and perceived ease of use were less impactful compared to previous research. In this study, attitude mainly functions as a partial mediator of effects stemming from various system-related opinions, such as usefulness, compatibility, and affordability in Belgium, and affordability in Vietnam, aligning well with its theoretical role in the TAM.

Finally, our findings support the hypothesis that complex structural interrelationships exist between domain-specific evaluation aspects and individual-specific variables. However, while moderational effects like education level, system experience, and personal innovativeness were evident in our study, such effects are less commonly reported in studies focusing on SAE levels 0 to 2, i.e., lower-level ADASs (see, for instance [51,118]). In contrast, these effects are more frequently observed and reported in studies concerning higher-level vehicle automation, as seen in reviews of ADAS acceptance at SAE levels 4 and 5 (e.g., [71,73]).

7.3. Cross-Country Comparison

Descriptive statistics indicate that Vietnamese respondents scored higher on all statements (except for affordability) than Belgians, meaning they were more supportive of the ADAS studied. Yet, whether this finding reflects an authentically more favourable predisposition or is a methodological artefact resulting from a tendency among Vietnamese respondents to respond in a socially desirable way remains an open question. Relevant mentioning here is that a higher percentage of Vietnamese respondents declared openness to innovation (74.3%) compared to Belgians (57.5%), which could explain their more pronounced support. Moreover, research indicates Southeast Asian consumers are the most optimistic to embrace an increasingly tech-infused world. The latter appears, for instance, from the VMware Digital Frontiers 4.0 Study in 2022, which is a multi-country study surveying the behaviours, preferences, and attitudes towards digital services and experiences of 9728 consumers from different countries worldwide (see "VMware" [120]). More in detail, South Korea came out as the most excited and ready country (64%) to welcome increased digital experiences in life, followed by the rest of the Southeast Asian region (62%). This was substantially higher than in the US (35%), UK (37%), Germany (46%), France (37%), Italy (50%), and Spain (47%). Currently, one can only speculate if this tech-favourable orientation is present in Vietnam as well. Whether such more encompassing tech-savviness can boost acceptance among Vietnamese consumers towards assistive vehicle technology, more specifically, is a topic that certainly merits further attention.

Cross-country similarities and differences emerged in examining the predictors of acceptance for the ADAS. Both Belgian and Vietnamese respondents showed that perceptions of usefulness, compatibility, and affordability significantly influence their intentions to use the system: the more people consider these features as outcomes expected to result from system use, the more probable it becomes they will employ the system. However, notable differences include the prominence of endorsement as a predictor of acceptance in Belgium and subjective norm in Vietnam. As for the former, even though multicollinearity might have affected the outcome for endorsement in the Vietnamese data, the stronger influence of endorsement in Belgium may relate to its longer exposure to ADASs, given its more established automotive market (or higher market penetration rates) compared to Vietnam. This exposure and positive experiences with ADASs could lead to more stabilised favourable opinions and advocacy for ADAS use in Belgium. Contrary to that, ADAS-related opinions and attitudes among Vietnamese consumers might not yet be mature enough to result in active endorsement, which could explain why endorsement was less important in determining acceptance among Vietnamese respondents. However, it is important to note that user experience with the ADAS features examined was relatively limited and showed only a slight difference between the two countries (35.09% in Belgium versus 29.37% in Vietnam). Furthermore, the mean value for endorsement obtained for Vietnamese respondents was slightly higher compared to Belgians (i.e., M = 5.65 for Vietnam versus M = 5.18 for Belgium), and endorsement was significantly associated with acceptance based on correlation and simple regression analysis in the Vietnamese data, too. Therefore, more research is required to elucidate the role of endorsement in predicting acceptance towards the ADAS in Vietnam.

Subjective norms were the strongest predictor of ADAS acceptance in Vietnam while much less important in Belgium, which may be attributed to cultural differences. There is indeed prior research available where cultural identity has been found to influence technology acceptance (e.g., Srite [121]). Hofstede's framework [122] on cultural identity, which includes dimensions such as power distance, masculinity, uncertainty avoidance, and individualism versus collectivism, could help explain this difference. As for individualism, some cultures score high on this dimension, while others score low, meaning they are collectivistic in nature. Collectivism is a personal or social orientation that emphasises the good of the group, community or society over and above the individual [123]. Comparing the two countries on this specific dimension reveals an outspoken difference with Belgians being individualistic and Vietnamese collectivistic, i.e., Belgium, scoring high on individualism (75), contrasts with Vietnam's collectivistic score of 20: see [124]. Collectivistic cultures, where community interests prevail over individual choices, likely influenced Vietnamese respondents to consider social opinions more heavily in their acceptance of the ADAS. In contrast, in Belgium, attitudes and personal evaluations, indicative of an individualistic culture, play a greater role in ADAS acceptance. Interestingly, and in support of this contention, Yerdon et al. [96] concluded their literature review on determinants of trust in automotive automation, stating that cultural aspects, such as the level of individualism versus collectivism, indeed can be assumed to play a role.

The fact that such differences in cultural orientation can affect the role of other predictors of ADAS acceptance can be derived from the results of the hierarchical multiple regression analysis and mediation analysis. In the Vietnamese sample (i.e., collectivistic orientation), attitude was no significant predictor of acceptance, and attitude only partially mediated the effect on acceptance generated by affordability, while no such mediation was found for the effect generated by the subjective norm. In the Belgian sample (i.e., individualistic orientation), attitude significantly contributed to the prediction of acceptance (although the effect was small), and attitude partially mediated the effect generated by all significant predictors of acceptance, i.e., endorsement, compatibility, perceived usefulness, and affordability. In other words, attitude, an individualistic-oriented concept, played a more pronounced role in predicting acceptance in Belgium than in Vietnam. This finding, related to attitude, is what one would expect in light of the hypothesis that personal predispositions play a more important role in individualistic-oriented cultures than in collectivistic-oriented cultures. More research, however, is necessary to corroborate this assumption.

In evaluating the candidate moderators in this study, most showed consistent effects across both countries. Age, gender, and driving experience did not influence the acceptance predictors, while system experience and personal innovativeness generally weakened the influence of certain predictors in both Belgium and Vietnam. The only difference was that the level of education strengthened the effect of perceived usefulness on acceptance in Vietnam, while it weakened the impact of perceived usefulness and endorsement in Belgium. Frankly, it is rather difficult to come up with a good explanation for such differences in countries since little research is available that allows for a comparison and a better understanding of this finding. Further investigations are required to elucidate the moderational roles of socio-demographic factors in ADAS acceptance more comprehensively.

8. Practical Recommendations

Both Belgian and Vietnamese respondents were generally open to using the studied ADAS (SAE level 0). System-specific opinions on expected usefulness, the ease of use, compatibility, and operator control were positively evaluated. Trust in the system was evident, along with a willingness to endorse it, though affordability remained a concern. In combination with the growing availability of ADAS technology in both European and Southeast Asian markets, this receptive disposition among Belgian and Vietnamese car drivers pleads in favour of policy measures aimed at translating intentions to adopt ADAS into actually purchasing (or retrofitting) and appropriately utilising such technology. Paraphrased in terms of the Transtheoretical Model of Behaviour Change [125], policy efforts should prioritise actions that encourage and maintain ADAS acquisition and use (i.e., behavioural processes of change) rather than focusing on influencing people's decisional balance and building self-efficacy (i.e., cognitive and affective processes of change). Recommended methods for encouraging this change include social liberation (i.e., measures that create changes in the individual's environment so that alternatives are more accessible for adoption and use of an ADAS), self-liberation (i.e., measures that stimulate individuals to choose and commit actually to adopting and using an ADAS), counter-conditioning (i.e., measures that allow individuals to substitute undesired behaviour with the desired behaviour, i.e., adopting and using an ADAS), stimulus control (i.e., measures that remove cues or avoid situations which initiate undesired behaviour and restructure the individual's environment in a way that makes alternatives for adopting and using an ADAS readily accessible), helping relationships (i.e., measures that create trust in others and bring individuals to accept and seek support from others to adopt and use an ADAS), and reinforcement management (i.e., measures that reward people for accepting and utilising an ADAS) (see [126,127]).

Regarding policy measures aimed at promoting behavioural change, Belgium is a few steps ahead in stimulating the adoption of ADASs. As a European Union member, Belgium follows the EU regulation (EU 2019/2144), which mandates certain ADAS features in new vehicle models starting in June 2022 and in all new vehicles by June 2024. This regulation is expected to increase the number of vehicles with an ADAS in Belgium significantly. However, due to the slow rate at which the vehicle fleet is renewed, it will take time before a significant proportion of vehicles are equipped with these systems. To address this, the European Commission is considering the potential to retrofit ADASs into older vehicles (see [35]). Stakeholders have advised the introduction of additional voluntary measures, as mandatory retrofitting is anticipated to face low public acceptance. According to Scholliers [35], these measures include awareness campaigns, subsidies, financial incentives (e.g., tax benefits, insurance discounts), and public procurement requirements.

An illustrative example of effective awareness-raising measures is the ADAS covenant in the Netherlands, where various actors (e.g., OEMs, insurance companies) collaborate on promoting safe ADAS use through awareness campaigns and sharing safety and economic benefits with professional organisations [35]. In the U.S., the 'MyCarDoesWhat' campaign [128] uses digital and traditional media to educate drivers about ADASs. Beyond social marketing, studies (e.g., [64–67]) emphasise the importance of delivering accurate ADAS-related information at the point of sale. Authorities and stakeholders should highlight the benefits, ease of use, and the changing role of drivers [87]. Given the findings in this study, interventions in Vietnam should also target influential social referents to enhance ADAS adoption.

European countries have experience using financial incentives to influence vehicle fleet characteristics, which could be applied to ADAS adoption. Tax incentives, such as favourable tax liability for employees retrofitting company cars or VAT benefits, can reduce costs. Government subsidies for private or fleet owners and insurance policies offering lower premiums or covering ADAS installation costs are also effective approaches. Public procurement requirements can increase ADAS use in public service vehicles. Given the limited willingness to pay for ADAS installation or retrofitting in both Belgium and Vietnam, financial incentives could serve as an effective strategy to accelerate the adoption and use of ADASs.

9. Limitations and Future Research

As with any study, this research has its limitations. First, this research was based on a cross-sectional survey design, which means that, strictly taken, no conclusions can be drawn in terms of causality. Secondly, the extent to which the samples investigated here represent their respective populations was not formally verified. For some background characteristics, caution is warranted. For example, in Belgium, data were collected from Dutch-speaking respondents, meaning the results largely reflect the Flemish perspective. In Vietnam, most of the data were mainly collected in Ho Chi Minh City, thereby putting a geographical constraint on the validity of the findings reported. Future research should replicate this study in a broader geographical and demographic setting. Thirdly, this study used self-report measures for both dependent and independent variables. This approach might have created a common method bias and potentially inflated the effects observed. The predictive validity of the predictors proposed by the UMDA should be examined using other (more objective) measures for acceptance. Moreover, it remains unclear to what extent answers provided by respondents in both Belgium and Vietnam were subject to a social desirability bias. Future research could examine to what extent such a bias might be present and control for it if necessary. Qualtrics was used to administer the questionnaire, which may lead to underrepresenting specific population segments, such as those with limited internet access or lower levels of technological literacy. Other survey administration methods should complement Qualtrics to ensure widespread population representation in future studies. This study did not distinguish between users with no or higher levels of ADAS experience from those with low levels of ADAS experience because it was beyond its scope to only cover a priori acceptance. From a data modelling perspective, this study was an exact replication of the analysis protocol proposed by Rahman et al. [51]. As in their study, multicollinearity was found for some of the variables examined, which implied some of the predictors proposed by the UMDA were excluded from analysis in the Vietnamese data. This outcome might have created a distorted picture of the true role of some UMDA variables in Vietnam. To illustrate: trust was not included in the hierarchical multiple regression analysis, even though both correlation and simple regression analysis identified large and significant associations with acceptance. Therefore, one should be careful in correctly interpreting the role of trust in the formation of acceptance towards ADASs. This finding merits further research. Related to that, more robust statistical techniques (like Structural Equation Modelling) might be required to confirm whether the assumed conceptual structure behind the UMDA can actually be replicated across different countries. This study focused on three ADAS features situated at SAE level 0. However, further research is needed to validate our findings for other assistive functionalities at higher levels of automation. Finally, while this study provided descriptions of the studied ADASs to participants, it did not include an overview of the systems and their capabilities via video or animations. Such visual aids could have enhanced participants' understanding, especially for those with no prior experience with ADASs. Therefore, future research should consider incorporating multimedia tools to better inform participants and improve the quality of their feedback.

10. Conclusions

This study investigated the predictive validity of the UMDA for ADASs in Belgium and Vietnam, two substantially different geographical, socio-cultural, and macroeconomic settings. The focus was on an SAE level 0 ADAS with three specific features, i.e., forward collision warning, headway monitoring and warning, and lane-keeping assistance. Previous studies demonstrated that the ADAS can contribute to safer driving, more efficient fuel usage, and optimised traffic flow. The improved safety aspect specifically motivated this paper. By understanding the determinants of driver acceptance, the acceptance and use of the ADAS can be stimulated, which could contribute to safe driving. The descriptive analysis of the survey data found moderate acceptance towards such a system in Belgium and Vietnam, with participants expressing positive opinions on system-specific aspects, such as expected usefulness, the ease of use, compatibility, and operator control. Both Belgians and Vietnamese seemed to trust the system, believed important social referents would support its use, and were willing to recommend it to others. In terms of affordability, the willingness to pay a cost for installation (or retrofitting) of the system was limited to EUR 200 (minimum) and EUR 600 (maximum). Even though compared to the Belgian ADAS market, the Vietnamese market is still quite young (though forecasted to grow rapidly in the coming years), Vietnamese respondents were overall more supportive than Belgians. This finding might relate to increased levels of personal innovativeness and an outspoken positive orientation towards a tech-infused society in the wider Southeast Asian region. Unlike what was reported in the literature on higher-level ADASs (i.e., SAE levels 4 and 5), the lack of actual user experience did not negatively impact the acceptance towards the ADAS examined here. Probably, the three ADAS features included in this study have already achieved enough market penetration rates for respondents to at least have heard about them or be familiar with their functionalities. Regarding predictive validity, the UMDA scored quite well in both countries, though better in Belgium than in Vietnam. Interestingly, differences in countries were found in terms of which factors were significant in the acceptance prediction. In Belgium, acceptance is mainly determined by endorsement, compatibility, perceived usefulness, affordability, and attitude. In Vietnam, acceptance mainly depends on subjective norms, perceived usefulness, compatibility, and affordability. Attitude partially mediated the effect generated by system-specific beliefs on acceptance, mainly in Belgium. Macroeconomic factors (e.g., difference in maturity of the ADAS market) and socio-cultural characteristics (e.g., individualistic versus collectivistic-oriented identity) could explain why endorsement is more important in Belgium as compared to Vietnam and why individual beliefs play a more prominent role in the prediction of acceptance in Belgium, while group norms and values are particularly important in Vietnam. The background characteristics, system experience, and personal innovativeness weakened the impact of system-specific beliefs on acceptance in both countries, while the level of education had a weakening effect in Belgium versus a strengthening effect in Vietnam. Policymakers should focus primarily on measures that promote the actual purchase and use of the ADAS rather than those aimed at influencing the underlying decisional balance. These recommendations align with the sustainability goals by directly promoting the acceptance of technologies that improve road safety, reduce crashes, and minimise environmental impact in transportation. Moreover, by adopting these actions, it could be assured that resources are directed towards tangible actions that contribute to long-term sustainability outcomes rather than solely influencing attitudes or intentions without necessarily leading to meaningful behavioural change. More research, however, is necessary to corroborate the findings reported here and address some of this study's limitations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/safety10040093/s1, **Mediation Analysis: Belgium**; Table S1: Attitude (Att) mediates the relationship between perceived usefulness (PU) and behavioural intention (BI); Table S2: Attitude (Att) mediates the relationship between endorsement (End) and behavioural intention (BI); Table S3: Attitude (Att) mediates the relationship between compatibility (Com) and behavioural intention (BI); Table S4: Attitude (Att) mediates the relationship between affordability (Aff) and behavioural intention (BI), **Mediation Analysis: Vietnam**; Table S5: Attitude (Att) mediates the relationship between affordability (Aff) and behavioural intention (BI), **Moderation Analysis: Belgium**; Table S6: Level of education as a moderating variable: results of regression analyses; Table S7: User experience as a moderating variable: results of regression analyses; Table S8: User experience as a moderating variable: results of regression analyses, **Moderation Analysis: Vietnam**; Table S9: Level of education as a moderating variable: results of regression analyses; Table S10: User experience as a moderating variable: results of regression analyses; Table S11: Personal innovativeness as a moderating variable: results of regression analyses.

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Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

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List of Abbreviations

BI	Behavioural Intention
Att	Attitude
PU	Perceived Usefulness
PEoU	Perceived Ease of Use
SN	Subjective Norm
PBC	Perceived Behavioural Control
Com	Compatibility
T	Trust
End	Endorsement
Aff	Affordability

Appendix A

Section 4 of the survey: ADAS acceptability and related determinants

In this section of the survey, we are interested in your personal acceptability (i.e., your future intentions to use) of ADASs, and the factors that determine this acceptability. Below, a series of statements will be presented. ATTENTION! In this section, we are focussing on an ADAS that combines three specific functionalities, i.e., (1) Forward Collision Warning, (2) Headway Monitoring and Warning, and (3) Lane Keeping/Assist.

Notice that for us, it does not matter whether you already know such an ADAS, or already have used such an ADAS. Also, you can ignore the cost of such an ADAS when providing your answers. It is your personal opinion that values to us. There are no wrong answers. Most of the statements that follow are accompanied by a 7-point answering scale. Please indicate your answer by selecting the answer option that is closest to your opinion.

While responding to the statements, please always keep in mind the following scenario:

Assume you recently bought a new car and among its features is a driver assistance system that is designed for safe driving. The system can be turned on using a button on the steering wheel. The system can be turned off at any time by pressing the same button on the wheel or by pressing on the brake pedal. The system never takes over control from the driver, it only signals and warns. Once the system is turned on, it will:

1. Alert you (visually and auditorily) to imminent hazards ahead so that you can brake or swerve in time (i.e., Forward Collision Warning)
2. Indicate (visually) the distance from vehicles travelling in front of you in the same driving lane and warn (visually and auditorily) in case headway distance becomes potentially dangerous (i.e., Headway Monitoring and Warning)
3. Indicate (visually and auditorily) unintentional edge line crossings as well as intentional lane switches without using the indicator (i.e., Lane Keeping Assist)

Now, suppose that on a regular weekday, you need to commute to work. This takes about 30 min on each way. Commuting to work could sometimes be frustrating; however, you are used to it. You live in a suburban area outside a large city, where you work. Your commute includes driving through the residential area in your town, then driving about 30 km on an interstate, followed by driving through the city centre. The traffic is generally sparse until you enter the city. Driving in the city involves several signalised intersections; therefore, frequent stop-and-go traffic. You are thinking about whether you should use the driver assistance system described above while commuting to work.

Scales used to measure the factors (Adopted from Rahman et al. [51])

Attitude

1. The use of the system when I am driving would be:

   Useless: 1: 2: 3: 4: 5: 6: 7: Useful

2. The use of the system when I am driving would be:

   Ineffective: 1: 2: 3: 4: 5: 6: 7: Effective

3. The use of the system when I am driving would be:

   Sleep-inducing: 1: 2: 3: 4: 5: 6: 7: Alerting

4. The use of the system when I am driving would be:

   Extremely annoying: 1: 2: 3: 4: 5: 6: 7: Not Annoying

Perceived Usefulness

5. Using the system when driving increases my safety.
6. Using the system would improve my driving performance.

Perceived Ease of Use

7. My interaction with the system would be clear and understandable.
8. I would find the system difficult to use.

9. Interacting with the system would not require a lot of mental effort.

Perceived Behavioural Control

10. I have control over using the system.
11. I have the resources necessary to use the system.
12. I do have the knowledge necessary to use the system.

Compatibility

13. The system is compatible with all aspects of my driving.
14. I think that using the system fits well with the way I like to drive.
15. Using the system would complement my driving style.

Trust

16. I think I can depend on the system for safe driving.
17. I would feel comfortable if my child, spouse, parents—or other loved ones—drove a vehicle equipped with the system.

Endorsement

18. I would recommend that my family and friends buy vehicles equipped with the system.
19. I would recommend that my child, spouse, parents—or other loved ones—use the system.

Subjective Norms

20. People who influence my behaviour would think that I should use the system.
21. People who are important to me would not think that I should use the system.

Affordability

22. How much would you be willing to pay for the system if it were an optional feature in a new car?

	1	**2**	**3**	**4**	**5**	**6**	**7**
Belgium	<€200	€200–€400	€401–€600	€601–€850	€851–€1000	€1001–€1300	>€1300
Vietnam	<$250	$250–$500	$501–$700	$751–$1000	$1001–$1250	$1251–$1500	>$1500

23. How much would you be willing to pay the system if it could be retrofitted to an existing car?

	1	**2**	**3**	**4**	**5**	**6**	**7**
Belgium	<€200	€200–€400	€401–€600	€601–€850	€851–€1000	€1001–€1300	>€1300
Vietnam	<$250	$250–$500	$501–$700	$751–$1000	$1001–$1250	$1251–$1500	>$1500

Personal Innovativeness

24. If I heard about a new technology, I would look for ways to experiment with it.

Behavioural Intention

25. If the system is available in the market at an affordable price, I intend to purchase the system.
26. If my car is equipped with a similar system, I predict that I would use the system when driving.
27. Assuming that the system is available, I intend to use the system regularly when I am driving.

Personal Experience

28. Please indicate your familiarity with the system.
    - I have never heard of a similar driving system.

- I may have heard of a similar driving system.
- I am moderately familiar with similar systems but never used such system when driving.
- I am quite familiar with similar systems but never used such system when driving.
- I have had few instances when I used similar systems when driving.
- I occasionally used a similar system when driving.
- I regularly use a similar system when driving.

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