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FULL PAPER

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Die Berichterstattung über autonome Mobilität im öffentlichen Nahverkehr vs. Individualverkehr im Kontext von Wissenschaft: Das Framing von Risiken, Chancen, und Governance in Deutschland von 2018 bis Anfang 2023

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Abstract: Recently, autonomous driving has received significant attention in risk and science communication research due to its increasing public visibility. However, media research has not differentiated between individual autonomous mobility (IAM) and autonomous public transport (APT), although autonomous and/or automated buses are being tested on the roads of many European municipalities. The reference to science in the media discourse has not been a major focus. Therefore, we analyzed regional and national German news media from 2018 to early 2023 using quantitative content analysis. The findings revealed three frames: Neutral traffic/business stories, safety and governance concerns, and benefits of science and technology. APT was framed more positively, while IAM was more often framed in terms of risk/safety concerns. References to science were scarce, with implications for science communication and reporting.

Keywords: Autonomous driving, autonomous mobility, science communication, framing, public transport

Zusammenfassung: In den letzten Jahren wurde Technologien autonomer Mobilität aufgrund ihrer zunehmenden öffentlichen Sichtbarkeit mehr Aufmerksamkeit in der Risiko- und Wissenschaftskommunikationsforschung zuteil. Allerdings mangelt es in der Medienforschung hier bislang an Unterscheidungen zwischen autonomer individueller Mobilität und dem autonomen öffentlichen Nahverkehr, obwohl autonome bzw. automatisierte Busse in zahlreichen europäischen Gemeinden auf den Straßen getestet werden. Auch der Bezug zur Wissenschaft im Mediendiskurs stand nicht im Mittelpunkt. Daher wurden im Rahmen dieser Studie regionale und überregionale Nachrichtenmedien von 2018 bis Anfang 2023 mithilfe einer quantitativen Inhaltsanalyse untersucht. Die Ergebnisse ergaben drei übergreifende Frames: (1) neutrale Storys über Verkehr und Wirtschaft, (2) Sicherheits- und Governance-Bedenken sowie (3) Vorteile von Wissenschaft und Technologie. Der **öffentliche** Nahverkehr wurde eher positiv dargestellt, während **über** individuelle autonome Mobilität häufiger im Zusammenhang mit Risiko-/Sicherheitsbedenken berichtet wurde. Verweise auf wissenschaftliche Forschung waren selten. Daraus folgen Implikationen **für** Wissenschaftskommunikation und -journalismus, die im Beitrag besprochen werden.

Schlüsselwörter: Autonomes Fahren, autonome Mobilität, Wissenschaftskommunikation, Framing, ÖPNV

1. Introduction

The public opinion about science and technology is highly influenced by their portrayal in the news media, which may impact funding, political support, career opportunities, science literacy, and trust in science (Nisbet et al., 2002; Schäfer, 2017). News media appear to be an important driver of individuals' risk perceptions of emerging technologies, particularly when personal experience with the risk is lacking (Renn & Benighaus, 2013). Therefore, both science communication and risk communication researchers have repeatedly analyzed news media content to identify representations of risks, benefits, governance issues, and the way science sources are used to shape emerging technologies such as biotechnology, nanotechnology, or artificial intelligence (AI) (e.g., Donk et al., 2011; Marks et al., 2007; Nguyen & Hekman, 2022). Mediated science communication is considered to play a crucial role in the intersection of science and society, in particular for emerging sciences that confront society with uncertain risks and requirements of regulation (Scheufele, 2022).

Among these emerging sciences, AI and automation have an increasing impact on public discourse and research. In particular, autonomous mobility has been ascribed an influential role in public perception and acceptance of AI applications, as "[t]ransportation is likely to be one of the first domains in which the general public will be asked to trust the reliability and safety of an AI system for a critical task" (Stone et al., 2016, p. 18). Ongoing tests of self-driving cars by major tech companies, as well as pilot projects of automated public transport, increasingly generate first-hand experiences with the technology and media coverage. A few studies have shown significant influence of the mass media on benefit and risk perceptions as well as the willingness to ride autonomous vehicles (Anania et al., 2018; Zhu et al., 2020). Nevertheless, the authors of two recent studies in Germany and the US noted the lack of research on the media's portrayal of autonomous driving (Jelinski et al., 2021; Penmetsa et al., 2023). Like political regulation and governance of autonomous mobility, research on mediated science and technology communication struggles to keep up with the rapid pace of technological development. Consequently, this study aims to examine how the news media have framed autonomous mobility and the role of science in recent years.

With the adoption of the Automated Driving Act in 2021, Germany can be considered a leading country in the field, as the regulation represents the first comprehensive national law on autonomous driving (Kriebitz et al., 2022). In addition, we have identified more than sixty partly publicly funded projects in German municipalities where automated buses have been and are being tested in public transport. This not only allows the local media to cover specific projects in their region but also makes the technology more tangible to the public (Appel et al., 2020). Most of these projects of autonomous/automated public transport (APT) have started after 2017 and were therefore not covered by previous media research on autonomous driving in Germany (Jelinski, 2021; Taddicken et al., 2020). Hence, this research was largely limited to news portrayals of the general technology or applications of individual autonomous mobility (i.e., the development, promotion, and use of autonomous vehicles for private use). Because many of the municipal APT projects included funding for partners at public universities to conduct research on various aspects of the technology during operation, as well as research on public acceptance (Riener et al., 2020), our goal was to identify media frames of APT and compare them to the coverage of individual autonomous/automated mobility (IAM). For IAM, previous research found a dominance of business frames as opposed to science frames or sources. Hence, from a science communication perspective, it is relevant to discern whether publicly funded APT projects with explicit involvement of science and science communication practitioners successfully stimulate news media frames with more pronounced references to science and scientific sources. This is of particular interest as public transport, APT, and APT-related research are highly subsidized in Germany, whereas IAM has largely moved to the business domain. As APT applications increasingly depend on public support, which in Germany remains limited in terms of autonomous mobility (KPMG, 2020; TÜV-Verband, 2021), the news media's framing of APT plays a crucial role.

2. Media coverage of autonomous mobility and its influence on public perceptions

General attitudes towards autonomous mobility in Germany appear to be somewhat ambivalent (KPMG, 2020). Surveys have shown that about half of the population would not consider using driverless vehicles, with younger Germans (18–34) being less skeptical (Bratzel, 2022). People's most prevalent concerns were general safety issues, cyberattacks, accidents, and costs. In a TÜV survey (2021), one-third of the respondents said they would not drive fully automated vehicles once they were allowed to circulate on German roads. Germans have a very low tolerance for accidents caused by autonomous vehicles, with only 4% accepting driving errors comparable to human drivers. Predictors of behavioral intentions to use automated vehicles are, for example, performance expectancy, effort expectancy, trust in driverless cars, hedonic motivation, risk perception, and social influence (e.g., Jing et al., 2020; Kaur & Rampersad, 2018; Nordhoff et al., 2021) according to international research. Few studies have focused on attitudes towards automated public transport (e.g., shuttle buses) in regional pilot projects in Germany or elsewhere. They often found rather positive attitudes among the local population (Beckmann and Zadek, 2022; Kostorz et al., 2019; Rauh et al., 2020). Perceived benefits were related to improved mobility for the elderly or disabled and environmental protection. Concerns were related to the risk of accidents, interaction problems with other road users, and data security. Qualitative research in Singapore has shown that parents, for example, are concerned about technical risks, AI systems, cybersecurity, or harassment related to their children using APT (Ho & Tan, 2023).

Media coverage of autonomous mobility was found to influence the public's perception of the technology. Fraedrich and Lenz (2016) investigated user comments on German and US news articles dealing with the Google Driverless Cars Road approval in California in 2012. Users attributed positive (e.g., safety advantage, more flexibility) and negative characteristics and consequences (e.g., loss of jobs) to autonomous vehicles. The general evaluation of the technology was ambivalent to negative. A survey of Chinese students showed that information about autonomous vehicles is much more frequently retrieved from mass media than social media (Zhu et al., 2020). Mass media use had a positive influence on self-efficacy, risk perception, perceived usefulness, and behavioral intentions. Anania et al. (2018) found that exposure to positive headlines on the subject leads to a higher willingness to use a driverless car than exposure to negative headlines. Attention to news about autonomous vehicles was found to negatively affect excitement and positively predicts anxiety as well as subjective knowledge about autonomous mobility (Myrick et al., 2019).

Although these findings demonstrate the relevance of news media coverage of autonomous mobility for public acceptance, risk perceptions, and behavioral dispositions, only a few studies analyzed the media coverage of autonomous mobility. Taddicken et al. (2020) analyzed German newspaper articles between 2014 and 2017. Four frames emerged from their cluster analysis. In the first frame, autonomous driving was depicted as technological progress with both positive evaluations and prognoses for the future. The second frame was more ambivalent and covered both benefits and risks in more balanced and longer articles. The third frame was more negative, dealing mainly with demands for political regulation. The fourth frame emphasized the benefits of autonomous driving for the economy. Scientific actors were rarely mentioned in comparison to business actors or the technology itself (Taddicken et al., 2020).

Jelinski et al. (2021) examined articles on autonomous driving in German online newspapers from 2017 to 2018. The authors found that most of the articles had a rather neutral tonality with a tendency towards more optimistic arguments with a low level of detail. The articles that were not neutral revealed a discrepancy between the negative headlines and the rather positive article content. The resulting assumption was that readers who only notice the headlines will get a more negative impression, and those who read the entire article will get a more positive impression of autonomous driving.

Using sentiment analysis, Penmetsa et al. (2023) investigated over 1.7 million news articles between 2016 and 2022 in the US. The highest number of articles dealing with autonomous driving was found in 2018, with significant spikes in negativity compared to the other years. The authors attributed this to several accidents in the US involving self-driving vehicles. They concluded that negative events like accidents or catastrophes can lead to media bias regarding autonomous mobility. Such events can be trigger events for processes of social risk amplification as conceptualized in the social amplification of risk framework (SARF) (Kasperson et al., 1988; Kasperson et al., 2022). From this perspective, technological risk events lead to information flows and communication processes through various social stations, including social media and the news media, and, therefore, amplify public risk perceptions. Passing a certain threshold, this process may cause further changes in attitudes and behavior (individual level) or political and social action, as well as changes in risk governance (societal level).

Our literature review shows that findings on media coverage of autonomous mobility are only available until 2018 (Germany) or are limited to sentiment data. In addition, experts have pointed out that while Germany is a leader in autonomous mobility innovation and technology, it lags behind in terms of consumer acceptance (KPMG, 2020). Understanding the dominant news media frames of technology in the country is therefore relevant to explaining this gap from both an aggregate (i.e., frames) and a diachronic perspective (i.e., frame development over time). As a result, our first research question was *How did national and regional news media in Germany frame autonomous mobility from 2018 to early 2023* (RQ1)*?*

Previous media research has not addressed APT as a specific topic or distinguished it from IAM, although a high number of publicly funded APT projects were realized in Germany after 2017 with a significant involvement of scientific actors. These projects have successfully moved autonomous vehicles from closed to public municipal spaces and are considered an important driver of innovation and public acceptance (KPMG, 2020). However, research on APT projects has been limited to surveys of local populations and found that APT was mostly perceived as positive, with some concerns about safety and traffic obstructions (Beckmann & Zadek, 2022; Kostorz et al., 2019; Rauh et al., 2020). Based on the lack of news media research on APT, we posed our second research question: *How did the national and regional news media in Germany frame APT in comparison to IAM (RQ2)?*

Public transportation in this context refers to non-rail and land-based passenger transportation available to the public, which was the most common in the aforementioned projects. In addition, local bus services and short-distance transit are the most important transportation modes in Germany, with approximately five billion passengers in 2023 (Statistisches Bundesamt, 2025).

3. The role of science in the media coverage of emerging technologies

Media research on emerging technologies is extensive and includes, for example, biotechnology (Marks et al., 2007; Matthes & Kohring, 2008), nanotechnology (Donk et al., 2011; Metag & Marcinkowski, 2014), and artificial intelligence (AI) (Cools et al., 2022; Nguyen & Hekman, 2022). Most of this research has used different versions of the framing concept. Since a complete review is beyond the scope of this article, we summarize major findings that exemplify tendencies in the media coverage of emerging technologies and the way science is framed.

German, Swiss and Austrian quality newspapers, for instance, were found to evaluate nanotechnology positively in the early 2000s, focusing mainly on the benefits for medicine, science, and the economy (Metag & Marcinkowski, 2014). Most of the media coverage was published in science sections, and science journalists were an important source of critical judgments. Studying the framing of biotechnology in the US, Matthes and Kohring (2008) identified three frames, one labeled as ‘research benefit’, in which scientists outline benefits for research on biomedicine and health, whereas risks were not discussed. Cools et al. (2022) analyzed news articles in the US between 1985 and 2020 on AI/automation and identified a balanced number of positive and negative frames. Concerning science, a positive frame, labeled ‘gate to heaven’, appeared frequently, presenting AI as a holy grail with very beneficial impact on human lives. A neutral frame with references to science was the ‘uncertainty’ frame, in which AI and automation were presented as complex and inscrutable technological systems or processes. A negative frame that appeared frequently with the topic of science was ‘shortcoming’, in which AI shortcomings were emphasized together with the need for human supervision (Cools et al., 2022).

In summary, media research on science and technology often found positive tendencies in the media coverage with more emphasis on benefits than on risks. The media content tended to feature business and politics more prominently than science and scientists, depending on the specific technology being examined. As shown before, the media coverage of autonomous mobility also rarely refers to science or scientific institutions. While this finding may be because IAM is mainly developed and promoted by business actors, the nature of publicly funded APT projects in Germany and their explicit involvement of public universities and science communicators raises the question of whether science plays a more prominent role in the coverage of APT. Hence, our third research question was: *To what extent did German national and regional news media refer to science topics and sources across frames when reporting about IAM in comparison to APT (RQ3)?*

4. Approach to detecting media frames of autonomous mobility

In general, framing is considered a powerful mechanism in (mediated) science communication, especially in the context of ambiguous stimuli such as emerging technologies, when audiences are required to make judgments about the risks or regulatory policies to manage the risks associated with these technologies (Scheufele, 2013). The field of media framing research was characterized by a vast variety of conceptual and operational approaches (de Vreese, 2012; Guenther et al., 2023). At the conceptual level, issue-specific frames are distinguished from generic frames. Issue-specific frames refer to specific topics or events, whereas generic frames can be identified independently from specific themes over space, time, and cultural contexts (de Vreese, 2012). Since our goal was to identify frames specifically used to report on autonomous mobility and compare them to previous research with similar approaches, an issues-specific approach was more feasible.

At the *operational level*, many approaches to frame measurement exist (Matthes & Kohring, 2008). A simplified distinction often refers to inductive and deductive approaches to frame detection. Inductive methods involve frames emerging from the data, allowing for the possibility of discovering new frames. On the other hand, deductive approaches rely on predefined frames and code for their presence or absence in the material (Iyengar, 1991; Semetko & Valkenburg, 2000). Due to the scarce media research on autonomous mobility and the lack of reference to APT, a list of predefined frames was not available. Therefore, an inductive variable-based approach to framing was used.

A widely adopted conceptual framework that is well-developed at the operational level, is Entman's (1993) frame definition according to which journalists frame certain subjects by selecting "some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation" (p. 52). Using this definition, Matthes and Kohring (2008) developed an operational approach that employs several indicators at the variable level to measure the four frame elements of problem definition, causal interpretation, moral evaluation, and treatment recommendation. Problem definitions consist of an issue (i.e., topics) and relevant actors. Causal interpretation is measured by attributions of failure or success regarding a specific issue. This refers, for instance, to the attribution of risks/benefits by specific senders to those responsible for risks/benefits. Moral evaluations were understood as positive/neutral/negative evaluations of different objects, while treatment recommendations were defined as calls for or against a certain action (Matthes & Kohring, 2008). Each frame element was measured by several variables, which subsequently were used to identify systematic groupings of texts (i.e., frames) using cluster analysis.

With this approach, we analyzed media reports about autonomous mobility according to (a) the main topics, risks and benefits, beneficiary and damaged actors (problem definition); (b) attributions of responsibility for risks and benefits of autonomous mobility *by* and *to* these actors (causal interpretation); (c) evaluations of autonomous mobility in general (moral evaluation); (d) and calls for actions to deal with the issue (treatment recommendation). Thus, for each of the four frame elements, we developed measures for content analysis that were adopted from previous framing research (Donk et al., 2011; Matthes & Kohring, 2008), mainly from the study of Taddicken et al. (2020) on autonomous mobility for reasons of comparability. Some adjustments were made to capture the particularities of APT as well as more differentiated measures of risks and benefits based on our literature review. Science was included as source/actor or topic in all frame elements except moral evaluation.

These indicators were subsequently used in several cluster analyses to detect statistically recurring patterns in the media coverage (i.e., frames). This method of frame detection that has been shown to be valid and reliable compared to alternative approaches and was frequently used to analyze science and technology reporting (e.g., Donk et al., 2011; Matthes & Kohring, 2008; Schwarz & Seidl, 2023; Taddicken et al., 2020).

5. Method

5.1 Sample

We included the nationally circulated newspapers and online magazines *Frankfurter Rundschau*, *Spiegel Online*, *TAZ*, *Welt*, and *ZEIT*. These are among the most influential and widely circulated news media outlets in Germany. As in Taddicken et al. (2020), we included the regional press at the automotive hub of Stuttgart, where companies such as Daimler, Porsche and Bosch are based. To extend the scope of this study compared to previous research and to include media coverage of regional pilot projects in APT, we added between one and three regional newspapers (depending on availability) with the highest circulation in the federal states where such projects were carried out between 2018 and 2023. Most articles were retrieved from Nexis. In some cases, articles were directly retrieved from the newspapers' websites since they were not available otherwise (see Table 1).

Table 1. Sample of regional and national news media outlets and exemplary pilot projects of automated public transport by state

State/region	News media outlets	*n*	Exemplary regional project of automated public transport and project websites
Baden-Württemberg	*Stuttgarter Nachrichten* *Stuttgarter Zeitung*	36 27	U-Shift MAD *https://verkehrsforschung.dlr.de/de/projekte/u-shift/u-shift-mad (website inactive)*
Bayern	*Passauer Neue Presse*	39	HEAL Bad Birnbach *https://heal-badbirnbach.de*
Berlin	*Tagesspiegel* *Berliner Zeitung* *Berliner Kurier*	29 17 4	First Mover *https://www.emo-berlin.de/aktuelles/detail-projekte/first-mover (website inactive)*
Hamburg	*Hamburger Morgenpost*	15	HEAT *https://www.hochbahn.de/en/projects/the-heat-project*
Hessen	*Frankfurter Rundschau** *Frankfurter Neue Presse*	8 16	Mainkai-Shuttle *https://www.probefahrt-zukunft.de/index%20-%20Frankfurt.html*
Niedersachsen	*Nordwest-Zeitung*	28	HubChain *https://www.ikem.de/projekt/hubchain/*
Nordrhein-Westfalen	*Rheinische Post* *Aachener Zeitung*	63 25	Monheim-Shuttle *https://www.bahnen-monheim.de/autonomer-bus/kurzportrait-der-altstadtstromer*
Rheinland-Pfalz	*Allgemeine Zeitung*	19	Hambach-Shuttle *https://www.hambach-shuttle.de/ (website inactive)*
Sachsen	*Sächsische Zeitung*	8	ABSOLUT *https://absolut-projekt.de/*

Sachsen-Anhalt	*Mitteldeutsche Zeitung*	15	AS-UrbanÖPNV *https://www.urban-shuttle.ovgu.de*
Thüringen	*Thüringer Allgemeine* *Ostthüringer Zeitung* *Freies Wort/ in Südthüringen*	53 30 16	CAMIL *https://www.camil-ilmenau.de/*
National (Germany)	*Frankfurter Rundschau** *Spiegel Online* *TAZ* *Welt* *ZEIT*	8 7 16 28 4	(does not apply)

Note. * Frankfurter Rundschau is a national newspaper but also covers regional issues in the state of Hessen, so is listed twice.

Articles published between 1 January 2018 to 22 February 2023 were included. This period was chosen to capture the development in German media coverage after the latest studies' timeframe of analysis ended (Jelinski et al., 2021; Taddicken et al., 2020). In addition, most of the APT projects we identified in Germany began testing automated vehicles in public after 2017.

To ensure that only articles dealing with the topic of autonomous driving and APT were analyzed, the following search term chain was used on Nexis (translated from German):

title((autonomous! OR automated! OR self-driving! OR driverless!) I/50 (drive OR car OR bus OR shuttle OR cars OR buses OR shuttles OR public transport))

We initially found 1,246 articles. These were manually screened to retrieve relevant articles based on their headline and/or lead paragraph, resulting in 785 articles. For the final screening, we reviewed the overall content of articles. Only those with sufficient thematic relevance were included based on the following criteria: (1) The topic of autonomous mobility was mentioned in the title, lead, and/or first paragraph, and (2) the topic was a main focus in most of the article (i.e., at least 50%). If autonomous driving was only briefly mentioned, the article was excluded. After applying these criteria, a final sample of 503 articles was included for coding.

5.2 Instrument

For reasons of comparability, our codebook was mainly based on Taddicken et al. (2020) as well as previous framing research (Entman, 1993; Matthes & Kohring, 2008). For a more detailed overview of coded categories, see Table 2. In addition to formal measures, the following categories and sub-categories were added to consider the reporting on APT and to answer RQ2 and RQ3. The variable "topic category" was included to differentiate between articles that covered IAM, APT, or both. Science/research was added as an additional main topic and as one of the stakeholders benefiting from (e.g., more funding opportunities) or being adversely affected ('damaged') by the technology (e.g., public criticism).

The indicator "future prospects" was excluded from the framing analysis since it does not really reflect a treatment recommendation and rarely occurred in the sample (<30%). We also excluded the mentioned "level of automation" from the frame detection procedure, as it does not really reflect the frame element problem definition and was often not addressed in our sample (46.3%).

Table 2. Operationalization of frame elements (main codebook categories)

Frame element	Main categories	Sub-categories	Gwet's AC1[d]
Problem definition	Main topic	Civil society, technology/innovation, economy, politics, environment, security, transport, science/research[a]	0.48
	Risks/problems	Lack of self-determination, lack of user competence, lack of acceptance, lack of support for people with disabilities[c], loss of the human element[c], high costs, social (professional) changes/ problems, lack of safety/limits of technology, ethical problems, data protection problems, regulatory limitations, traffic problems, disruptions due to unexpected weather or road conditions[c], problems in interaction with other road users[c]	0.88
	Benefits	Mobility and comfort, time savings and convenience, low individual costs, improved safety, economic benefits, environmental protection, low societal costs, solving traffic problems	0.81
	Damaged stakeholders	Human, company/ economy, science/research[a], politics/legislature[a]	0.88
	Beneficiary stakeholders	Human, company/ economy, science/research[a], politics/legislature[a]	0.76
Causal attribution	Stakeholders responsible for risks/problems	Human, car/ technology, company/ economy, science/research, politics/legislature	0.85
	Stakeholders responsible for benefits	Human, car/ technology, company/ economy, science/research, politics/legislature	0.81
Moral evaluation	Evaluation tendency/ acceptance	No evaluation/neutral, positive tendency/acceptance, negative tendency/lack of acceptance, balanced evaluation	0.61
Treatment recommendation	Recommendation for action/solution	Promoting individual competence, social debate/education, financial support/investment, technical development, expansion of infrastructure[a], creating a political/legal framework	0.89
	Sender of recommendation	Human/ private individual/ user, company/economy, science/research, politics/legislature	0.89
	Receiver of recommendation	Human/ private individual/user, car/technology, company/economy, science/research, politics/ legislature	0.87

Further categories (not frame element indicators)	Topic category[a]	Autonomous driving in general, autonomous public transport, both	0.79
	Initial reason for reporting[b]	Crisis/scandal, start/status/end of a (pilot) project with autonomous vehicles (test tracks, etc.), economic activities/developments, scientific development/discovery, developments in politics and legislation, event, art and entertainment	0.65
	Future prospects of the technology	None, positive, negative, uncertain, mixed[a]	0.68

Note. Most measures are based on Taddicken et al. (2020) with the following exceptions: [a]inductively added based on an initial qualitative review of the material, [b]based on the authors' previous research, [c]based on Nordhoff et al. (2019), [d]average of AC1 measures for categories listed in the third column

Based on the extensive literature analysis of Nordhoff et al. (2019), four more sub-categories were added to the list of risks as they appeared to be relevant in the context of APT: Lack of support for people with disabilities, loss of the human element, disruptions due to unexpected weather or road conditions, and problems in interaction with other road users.

Following recent best practice recommendations for content analysis research (Lacy et al., 2015) and due to well-documented limitations of other measures, we calculated Gwet's AC1 (Gwet, 2008) to determine reliability. This measure was demonstrated to be a more stable indicator of inter-rater reliability, that is, based on more realistic assumptions about coder behavior and task difficulty (Feng, 2013; Zhao et al., 2022). After intensive coder training, a final pretest of 50 articles coded by four coders resulted in a satisfactory average reliability value of 0.83 (Gwet's AC 1) for the codebook. The average reliability scores for each of the four frame elements resulted in *problem definition* = 0.84, *causal interpretation* = 0.83, *moral evaluation* = 0.61, and *treatment recommendation* = 0.88 (Table 2). While satisfactory reliability was achieved for most of the main categories, the variables used to code the articles' topic and moral evaluation must be treated with caution. Because these measures were derived from previous research (e.g., Taddicken et al., 2020), we decided to include them in the data analysis for comparability purposes.

5.3 Data analysis

Besides descriptive statistics, chi-square tests, t-tests, and analysis of variance (ANOVA) were used to explore relationships between variables. Effect sizes were reported as Cramer's V (chi-square tests), eta-squared (ANOVA), and Cohen's d (t-tests). The interpretation of effect sizes followed Cohen's (1988) recommendations. We applied two-step cluster analysis for frame detection. This technique has been reported to produce reliable and robust cluster solutions compared to other clustering methods, such as latent class analysis or hierarchical cluster analysis (Kent et al., 2014) and has been used in recent framing research in science communication (Donk et al., 2011; Schwarz & Seidl, 2023). Following Matthes and Kohring (2008), we excluded frame element indicators that occurred with a frequency of less than 5% in the sample. Cluster solutions were regarded as stable when a repeated analysis yielded the same cluster solution and produced a silhouette coefficient above zero (fair cluster solution). Following the approach of Wessler et al. (2016), we first conducted a cluster analysis on all articles to detect the most salient frames in the overall coverage of autonomous mobility. This was followed by two separate cluster analyses on the subsamples of APT and IAM coverage to test whether the frames found in the overall coverage can be replicated in the subsamples, or whether differences emerge that are specific to the coverage of IAM and APT news.

Highly correlated variables that refer to underlying constructs may pose problems of multicollinearity in cluster analysis, which can lead to overweighting those underlying constructs and/or variables (Ketchen & Shook, 1996). Such issues of multicollinearity were often disregarded in previous framing research. A recommended remedy is principal component analysis (PCA) and standardization of variables. Therefore, we performed several PCAs on correlated and conceptually similar frame element indicators before entering them as standardized factor scores (Bartlett method) into the cluster analysis. The number of components were calculated with Eigenvalues > 1 as the criterion, followed by a Kaiser-Varimax rotation. The Kaiser-Meyer-Olkin measure (KMO, at least 0.5) as well as Bartlett's test for sphericity (should be significant, $p < .05$) were used to assess sampling adequacy. Factor loadings > .3 were considered substantial for interpretation (Hair et al., 2019). Some follow-up analyses were conducted using ANOVA with the cluster solution as the factor and, in some cases, binary outcome variables. ANOVA has been shown to work well in such contexts, although some of the classis statistical assumptions are not met (Glass et al., 1972).

6. Results

The 503 articles on autonomous mobility had an average length of 512 words ($SD = 366.26$). The majority was published in local/regional news media (87.5%) compared to national news media (12.5%). This finding points to the importance of regional projects or events related to autonomous mobility and their impact on the regional news media agenda. Most of the news coverage was found in the years of 2018 (28.6%) and 2019 (22.3%), and the least in 2020 (12.9%) and 2022 (14.7%). Most articles referred to IAM (58.8%), followed by APT (37.6%), or both (3.6%).

6.1 Aggregation of frame element indicators

Since many indicators of frame elements were substantially correlated, we conducted several PCA with these variables to reduce multicollinearity (Table 3). Following previous framing research using Entman's frame elements, we excluded variables that were coded with frequencies lower than 5%.

The first PCA comprised 18 indicators for risks and benefits of autonomous mobility about the frame element of problem definition. This resulted in a robust component solution (*KMO* = .80; *Bartlett's test* $p < .001$). Further analysis yielded empirical justification for retaining six factors, which accounted for 57.6% of the total variance. The varimax-rotated factor solution revealed six interpretable components of risks and benefits in autonomous mobility with substantial factor loadings: Traffic/economic benefits, safety and traffic risks, regulatory and ethical risks, individual and environmental benefits, risks related to the users/drivers of autonomous vehicles, and ambivalent cost issues that refer to both low and high costs of autonomous mobility for society.

The second PCA included five indicators that measure the appearance of affected stakeholders in the news coverage. While the KMO was mediocre (.6), substantial factor loadings (> .7) and the high amount of explained variance (59.4%) justified retaining two factors. The first factor refers to beneficiary stakeholders, and the second factor refers to damaged stakeholders.

The third PCA was calculated with seven indicators for causal interpretation. Again, sampling adequacy was only mediocre (*KMO* = .6). Because of robust factor loadings and a good interpretability of the components, we retained the solution with two factors. The first factor, causes of risk, contained four entities that were mentioned as (potential) sources or causes of risk of autonomous mobility. The second factor referred to sources/causes of benefits.

The fourth PCA included treatment recommendations as well as senders and addressees of treatment recommendations (nine indicators). A robust solution (*KMO* = .69; *explained variance* = 59.3%) revealed three components. The first factor (development of technology and skills) included demands for more technological progress, the development of skills, and the expansion of infrastructure. Attributions to the industry/companies as senders and the technology itself as addressee of these demands also loaded on this factor. The second component (politics and governance) referred to political senders and demands for more legal regulation. The third factor (civil demands on the industry) entailed citizens/users as senders and the industry/companies as addressees of treatment recommendations.

Table 3. Principal component analyses (PCA) of frame element indicators

Frame element indicators	Principal components and factor loading					
	1	2	3	4	5	6
PCA1: Problem definition – Risks and benefits (*KMO* = .80, Cumulative % of variance = 57.60)						
Factor 1: Traffic/economic benefits						
Solving traffic problems	0.76					
Economic benefits	0.75					
Mobility and comfort benefits	0.67			0.20	0.24	
Factor 2: Safety and traffic risks						
Safety issues and limits of technology		**0.72**	0.25		0.22	
Disruptions due to unexpected weather or road conditions		0.66				
Problems in interaction with other road users	-0.22	**0.65**				
Traffic problems	0.40	**0.50**	0.22		0.33	
Factor 3: Regulatory and ethical risks						
Regulatory limitations			0.81			
Ethical issues			0.72		0.23	
Data protection issues		0.21	**0.64**			
Factor 4: Individual and environmental benefits						
Individual cost savings				0.78		
Time savings and secondary activities				**0.65**	0.25	
Environmental protection	0.44			0.45		0.19
Improved safety	0.28	0.35		0.36		
Factor 5: User risks						
Lack of user competence					0.78	
Lack of acceptance	0.24				0.73	
Factor 6: Ambivalent cost issues						
High overall social/economic costs						0.86
Low overall social/economic costs				0.46		0.58
PCA2: Problem definition – Affected stakeholders (*KMO* = .60, Cumulative % of variance = 59.43)						
Factor 1: Beneficiary stakeholders						
Companies/industry as beneficiary	.78					
Human as beneficiary	.73					
Science/research as beneficiary	.73					
Factor 2: Damaged stakeholders						

Human as damaged stakeholder		.81				
Companies/industry as damaged stakeholder		.76				
PCA3: Causal interpretation (*KMO* = .60, Cumulative % of variance = 46.13)						
Factor 1: Causes of risk						
Vehicle/technology as cause of the problem	.79					
Human as cause of the problem	.66					
Companies/industry as cause of the problem	.60					
Politics/legislators as cause of the problem	**.37**	.36				
Factor 2: Causes of benefits						
Vehicle/technology as cause of the benefit	.27	**.72**				
Companies/industry as cause of the benefit		.71				
Science/research as cause of the benefit		.64				
PCA4: Treatment recommendations (*KMO* = .69, Cumulative % of variance = 59.26)						
Factor 1: Development of technology and skills						
Companies/industry as sender	.80					
Demand for technological progress	**.69**	.29	.30			
Demand for individual skills development	**.62**	-.27	.25			
Technology/vehicle as addressee	.61		.44			
Demand for infrastructure expansion	**.46**	.39				
Factor 2: Politics and governance						
Demand for political/legal framework		.79				
Politics/legislator as sender	.21	**.78**				
Factor 3: Civil demands on the industry						
Human/user as sender			.88			
Companies/industry as addressee	.24		.64			

Note. Factor loadings < .20 suppressed; Bartlett's tests for all PCAs: $p < .001$; determinants > 0.00001

6.2 Frames of autonomous mobility (RQ1)

To detect frames in the news media, we included the PCA factor scores, the main topic (one indicator), and three binary variables for moral evaluation (positive, neutral/balanced, negative) in a two-step cluster analysis on all articles ($n = 503$). A robust and stable cluster solution with three clusters was calculated (*silhouette coefficient* = .4) (Table 4, Table A.1). For all indicators, significant differences were found between the three clusters ($p < .01$). Using ANOVA, the largest effects were found for safety and traffic risks, the mention of damaged stakeholders, causes of risks, and positive as well as balanced evaluations. For the main topic (categorical variable), a chi-square test also revealed significant differences between the clusters ($X^2(12) = 168.56$, $p < .001$, *Cramer's V* = .41).

Table 4. Two-step cluster analysis (BIC) with frame element indicators and follow-up ANOVA

Frame element	Frame element indicators		Cluster[a] 1 (37%)	2 (29%)	3 (34%)	Com-bined	ANOVA[b] (η²)
Problem definition (risks/benefits)	Traffic/economic benefits	*M*	-0.40	0.00	**0.42**	0.00	.12**
		SD	0.69	1.10	1.03	1.00	
	Safety and traffic risks	*M*	-0.37	**0.75**	-0.23	0.00	**.23****
		SD	0.51	1.24	0.83	1.00	
	Regulatory and ethical risks	*M*	-0.22	**0.58**	-0.25	0.00	**.14****
		SD	0.56	1.48	0.59	1.00	
	Individual and environmental benefits	*M*	-0.17	0.01	**0.17**	0.00	.02*
		SD	0.53	1.05	1.28	1.00	
	User risks	*M*	-0.12	**0.41**	-0.21	0.00	.07**
		SD	0.48	1.55	0.68	1.00	
	Ambivalent cost issues	*M*	-0.22	**0.13**	**0.13**	0.00	.03**
		SD	0.45	1.17	1.22	1.00	
Problem definition (affected stakeholders)	Beneficiary stakeholders	*M*	-0.48	0.12	**0.42**	0.00	**.15****
		SD	0.49	0.97	1.19	1.00	
	Damaged stakeholders	*M*	-0.37	**0.96**	-0.41	0.00	**.37****
		SD	0.47	1.26	0.52	1.00	
Causal interpretation	Causes of risk	*M*	-0.43	**1.03**	-0.39	0.00	**.43****
		SD	0.39	1.26	0.44	1.00	
	Causes of benefits	*M*	-0.44	0.06	**0.43**	0.00	**.14****
		SD	0.48	1.00	1.20	1.00	
Moral evaluation[c]	Positive evaluation	*M*	0.03	0.15	**0.98**	0.39	**.78****
		SD	0.18	0.35	0.13	0.49	
	Negative evaluation	*M*	0.00	**0.19**	0.00	0.06	**.15****
		SD	0.00	0.40	0.00	0.23	
	Neutral/balanced evaluation	*M*	**0.97**	0.66	0.02	0.55	**.67****
		SD	0.18	0.48	0.13	0.50	
Treatment recommen-dation	Development of technology and skills	*M*	-0.30	**0.33**	0.05	0.00	.07**
		SD	0.30	1.35	1.06	1.00	
	Politics and governance	*M*	-0.19	**0.35**	-0.09	0.00	.05**
		SD	0.26	1.65	0.65	1.00	
	Civil demands on the industry	*M*	-0.25	**0.64**	-0.26	0.00	**.17****
		SD	0.26	1.61	0.44	1.00	

Note. The cluster solution's silhouette coefficient was 0.4. All frame element indicators are factor scores resulting from PCA (Table 3) except for the binary moral evaluation indicators. [a]Cluster 1 = Neutral traffic and business stories frame; Cluster 2 = Safety and governance concerns frame; Cluster 3 = Benefits of science and technology frame. [b]Follow-up analysis with one-way ANOVA and three-cluster solution as factor; $\eta^2 \geq .14$ are considered large effects. [c]Recoded to binary variables with 1 (evaluation present) or 0 (evaluation not present).

The first cluster (N = 186, 37%) mainly referred to traffic-related stories (31.7%), technology and innovation (28.5%), as well as business topics (22%). Articles in this cluster contained more neutral/balanced evaluations than the other two clusters. Most of the remaining frame element variables were rarely present, as indicated by the low factor scores. We termed this cluster as the frame of *neutral business and traffic stories*. Exemplary headlines included "Smart City Ilmenau: From assistance systems to autonomous driving" (Freies Wort, 05/18/2022) or "Autonomous buses will soon be in regular service in Monheim" (Rheinische Post, 03/27/2019).

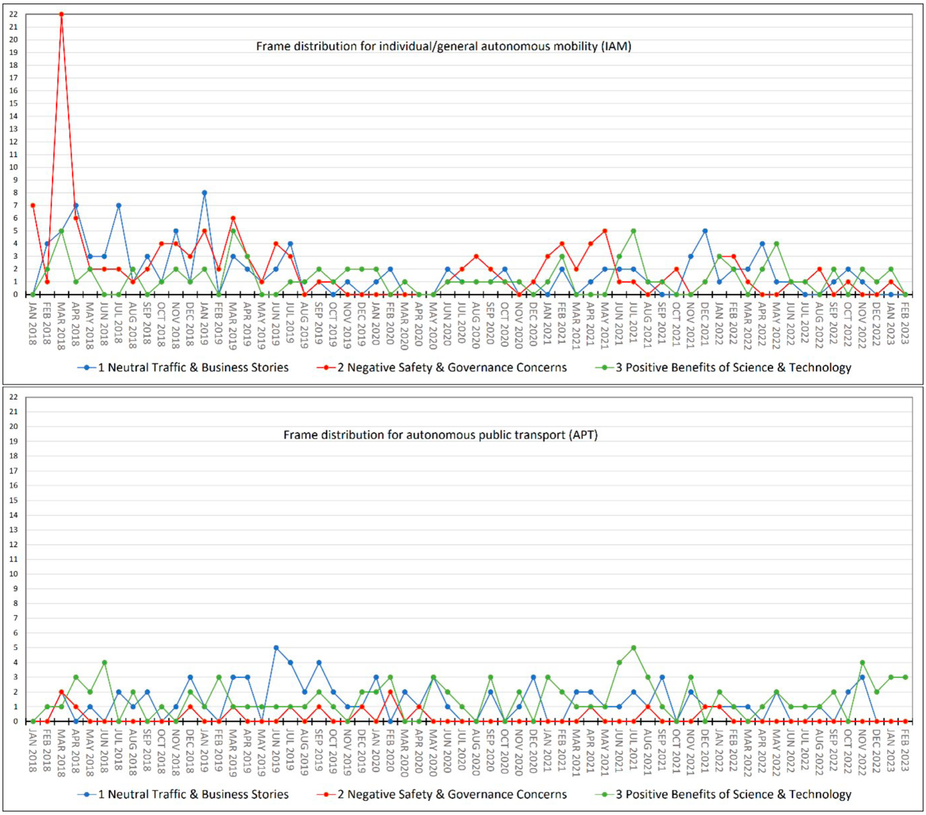
The second cluster (N = 144, 28.6%) addressed the topics of civil society (18.1%), safety issues (20.8%), and politics (7.6%) more frequently than the other frames. We found a strong emphasis on risks, especially safety and traffic risks, as well as regulatory and ethical risks. Benefits were rarely addressed. This frame emphasized damaged stakeholders over beneficiary stakeholders and mainly pointed to causes of risks instead of benefit sources. While neutral/balanced evaluations were frequent, this frame also included negative evaluations, which were largely absent from the other two frames. Treatment recommendations were salient, with demands for development of technology/skills, politics and governance, and civil demands on the industry being more emphasized than in the remaining clusters. We labeled this frame *safety and governance concerns*. Articles with that frame used headlines such as "Robot car kills woman; USA Tragic accident involving a self-driving motor vehicle" (Mitteldeutsche Zeitung, 03/20/2018) or "Robots, ethics and responsibility" (Thüringer Allgemeine, 02/12/2022).

The third cluster (= 173, 34.4%) was termed *benefits of science and technology* since the main topics were technology and innovation (50.3%), science/research (8.1%) – both more frequent within the frame than within the other frames – and business stories (20.2%). This frame mainly stressed traffic/economic benefits as well as individual and environmental benefits of autonomous mobility, while risks did not matter. Only ambivalent cost issues were found with a similar share as in the frame of safety and governance concerns. Most of the stories contained positive evaluations. Treatment recommendations were almost irrelevant, except some demands for more development of technology and individual skills. Exemplary headlines were "ZF sees Passau in first place for shuttle: Autonomous electric bus publicly presented" (Passauer Neue Presse, 05/07/2022) or "Autonomous minibuses in HVV; driverless buses to take passengers door-to-door in Hamburg's public transport from 2024 on a trial basis" (TAZ, 01/17/2023).

Over time, the media's use of the *benefits of science and technology frame* was relatively stable, with smaller peaks in July 2021, May 2022, and November 2022, for both APT and IAM coverage (Figure 1). These spikes were often related to the start or end of APT projects. The *safety and governance concerns frame* was most notably found in 2018, with a huge spike in March, exclusively for

IAM reporting. This spike was mainly the consequence of the accident of an Uber test vehicle on March 18 that killed a 50-year-old woman. The frame decreased in frequency the subsequent years and was not salient in APT reporting. *Neutral traffic and business stories* were found more often in 2018 and 2019 compared to 2020 to 2022.

Figure 1. Frequencies of news media articles on autonomous mobility for each frame over time



The comparison of national and regional/local news media outlets revealed a significant difference ($X^2(2) = 27.66$, $p < .001$, *Cramer's V* = .23), with national media focusing more often on *safety and governance concerns* (54%) than regional/local media (25%). No notable difference was found for the *benefits of science and technology frame*. *Neutral traffic and business stories* were most often found in regional/local news media (40.5%).

The initial reasons for reporting about autonomous mobility differed significantly between frames ($X^2(16) = 134.02$, $p < .001$, *Cramer's V* = .37). The frame of *safety and governance concerns* was more likely to result from crises/accidents (26.4%) compared to the other two frames (< 5%), and less likely to be used for reporting about the start of an APT project (10.4%) compared to the other two frames (> 44%). The future prospects of the technology (not mentioned in 72.8% of the articles) were evaluated more positively in the frame of *benefits of science and technology* and more negatively in the *safety and governance concerns* frame ($X^2(8) = 66.04$, $p < .001$, *Cramer's V* = .26).

6.3 Framing APT compared to IAM (RQ2)

We split the sample in two parts: Articles with exclusive reference to APT (37.6%) and articles addressing IAM (e.g., self-driving cars) (62.4%). A comparison of the distribution of the three frames across the two sub-samples revealed significant differences ($X^2(2) = 68.34$, $p < .001$), with a moderate effect size (*Cramer's V* = .37). Articles with focus on APT were most likely to use the frames *benefits of science and technology* (49.7%) and *neutral business and traffic stories* (42.3%). *Safety and governance concerns* (7.9%) were almost irrelevant. News coverage of IAM was more likely to stress *safety and governance concerns* (41.1%) and least likely to use the *benefits of science and technology frame* (25.2%) (Table 5). This is also shown in the frame salience for IAM and APT reporting over time (Figure 1).

Table 5. Frequency of articles on general/individual and public autonomous mobility for each frame

		Frames (Clusters)			
Focus		Neutral traffic & business stories	Safety & governance concerns	Benefits of science & technology	Total
Focus on individual/ general autonomous mobility	Count	106	129	79	314
	% within Focus	33.8%	41.1%	25.2%	100.0%
	% within Frames	57.0%	89.6%	45.7%	62.4%
Focus on autonomous public transportation	Count	80	15	94	189
	% within Focus	42.3%	7.9%	49.7%	100.0%
	% within Frames	43.0%	10.4%	54.3%	37.6%
Total	Count	186	144	173	503
	% within Frames	100.0%	100.0%	100.0%	100.0%

Note. $X^2(2, N = 503) = 68.34$, $p < .001$, *Cramer's V* = .37

Following the analysis approach of Wessler et al. (2016), we conducted separate exploratory cluster analyses for the two sub-samples of IAM ($n = 314$) and APT ($n = 189$) reporting to verify if the overall frame structure can be replicated and/or whether specific differences emerge. The analysis of APT-related articles resulted in a robust cluster solution of three frames (Table 6). This frame structure is similar to the overall frame structure that we found for the entire sample in that the first frame (37%) contained mostly neutral evaluations and few references to risks, benefits, or governance. The main topics were traffic and technology/innovation, which is why the frame was named *neutral traffic and technology stories*. The second frame (25%), however, contained both references to risks and benefits of automated mobility. It emphasized beneficiary stakeholders, while damaged stakeholders played only a minor role. Evaluations were ambivalent with positive, negative, and neutral stories. In terms of treatment recommendations, the development of technology and skills, as well as politics/governance measures, were emphasized. This frame is not primarily negative and not as much dominated by risk references compared to the safety and governance concerns frame of the initial cluster solution. Therefore, it was termed the *ambivalent technology and governance concerns frame*. The third frame (38%) mainly contained positive evaluations, referred to beneficiary stakeholders, and stressed traffic/economic benefits, similar to the initial cluster solution (*benefits of technology frame*).

Table 6. Two-step cluster analysis (BIC) with frame element indicators and follow-up ANOVA for articles about autonomous public transport (APT)

Frame element	Frame element indicators		Cluster[a] 1 (37%)	2 (25%)	3 (38%)	Combined	ANOVA[b] (η^2)
Problem definition (risks/ benefits)	Traffic/economic benefits	*M*	-0.50	**0.61**	**0.61**	0.20	.26***
		SD	0.61	1.05	1.03	1.05	
	Safety and traffic risks	*M*	-0.40	**0.08**	-0.19	-0.20	.04*
		SD	0.40	1.14	1.01	0.89	
	Regulatory and ethical risks	*M*	-0.40	**-0.11**	-0.51	-0.37	.15***
		SD	0.07	0.72	0.17	0.41	
	Individual and environmental benefits	*M*	-0.27	**0.17**	-0.22	-0.14	.06**
		SD	0.37	1.19	0.64	0.76	
	User risks	*M*	-0.07	**0.14**	-0.23	-0.08	.03 n.s.
		SD	0.40	1.43	0.48	0.82	
	Ambivalent cost issues	*M*	-0.20	**0.00**	-0.20	-0.15	.02 n.s.
		SD	0.18	1.17	0.49	0.67	
Problem definition (affected stakeholders)	Beneficiary stakeholders	*M*	-0.57	**0.64**	0.36	0.08	.21***
		SD	0.39	1.19	1.24	1.12	
	Damaged stakeholders	*M*	-0.35	**-0.06**	-0.36	-0.28	.03*
		SD	0.51	0.97	0.62	0.70	

Causal interpretation	Causes of risk	*M*	-0.46	**0.14**	-0.45	-0.31	.21***
		SD	0.28	0.93	0.19	0.57	
	Causes of benefits	*M*	-0.56	**0.52**	0.06	-0.06	.21***
		SD	0.20	1.27	0.87	0.94	
Moral evaluation[c]	Positive evaluation	*M*	0.00	0.57	**0.97**	0.51	.71***
		SD	0.00	0.50	0.17	0.50	
	Negative evaluation	*M*	0.00	**0.06**	0.00	0.02	.05*
		SD	0.00	0.25	0.00	0.13	
	Neutral/balanced evaluation	*M*	1.00	0.36	0.03	0.47	.73***
		SD	0.00	0.49	0.17	0.50	
Treatment recommendation	Development of technology and skills	*M*	-0.34	**0.37**	-0.31	-0.15	.18***
		SD	0.11	1.27	0.18	0.71	
	Politics and governance	*M*	-0.18	**0.32**	-0.20	-0.07	.08***
		SD	0.27	1.50	0.10	0.79	
	Civil demands on the industry	M	-0.27	**-0.02**	-0.28	-0.21	.04*
		SD	0.05	1.14	0.09	0.58	

Note. The cluster solution's silhouette coefficient was 0.4. All frame element indicators are factor scores resulting from PCA (Table 3) except for the binary moral evaluation indicators. [a]Cluster 1 = Neutral traffic and technology stories frame; Cluster 2 = Ambivalent technology and governance concerns frame; Cluster 3 = Benefits of technology frame. [b]Follow-up analysis with one-way ANOVA and three-cluster solution as factor; $\eta^2 \geq .14$ are large effects. [c]Recoded to binary variables with 1 (evaluation present) or 0 (evaluation not present).

The cluster analysis on IAM coverage (Table 7) was less robust in comparison (*silhouette coefficien*t = 0.1) and resulted in two frames. The first frame (45%) contained both negative and positive evaluations as well as risks and benefits. However, risks, damaged stakeholders, and causes of risks were more salient than benefits, causes of benefits, or beneficiary stakeholders. Governance issues were often addressed in this frame and rarely in the second frame. Therefore, the first frame was termed *ambivalent technology, safety, and governance concerns*. The second frame (55%) only contained positive and neutral stories with an emphasis on business topics. Thus, we named it the *positive business frame*.

The comparison of these two separate cluster solutions revealed that articles on APT, compared to IAM, less often emphasize risks and more often address benefits in the according frames. In addition, APT frames rarely emphasize damaged stakeholders and more often address beneficiary stakeholders. IAM frames are either business-oriented and rather positive or, on the other hand, are very ambivalent in stressing risks and benefits of automated mobility, whereas risks, damaged stakeholders, and governance concerns outweigh the benefits.

Table 7. Two-step cluster analysis (BIC) with frame element indicators and follow-up ANOVA for articles about individual/general autonomous mobility (IAM)

			Cluster[a]			
Frame element	Frame element indicators		1 (45%)	2 (55%)	Com-bined	ANOVA[b] (η^2)
Problem definition (risks/bene-fits)	Traffic/economic benefits	*M*	**0.04**	-0.25	-0.12	.02**
		SD	1.15	0.74	0.95	
	Safety and traffic risks	*M*	**0.70**	-0.35	0.12	.25***
		SD	1.23	0.48	1.04	
	Regulatory and ethical risks	*M*	**0.65**	-0.12	0.22	.11***
		SD	1.49	0.64	1.17	
	Individual and environmental benefits	*M*	**0.21**	-0.02	0.08	.01 n.s.
		SD	1.31	0.90	1.11	
	User risks	*M*	**0.36**	-0.21	0.05	.07 ***
		SD	1.51	0.44	1.09	
	Ambivalent cost issues	*M*	**0.16**	0.04	0.09	.00 n.s.
		SD	1.22	1.09	1.15	
Problem definition (affected stakehold-ers)	Beneficiary stakeholders	*M*	0.18	-0.24	-0.05	.05***
		SD	1.07	0.73	0.92	
	Damaged stakeholders	*M*	**0.83**	-0.37	0.17	.29***
		SD	1.31	0.46	1.11	
Causal interpreta-tion	Causes of risk	*M*	**0.88**	-0.38	0.18	.30***
		SD	1.34	0.48	1.15	
	Causes of benefits	*M*	**0.24**	-0.13	0.03	.03**
		SD	1.18	0.88	1.04	
Moral evaluation[c]	Positive evaluation	*M*	0.21	**0.41**	0.32	.05***
		SD	0.41	0.49	0.47	
	Negative evaluation	M	**0.18**	0.00	0.08	.11***
		SD	0.38	0.00	0.27	
	Neutral/balanced evaluation	*M*	**0.62**	**0.59**	0.60	.00 n.s.
		SD	0.49	0.49	0.49	
Treatment recommen-dation	Development of technology and skills	*M*	**0.50**	-0.24	0.09	.11***
		SD	1.52	0.45	1.13	
	Politics and governance	*M*	**0.29**	-0.16	0.04	.04***
		SD	1.58	0.33	1.11	
	Civil demands on the industry	*M*	**0.60**	-0.26	0.13	.13***
		SD	1.59	0.31	1.17	

Note. The cluster solution's silhouette coefficient was 0.1. All frame element indicators are factor scores resulting from PCA (Table 3) except for the binary moral evaluation indicators. [a]Cluster 1 = Ambivalent safety and governance concerns; Cluster 2 = Positive business frame. [b]Follow-up analysis with one-way ANOVA and three-cluster solution as factor; $\eta^2 \geq .14$ are considered large effects. [c]Recoded to binary variables with 1 (evaluation present) or 0 (evaluation not present).

In summary, the separate cluster analyses replicated the general pattern of risk versus benefit salience found in the overall cluster solution. Chi-square tests validate this as the overall cluster solution was significantly related to both the IAM frames ($X^2(2) = 226.82$, $p < .001$, *Cramer's* $V = .85$) and the APT frames ($X^2(2) = 190.60$, $p < .001$, *Cramer's* $V = .72$). However, we also found differences between APT and IAM frame structures that mainly point to higher levels of concern and more business focus in IAM, and generally more positive reporting tendencies with less emphasis on business and risks in the APT coverage.

6.4 Media references to science (RQ3)

Our findings suggest that science plays a minor role in the German news coverage of autonomous mobility. This was shown for science/research as the main topic (5%), science as a damaged stakeholder (e.g., reduction in funding, loss of credibility) (1.2%), science as beneficiary stakeholder (e.g., increase in funding for APT projects, awards) (8%), science as causing a risk/problem (e.g., lack of APT research increases safety risks) (2.4%), and science as causing a benefit (e.g., academic research increasing safety of autonomous vehicles) (5.2%). Scientific actors also played a minor role in treatment recommendations, with science rarely mentioned as a sender (e.g., scientists calling for more funding for APT infrastructure) (4.4%) or addressee (e.g., universities should do more research on security aspects of APT) (1.2%).

Regarding the detected frames, the reference to science was most prevalent in the *benefits of science and technology frame*, mainly with science as beneficiary stakeholder and cause of benefits (Table 4). Further indicators referring to science had to be excluded from the previously reported cluster analyses because of frequencies below 5%. Therefore, we conducted a follow-up ANOVA with the three frames found in the entire sample as factor (cluster solution) and the previously excluded science indicators as dependent variables. The analysis showed that science as causing a risk/problem was more likely ($F(2, 500) = 6.68$, $p = .001$, $\eta^2 = .03$) mentioned in the *safety and governance concerns frame* ($M = 0.06$, $SD = 0.24$) than in the *neutral traffic and business story frame* ($M = 0.01$, $SD = 0.07$) or the *benefits of science and technology frame* ($M = 0.01$, $SD = 0.11$). Science as sender of treatment recommendations was more likely ($F(2, 500) = 5.21$, $p = .006$, $\eta^2 = .02$) mentioned in the *safety and governance concerns frame* ($M = 0.08$, $SD = 0.28$) than in the *neutral traffic and business story frame* ($M = 0.01$, $SD = 0.10$) or the *benefits of science and technology frame* ($M = 0.05$, $SD = 0.21$).

Comparing the science indicators in APT media coverage to IAM revealed only negligible effect sizes ($\eta^2 < .02$). Science was slightly more likely to be mentioned as a beneficiary stakeholder in the APT context and more likely to be mentioned as the cause of a risk/problem or the source of treatment recommendations in the

IAM context. Science as a main topic was found more often in IAM coverage (6.7%) than in APT-focused articles (2.1%).

The differences in references to science between national and regional news media were also negligible ($\eta^2 < .02$). Science was slightly more likely to be mentioned as a damaged stakeholder and more likely to be mentioned as the cause of a benefit or the source as well as the receiver of treatment recommendations ($p < .05$) in national than in regional news. Science as a main topic was found more often in regional (5.5%) than in national news (1.6%). This difference was not significant ($X^2(6) = 8.32$, $p = .21$).

7. Discussion

The analysis revealed that most of the German news media coverage of autonomous mobility between 2018 and 2023 was positive or neutral, while a minority of articles contained negative evaluations and stressed technological or societal risks. This is in line with findings of previous research on media representations of emerging technologies such as nanotechnology (e.g., Donk et al., 2011) or AI (Garvey & Maskal, 2019), which tended to emphasize benefits over risks and/or positive over negative tone. It also confirms the results of previous media analyses in Germany on autonomous mobility (Jelinski et al., 2021; Taddicken et al., 2020).

We identified three frames (RQ1): *neutral business and traffic stories* (37%), *safety and governance concerns* (28.6%), and *benefits of science and technology* (34.4%). The *benefits of science and technology* frame was mostly positive, emphasizing the benefits of autonomous driving for mobility, the economy, and science, as well as for a range of beneficiary stakeholders. The frame has similar features as frames found in past framing research on nanotechnology (e.g., the 'research and development' frame in Donk et al. (2011)), biotechnology (e.g., the 'research benefit frame' in Mathes & Kohring (2008)), and space exploration (e.g., the 'beneficial space exploration' frame in Schwarz & Seidl (2023)). The study on autonomous mobility by Taddicken et al. (2020) found a 'technological progress' frame, which was also related to positive evaluations and innovation, but did not emphasize science very much.

The frame of *safety and governance concerns* stressed the risks of autonomous mobility, contained negative as well as positive or balanced evaluations, and addressed several required actions to control or regulate risks of the technology. This frame had similar characteristics as the 'ambivalence' frame of Donk et al. (2011) for nanotechnology or the 'SETI risk' frame for scientific space exploration (Schwarz & Seidl, 2023). Compared to Taddicken et al.'s (2020) study on autonomous mobility, this frame contained features of both the 'ambivalence' and the 'technology regulation' frame that Taddicken et al. found. Ambivalent evaluations, as well as risks and benefits, along with the need for risk governance, seem to be a recurring pattern (i.e., frame) in the media coverage of emerging technologies and science.

The frame of *neutral business and traffic stories* is the least comparable to previous research. It was mainly defined by the absence of frame indicators and mostly addressed topics such as traffic, technology, and business. News with that frame often resulted from the start of new municipal APT projects or the release of a new product. Taddicken et al. (2020) detected a group of articles they labeled as 'short stories' that had similar characteristics as our neutral frame. The authors decided not to consider this cluster a frame. However, since the absence of certain frame elements and the focus on balanced evaluations and specific topics can be interpreted as a journalistic approach to presenting stories and concise information about events, we granted this cluster of articles the frame status.

Despite the significance of the public transportation sector in Germany (Statistisches Bundesamt, 2025) and APT being a major driver of the autonomous mobility technology and its acceptance in the country (KPMG, 2020; Rauh et al., 2020), previous media research on autonomous driving has not differentiated between individual and public transportation. This study is the first to do so (RQ2). The findings show that APT is a major topic in Germany, with more than a third of the news coverage on autonomous mobility. These news stories were frequently triggered by regional and publicly funded municipal APT projects and were mostly responsible for the positive framing of the technology. *Safety and governance concerns*, on the other hand, were much more driven by accidents and risks of IAM, such as the Uber accident in 2018, which triggered a significant amount of news coverage. This points to potential effects of IAM accidents as technological risk or trigger events that lead to mediated social risk amplification according to SARF (Kasperson et al., 2022), as we have addressed in the literature review.

The broader societal benefits of public transport (e.g., environmental benefits, advantages for elderly and disabled people) together with the fact that, so far, no major accidents have involved automated buses in Germany, seem to favor a more positive framing of the technology. Rather positive perceptions of the local population in the German municipalities where automated shuttle buses have been operated support this assumption (Kostorz et al., 2019; Rauh et al., 2020).

The presence of scientific stakeholders in the media coverage on autonomous mobility was limited (RQ3). This confirms the findings of previous media research, which indicated that the news coverage lacks scientific detail (Jelinski et al., 2021) and rarely refers to scientific actors compared to business or politics (Taddicken et al., 2020). The presence of science was much more notable in the news media's framing of other technologies, such as AI (Brantner & Saurwein, 2021) or nanotechnology (Donk et al., 2011; Metag & Marcinkowski, 2014). Journalists covering autonomous mobility seem to favor and emphasize the technology and its application as well as business-related developments, whereas scientific research is of minor interest. Although a high number of APT projects in Germany have explicitly involved publicly funded scientific institutions, their impact on media frames is limited.

7.1 Implications

Municipal APT projects and the resulting positive media coverage compared to IAM seem to be a good opportunity to narrow the gap between technology leadership and public acceptance in Germany (KPMG, 2020). Bringing automated buses to the streets of German municipalities successfully enabled citizens, but also journalists, to have direct contact with the technology and generate mostly positive personal experiences (Beckmann & Zadek, 2022; Kostorz et al., 2019; Rauh et al., 2020). At the same time, our findings suggest that individual accidents pose a substantial risk for public acceptance as they may lead to significant news media attention, at least temporarily. According to risk communication research on emerging technologies (e.g., Renn & Benighaus, 2013; Schwarz & Unselt, 2024), strict security measures and transparent communication of risks and related risk control measures are crucial in municipal APT projects.

From a science communication perspective, the active involvement of scientific partners in publicly funded APT projects is an appropriate measure to increase trust and transparency. Surveys have shown that scientists and AI engineers are more trusted than business actors and that trust in science increases support for emerging technologies (Yang et al., 2023), and/or intentions to use autonomous vehicles (Ho & Cheung, 2024). However, the scientific institutions participating in German APT projects need to professionalize their communication efforts to be better reflected as contributors in the news media, as our findings revealed few references to scientific actors or perspectives. A stronger involvement of science communicators and more emphasis on professionalized media relations in the context of APT projects can increase public support for autonomous mobility and increase subjective knowledge and insight into the scientific process of developing emerging transportation technologies. In addition to traditional techniques (e.g., press releases, press conferences), participatory formats involving local citizens (e.g., open doors, free test rides, public inauguration events with citizens and scientists, etc.) are considered effective measures (e.g., Kostorz et al., 2019; Rauh et al., 2020).

8. Limitations and future research

Future research should extend the analysis to further types of media outlets (e.g., tabloid press, local broadcasters) in Germany and/or take a cross-national comparative approach. Social media platforms (e.g., YouTube, TikTok, Instagram) are increasingly relevant in shaping perceptions and communication about emerging technologies. In future studies, topics, evaluations, and science representations on these platforms should be examined along with user comments that reflect concerns, attitudes, and trusted stakeholders in the context of autonomous mobility. In addition, municipal APT projects offer many opportunities to conduct local surveys or qualitative research to better understand the interactions between scientists, engineers, science communicators, journalists, and citizens using autonomous vehicles. In terms of theoretical implications, future research should further explore the intersections between risk communication and science communication as both are influential in understanding public perceptions, diffusion, and safety-related behavior in the context of autonomous mobility. Framing can serve as a useful approach to bridge the two fields (Scheufele, 2013; Schwarz & Unselt, 2024).

9. Conclusion

In their report on autonomous mobility in 2017, the ethics commission of the German government concluded that "[t]he public has a right to receive sufficiently differentiated information about new technologies and their use. […] [G]uidelines for the use and programming of automated vehicles should be derived and communicated to the public and reviewed by a suitable, independent body." (Ethik-Kommission, 2017, p. 12). The news media play an important role in this process by framing risks, benefits, and governance of autonomous mobility in Germany. Local APT projects with public funding and the involvement of scientists and other stakeholders beyond the business domain are effective in facilitating largely positive media coverage. However, scientists and science communicators should professionalize their communication related to developing and testing APT technologies. Future research at the intersection of risk and science communication should further analyze institutional science communication about APT and its impact on public framing, as well as public acceptance across countries where the technology is introduced.

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Appendices

Table A.1. Frequency of frame element indicators by frame (in %)

Frame element	Frame element indicators		Frames (Clusters)[a] Neutral traffic & business stories	Negative safety & governance concerns	Positive benefits of science & technology	**Total**
Problem definition	Risks/ problems	Lack of user competence	0.54	**16.67**	1.16	5.37
		Lack of acceptance	5.91	**35.42**	12.14	16.50
		Lack of safety/ limits of technology	9.14	**66.67**	20.81	29.62
		Ethical problems	3.23	**23.61**	0.58	8.15
		High costs	1.61	**13.19**	12.72	8.75
		Data protection problems	2.69	**28.47**	3.47	10.34
		Regulatory limitations	7.53	**38.19**	13.29	18.29
		Traffic problems	5.91	**40.28**	12.72	18.09
		Disruptions due to unexpected weather or road conditions	3.23	**27.08**	7.51	11.53
		Problems in interaction with other road users	1.08	**23.61**	3.47	8.35
	Benefits	Mobility and comfort	16.13	40.28	**57.23**	37.18
		Time savings and convenience	5.38	**18.06**	16.18	12.72
		Low individual costs	2.69	4.86	**9.83**	5.77
		Improved safety	10.22	**40.97**	24.28	23.86
		Economic benefits	17.20	41.67	**49.71**	35.39
		Environmental protection	5.91	18.06	**22.54**	15.11
		Low societal costs	0.00	7.64	**9.83**	5.57
		Solving traffic problems	13.98	31.94	**43.93**	29.42
	Damaged stakeholders	Human	3.76	**47.92**	2.31	15.90
		Company/ economy	3.23	**32.64**	3.47	11.73
	Beneficiary stakeholders	Human	11.29	44.44	**46.24**	32.80
		Company/ economy	9.14	35.42	**42.20**	28.03
		Science/ research	1.08	7.64	**15.61**	7.95

Causal attribution	Stake-holders responsible for risks/ problems	Human	0.54	**24.31**	0.00	7.16
		Car/ technology	3.76	**55.56**	5.78	19.28
		Company/ economy	1.08	**21.53**	0.00	6.56
		Politics/ legislature	1.08	**12.50**	4.62	5.57
	Stakeholders responsible for benefits	Car/ technology	10.22	50.00	**54.91**	36.98
		Company/ economy	2.69	11.11	**16.76**	9.94
		Science/ research	0.54	3.47	**11.56**	5.17
Moral evaluation	Evaluation tendency/ acceptance	Positive tendency/ acceptance	3.23	14.58	**98.27**	39.17
		Negative tendency/ lack of acceptance	0.00	**19.44**	0.00	5.57
		Balanced evaluation	**96.77**	65.97	1.73	55.27
Treatment recommedation	Recommendation for action/ solution	Promoting individual competence	0.54	**13.19**	2.89	4.97
		Technical development	1.61	**27.08**	8.09	11.13
		Expansion of infrastructure	1.61	6.94	**9.25**	5.77
		Creating a political/ legal framework	0.54	**15.28**	0.58	4.77
	Sender of recommendation	Human/ private individual/ user	1.08	**20.83**	1.16	6.76
		Company/ economy	1.61	**20.83**	10.40	10.14
		Politics/ legislature	0.54	**13.19**	3.47	5.17
	Receiver of recommendation	Car/ technology	0.00	**29.17**	8.09	11.13
		Company/ economy	0.54	**17.36**	4.05	6.56

Note. All frame element indicators are binary variables (mentioned/not mentioned). Values are relative frequencies (%) based on within-Cluster [a]Cluster 1 = Neutral traffic and business stories frame; Cluster 2 = Safety and governance concerns frame; Cluster 3 = Benefits of science and technology frame. *N* = 503.