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Transport Research Arena (TRA) Conference

Autonomous Delivery Robots for Urban Last-mile Logistics Operations: a modified UTAUT framework

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Abstract

Interest in autonomous deliveries among logistics service providers (LSP) is growing. This is due to pressure regarding emission reduction regulations, driving bans inside cities, and growing service demands. Autonomous Delivery Robots (ADR) can form a solution and help to optimize current logistics operations. This work investigates factors that might influence the behavioural intention to use ADR. Focus is on decision-makers of LSP. Data was collected through an online survey. The questionnaire is based on the Unified Theory of Acceptance and Use of Technology (UTAUT). Results provide insights concerning factors shaping the acceptance of ADR for last-mile logistics operations. The factors performance expectancy, facilitating conditions, experience, trust, and perceived risk were found to affect the behavioural intention.

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Keywords: Autonomous Delivery Robots; Last-mile Delivery; Logistics Service Providers; UTAUT

1. Introduction

Autonomous Vehicles (AVs), also understood as ‘automated or self-driving vehicles, robots or robot cars (Baum et al. 2019, p. 2455) are seen as a promising solution among various stakeholders, particularly regarding transport related external cost. AV can help reduce overall emissions and road accidents and improve service and operation levels (Baum et al., 2019).

AV offers a solution to urban logistics that are increasingly facing constraints and pressure. For example, the amount of deliveries of goods is increasing with the emergence of the e-commerce sector and changing consumer demands (Baum et al., 2019). Concurrently, aspects such as delivery time and service are getting increasingly important for receivers (Macrina et al., 2020). Referring to driving bans in cities, autonomous delivery robots (ADR) operating on side-walks and defined as “(. . .) pedestrian sized robots that deliver items to customers without the intervention of a delivery person” (Jennings and Figliozzi, 2019, p. 317) can provide a solution (Figliozzi, 2020; Poeting et al., 2019; Baum et al., 2019). Particularly for Logistics Service Providers (LSP), interest in AV is growing (Poeting et al., 2019).

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the total delivery cost. The algorithm developed allows goods to be delivered in an optimal makespan (Wu et al., 2021). Given optimized delivery processes would lead to reduced cost, this could result in increased profits for LSP and decreased delivery costs for receivers which might form a competitive advantage. However, successfully implementing automated machines in general is considered having a great impact on both business and technological development (Barrat 2013 in Klumpp, 2018).

Previous projects about sustainable last-mile deliveries in cities were conducted. ALEES (Autonome Logistieke, Elektrische Eenheden voor Steden) for example, was aiming at identifying requirements for the usage of AV. ALEES is a regional project in Belgium which was launched in 2016 and completed in 2018. ALEES has seen clear advantages of AV for city logistics operations such as 24/7 operation window, reduction of vehicles on the road and safety-related aspects. ULaaDS (Urban Logistics as an on-Demand Service) is led by three European cities (Bremen, Melechen, Groningen) and aims at zero-emission on-demand deliveries. The use case includes an autonomous shuttle bus capable of transporting both passenger and goods. This ongoing project provides a framework including impact areas and related objectives as well as KPIs. To cite an example, for one of the identified impact areas 'user experience and acceptance', the objective is to reach increased service levels compared to existing delivery schemes which can be measured in terms of customer satisfaction (KPI). A further pilot example is the SAT project (Synergetic Autonomous Transports) which started in January 2021 in Sweden and aims at testing a self-driving shuttle bus and an autonomous delivery robot. The project investigates how these two can co-exist in urban areas. In the context of adoption of new technologies, this study uses the Unified Theory of Acceptance and Use of Technology (UTAUT) framework (Venkatesh et al., 2012) aiming to identify and understand factors influencing the acceptance of ADR.

The paper is organized as follows: Section 2 is composed of literature describing the applied technology acceptance model and previous acceptance studies. Section 3 describes the research approach applied in this work, the data collection as well as data analysis. Finally, in Section 4 results will be presented followed by discussion, future research implications, and limitation in Section 5.

2. Literature

This section briefly presents UTAUT, the theoretical model which this study is based on. UTAUT serves as guidance, to investigate the acceptance of ADR among LSP. This helps to ensure that none of the previously identified and important acceptance constructs are disregarded with this research.

2.1. Technology Acceptance Model

Literature shows multiple models explaining technology acceptance. Taking these into account, an extensive literature review was done by Venkatesh et al. (2003) highlighting eight existing technology acceptance models and their characteristics and Unified Theory of Acceptance and Use of Technology (UTAUT) was developed. The theory contains factors which help to understand human behavioural intentions and was developed for both organizational contexts and consumer contexts. The constructs which are constituting the behavioural intention towards using the technology are performance expectancy, effort expectancy, social influence, and facilitating conditions in the organizational context. Venkatesh et al. (2012) extended the original UTAUT framework and added hedonic motivation, price value, and habits (Venkatesh et al., 2012) for the consumer context. All constructs will be reviewed in the following sections.

2.2. UTAUT constructs and the acceptance of AV

The usefulness of the UTAUT framework (Venkatesh et al., 2012, 2003) was already demonstrated in previous studies (Madigan et al., 2017, 2016; Kapsler and Abdelrahman, 2020; Rahman et al., 2017). To mention a few, Madigan et al. (2016) investigated the acceptance of automated road transport systems by applying the UTAUT framework. Their findings identified performance expectancy and entertainment-related factors, which can be referred to as hedonic motivation, to be crucial. Kapsler and Abdelrahman (2020) investigated the acceptance of autonomous delivery vehicles by receivers. The study was conducted in Germany applying a modified framework based on UTAUT. Results

lead to adding an additional construct to the framework which is price sensitivity. Besides UTAUT, other technology acceptance frameworks were previously used to explore acceptance in the context of the automotive sector. Rahman et al. (2017) did an assessment of existing technology acceptance models such as Technology Acceptance Model (TAM), Theory of Planned Behaviour and UTAUT concerning advanced driver assistance systems. They claim acceptance to be a precondition for an implementation of automated systems into the transportation system. They found all three theories to be providing the right set of constructs to explain driver acceptance. Based on a review of previous studies and findings regarding the UTAUT constructs, a framework was developed which is applied in this work (see Fig 1). In the following subsections, UTAUT constructs and two added constructs which were identified relevant for this study will be presented and discussed.

2.2.1. Performance Expectancy

Performance Expectancy is defined as the “degree to which an individual believes that using the system will help to attain gains in job performance” (Venkatesh et al., 2003), p. 447). Other frameworks such as TAM include constructs such as Perceived Usefulness (Davis, 1989) which can be related to performance expectancy included in UTAUT (Xu et al., 2018). Thus, studies applying TAM were equally considered during the literature review and framework development subsequently. Performance expectancy was found to have the strongest effect on behavioural intention to use an AV by Madigan et al. (2016) and Madigan et al. (2017). Similarly, Fröhlich et al. (2018) identified resistance towards the use of automated trucks among drivers due to uncertainties regarding the AV performance. Further studies argue performance expectancy to have a strong and direct influence on the behavioural intention to use AV (Choi and Ji, 2015; Rahman et al., 2017; Adnan et al., 2018; Xu et al., 2018; Kapsler and Abdelrahman, 2020). Concluding, previous works confirm a positive influence of performance expectancy on the behavioural intention to use AV.

2.2.2. Effort Expectancy

Effort Expectancy is defined as the “degree of ease associated with the use of the system” (Venkatesh et al. (2003), p. 450). Perceived ease of use which is the respective construct included in TAM comes close to effort expectancy (Venkatesh et al., 2003). Studies that refer to perceived ease of use are therefore equally considered. Previous studies reveal differentiating results concerning the effect of effort expectancy. For instance in their study about the acceptance of autonomous shuttle busses Madigan et al. (2017) found only weak effect of effort expectancy. Similarly, did Choi and Ji (2015) identify only weak influences when investigating the acceptance of autonomous passenger vehicles by drivers. One study (Kapsler and Abdelrahman, 2020) which can probably be related most to this work at hand reveals effort expectancy to not have any influence on the behavioural intention. Contrary, the study by Fröhlich et al. (2018) reveals effort expectancy to be a “highly decisive factor” (p. 134) for the intention to use highly automated trucks. As the work at hand focuses on LSP, it is not evident based on previous research findings what the relationship of effort expectancy and behavioural intention to use ADR looks like. Positive effects are assumed based on the UTAUT model, yet it requires further investigation.

2.2.3. Social Influence

(Venkatesh et al. (2003), p.451) define social influence as the “degree to which an individual perceives that important others believe he or she should use the new system”. Subjective Norm is the respective construct included in TAM (Davis, 1989) and Social Norm was included in the Theory of Planned Behaviour (Ajzen, 1991). Previous research about the acceptance of AV reveals social influence to be affecting the behavioural intention (Madigan et al., 2016; Rahman et al., 2017; Kapsler and Abdelrahman, 2020) and even more to have a strong impact on the behavioural intention (Madigan et al., 2017). One study was found stating the opposite and arguing that as so far AV are not available yet, it would be difficult for respondents to imagine the influence of of society (AJT 2016 in Jing et al., 2020). In the context of this work it is assumed that social influence shows an effect and is further investigated.

2.2.4. Facilitating Conditions

Facilitating Conditions are defined as the “degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system” (Venkatesh et al. (2003), p.453). In their study Madigan et al. (2017) see facilitating conditions being crucial when it comes to shaping the behavioural intention to use a technology. They argue that such would promote public engagement and awareness of the technology and its capabilities and thus positively affect the behavioural intention. Also Kapsler and Abdelrahman (2020) argue facilitating conditions to be influential and refer to external resources for instance when needing help. Given the limited knowledge about the acceptance of ADR by LSP, assumptions are made that facilitating conditions positively affect the direct usage of ADR.

2.2.5. Hedonic Motivation

Venkatesh et al. (2012) refer to hedonic motivation as “fun and pleasure derived from using a technology” (p.161). With regards to this, Madigan et al. (2017) investigated the influence of hedonic motivation on the behavioural intention to use the autonomous technology and found it to be the strongest predictor. Yet, their study investigated the acceptance of autonomous shuttle buses for which vehicle features can become very relevant determinants. Similarly, Kapsler and Abdelrahman (2020) found hedonic motivation to be important concerning the acceptance of autonomous delivery vehicles by the public. Further exploration will be done with this work, yet, positive effects are assumed.

2.2.6. Experience

Experience was found to have a direct effect on the actual usage (Venkatesh et al., 2012). For instance, Castritius et al. (2020) investigated the acceptance of automated trucks in platoons both before and after participants gained driving experience and the construct was found influencing. Similarly, Rahman et al. (2017) report positive effects of experience when providing participants of their study with a simulation prior to participation. Based on the above, this work will further explore the influence of experience.

2.2.7. Added constructs: Trust and Perceived Risk

Trust in technology was found to be a major influencing factor on using automated technologies (Numan, 1998; Pavlou, 2003 in Choi and Ji, 2015). Choi and Ji (2015) found trust to be a “major construct for predicting the adoption of autonomous vehicles” (p.699). Moreover, Adnan et al. (2018) emphasize to deeper research the influence of trust in the context of AV. Trust and Perceived Risk are interlinked as perceived risk is defined a key component of trust models (see Berry, 1995; Mayer et al., 1995 in Choi and Ji, 2015). Consumer behaviour theories refer perceived risk to the “expectation of experiencing losses in uncertain situations” (Featherman & Pavlou, 2003; Peter & Ryan, 1976 in Choi and Ji (2015), p.694). Although Venkatesh et al. (2012, 2003) did not include perceived risk in their framework, Kapsler and Abdelrahman (2020) found perceived risk an important predictor for the acceptance of ADV. Yet, in their work, Choi and Ji (2015) found perceived risk to be irrelevant as it is “only” a predictor of trust. Due to the linkage of previous findings, this work foresees to further investigate both constructs.

3. Methodology

3.1. Research Approach and Survey Design

This study is based on the Unified Theory of Acceptance and Use of Technologies (Venkatesh et al., 2003) which originates from quantitative survey-based research. Hedonic motivation, a consumer construct (see Venkatesh et al., 2012) was added to the original organizational model as it was found by previous AV studies to be influential (see Section 2.2.5). The hereby developed and modified UTAUT framework serves as orientation for data collection and analysis. For data collection a survey was designed. The survey was built based on the modified UTAUT framework developed for this work (Fig 1). Adaptations of the original model were brought in order to investigate the the acceptance of ADR by LSP. Thus, the constructs perceived risk and trust were added and experience as an own construct is further explored. Previous research showed selected constructs to have an effect on the behavioural intention to use ADR. Items were measured on a scale signifying responses from “I totally agree” to “I totally disagree” with “I don’t know” as an option to investigate awareness of ADR. Furthermore, socio-demographic questions were asked. Survey ratings were descriptively analyzed as explained in Section 3.2

While hypothesis development in combination with conducting a survey is a common method used when applying UTAUT, this work takes an exploratory approach aiming to get a first-hand understanding of the perception of LSP on ADR. The survey questionnaire is comprised of two sections; the first includes demographic aspects and second presents statements related to the previously presented constructs. In line with Suarez-Álvarez et al. (2018) two questions were formulated as reverse questions in order to avoid response style bias.

3.2. Data Collection and Analysis

Target group of this study is decision-makers of Logistic Service Providers (LSP) in Belgium and other European countries. In total, 38 responses were recorded through online survey. It needs to be noted that 1 decision-maker would usually represent one LSP which makes the sample become more relevant in terms of the number of organizations considered. After filtering incomplete surveys and erasing test answer and duplicates, 19 valid responses remained for data analysis. After the socio-demographic results were evaluated, ratings were descriptively analyzed. Due to

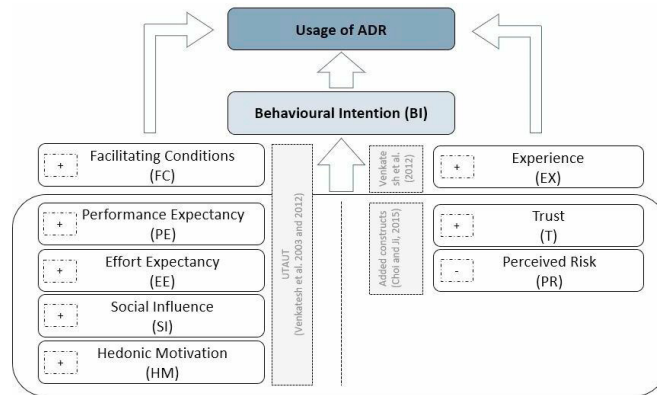


Fig. 1: Acceptance of Autonomous Delivery Robots for Last-mile Logistics Operations: Conceptual Framework (own framework based on Venkatash et al. (2003))

the amount of responses, a rather exploratory approach was undertaken. Results indicate perceptions of the proposed constructs in the context of using ADR.

4. Results

Data was collected through an online survey. In total, 19 valid responses were collected of which 17 are decision-makers and working in a managerial position and 2 classified themselves as others (i.e. self-employed, researcher). 18 respondents are male, while 1 is female. Respondents indicated the country in which their organization is located with Belgium (10), The Netherlands (2), France (1), Spain (1) Germany (1) UK (1) and Sweden (1). Two respondents did not indicate their country. Respondents were asked to fill in their degree of experience; interestingly, 57.9% have at least heard about ADR, 15.8% have actually worked with ADR, 10.5 % have learned about ADR and 15.8% claim to have no experience. In the following results concerning the applied constructs will be presented.

Concerning performance expectancy (Fig. 2a), the majority of 31.6% agree with ADR being generally useful (blue). 52.6% agree and think that ADR can help with accomplishing the delivery task while 21% disagree (orange). 36.8% agree and do think using ADR would save time, yet 47.4% don't know about that (green). The majority of 47.4% agree that ADR can be particularly useful in areas which are difficult to access by a conventional car or van (red). Investigating the construct effort expectancy, more than 57.9% of the respondents disagree with ADR being difficult to understand. However, 42.1% do not know if using and interacting with ADR is easy while 36.8% do agree. When it comes to integrating ADR in daily workflows, 36.8% agree that this can be easy, while 42.1% disagree.

Referring to the influence others have on the intention to use ADR, 31,6.1% agree that they would be more likely using ADR if others would do so. On the other hand, the same share disagrees while 36.8% do not know. A clear majority of 47.4% is unsure whether people around them think they should use ADR or not. 31.6% disagree.

Aiming to get a better understanding of the effect of facilitating conditions on the usage of ADR (Fig. 2b), the clear majority agrees or strongly agrees with all statements. 52.6% agree that if they had the right technical resources, they could think of using ADR (blue) and the same share agrees that if they had the right knowledge about ADR, they would feel confident using them (orange). Again, most of the respondents (36.8%) agree that ADR could be technically and practically integrated in work routines (green). Due to a lack of responses, no clear result can be derived from this survey whether respondents think they could receive help from others when facing difficulties (red). Yet, out of 5 ratings for this question, 40% strongly agree, 20% agree and 40% do not know.

Only for one of the statements related to hedonic motivation an obvious result can be presented; a clear majority of 36.8% agrees with using ADR for performing tasks could be fun, 26.38% strongly agree and 21% disagree.

Concerning the influence of experience, 57.9% of the respondents agree that experiencing ADR (Fig. 2c) could help them understanding their usefulness while 31.6% even strongly agree (blue). Similar results were revealed with 52.6% agreeing and 31.6% strongly agreeing that already having experience could help them using ADR (orange). Concerning trust (Fig. 2d), 47.4% agree that they could not rely on ADR for the performance of tasks (blue). Yet, 63.1% think and agree that they could trust ADR from a technical point of view (orange).

Investigating the risk perception of ADR (fig. 2e), 36.8% of the respondents strongly disagree with ADR being a potential threat that could lead to job loss, the same share disagrees while 5.2% agree and 15.8 % don't know (blue).

When it comes to the performance of ADR, the majority agrees with 36.8% that ADR could not perform well and therefore create problems. 31.6% disagree and 26.3% do not know. (orange). The reverse statement whether respondents do not think using ADR could be risky was answered positively by 31.6.3% agreeing, meaning they do think ADR could be risky while 47.4% do not know (green) and 21.% disagree.

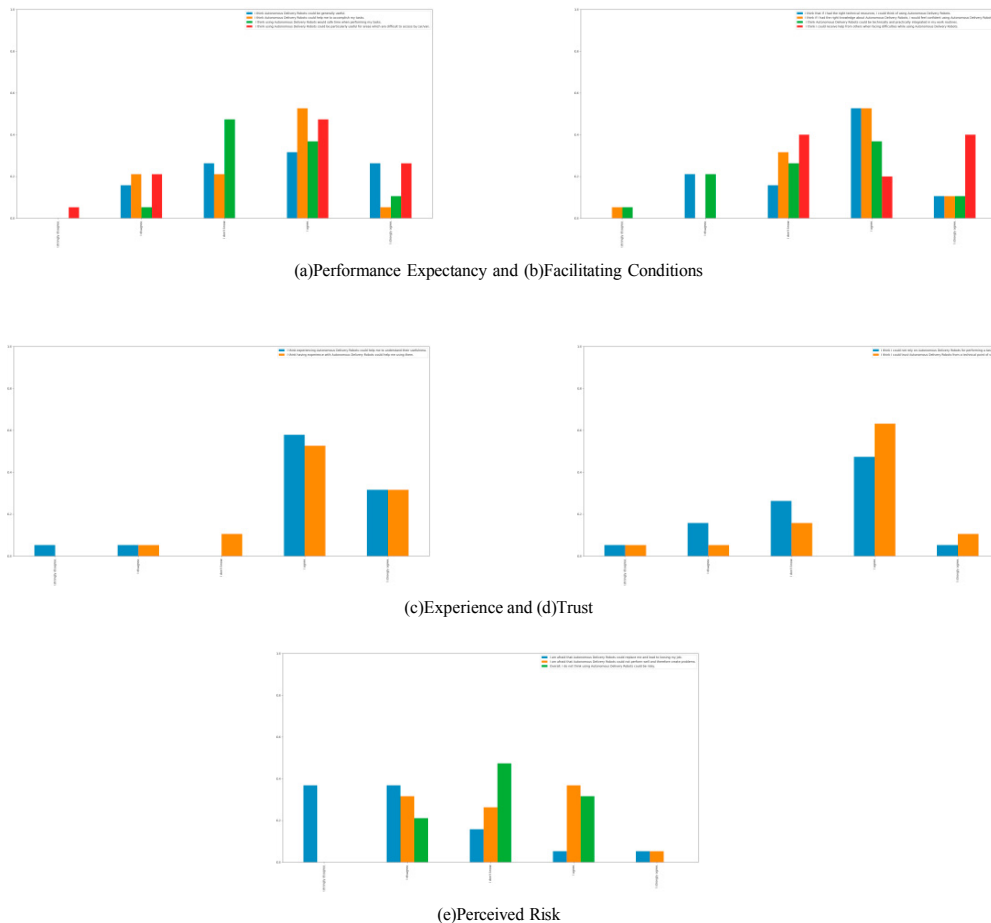


Fig. 2: Plots concerning the constructs of the modified UTAUT model

5. Discussion and Future Work

Investigating the effect of performance expectancy, the majority of respondents perceives ADR being generally useful and that they could even help accomplishing tasks. Moreover, ADR are seen useful for areas which are difficult to access by vans or cars. A notable number agrees that ADR could save time, yet almost 50% do not know. This can be explained by the fact that ADR are not implemented in their fleets yet and no real-life experience could be gained. Summarizing, positive influences of performance expectancy could be observed. Concerning effort expectancy, more than half of the respondents believe that learning about ADR would be easy. Yet, when it comes to interacting with ADR, the majority does not know which can be explained by the newness of the technology.

Concerning the integration of ADR in daily tasks, no meaningful result can be revealed since approximately the same share agrees or disagrees. No clear effect of effort expectancy can be analyzed. Further research for instance in the context of a real-life test study is recommended. To which extend social influence is related to the behavioural intention to use ADR was not observed in this study. Participants equally responded with agree and disagree whether they would use ADR if others did and the nearly same amount does not know. Yet, there are no clear results revealing if others think they should use ADR. It can be assumed that due to the novelty of ADR and the fact that

only 15.8% have actually made real-life experience with ADR, the social influence cannot be sufficiently investigated

at this point in time. Another target group such as work forces or receivers might be more influenced by their peers than decision-makers. As presented in Sec 4 respondents state that the availability of the right technical resources as well as the right knowledge would positively influence their willingness to use ADR. Also, the integration in daily work routines is perceived possible. As mentioned earlier, this aspect is not in line with results revealed for effort expectancy, which similarly aimed to identify the perception of participants concerning the integration of ADR in work routines. This fact can be further explored in future studies.

Concluding positives effects of facilitating conditions could be observed. No clear result could be revealed concerning the effect of hedonic motivation due to lack of responses for 2 of the statements asked. However, for the one statement results could be revealed for, the majority of respondents believes that using ADR could be fun. This construct can be further investigated in future studies by for instance addressing another target group such as work forces or receivers of goods. As outlined before Sec 2.2.6, the factor experience was given attention. Interestingly, the clear majority of respondents supports the fact that experiencing ADR could help them understanding the usefulness and actually using ADR. Thus, in line with Venkatesh et al. (2012), a strong connection between experience and the actual usage of ADR can be assumed. As presented in Sec 4, results showed that a clear majority believes that they could trust ADR from a technical point of view while a notable amount of respondents think that they could not rely on ADR when it comes to actually performing a delivery task. Obvious results could be interpreted as slightly contradicting and can be further explored in future studies. Concerning perceived risk, half of the respondents do not know whether they perceive ADR generally risky. Interestingly, the clear majority does not see ADR being a threat to i.e. job loss. However, a notable number of respondents believes that ADR could cause problems. This is congruent with before-hand discussed when it comes to lacking reliance and ADR for performing daily tasks. Results of this study indicate a link between the constructs trust and perceived risk. This supports Choi and Ji (2015) who refer to risk as a key component of trust. Yet, whether perceived risk as a standalone construct is considered influential for the behavioural intention cannot be confirmed at this point and requires further investigation.

Summarizing, this research reveals first hand insights which help to understand the perception of ADR by LSP. To the best of the authors' knowledge, this is the first study that focuses on decision-makers of LSP when it comes to the acceptance of ADR. To conclude the results presented above, based on positive judgement of performance expectancy, a positive influence on behavioural intention to use ADR can be expected. Similar phenomenon was observed for the constructs facilitating conditions and experience with regards to using ADR. For the added constructs perceived risk and trust, the analysis shows that both constructs are related. No clear influence can be seen for the constructs social influence and hedonic motivation. As discussed in Sec 5 reason could be that decision-makers in their role do not know whether these factors can be influential or not. Addressing this to another audience such as work forces or receivers might reveal more meaningful results.

A clear limitation of the research is that ADR are currently in their testing and piloting phase. Consequently, a real-life experience is limited or non-existing. If ADR were available and participants of the study could experience them, some of the statements might receive more meaningful answers. This refers particularly to those who answered with I do not know which indicates unawareness. Moreover, this study takes into account the view of 19 decision makers located in Europe with the majority in Belgium. Reaching the target group was challenging and exploratory research might be needed. Thus qualitative research such as interviews can be conducted. Additionally, enlarging the scope to other countries could help conducting quantitative research. Both can help validating relationships presented in the herewith used framework.

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