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Enhancing the perceived resilience of the road transportation system: Utilizing cues from ridesharing

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ABSTRACT

Ridesharing plays a potential role in supporting transportation systems. However, the impact of service cues on individuals' perceptions of transportation system resilience has yet to be fully examined. Building on cue utilization theory, this study adopted a mixed-methods approach to investigate the influence of congestion relief services provided by ridesharing platforms on individuals' perceived resilience and trust in the road transportation system and the impact of passengers' time urgency in this context. In Phase 1, semi-structured interviews were conducted to identify the cues derived from ridesharing platforms and those utilized by ridesharing users during the processes of calling and waiting for a ride. Subsequently, a research model and hypotheses were proposed. In Phase 2, path analysis was performed to validate the model. Results revealed that the intrinsic and extrinsic cues during the calling and waiting processes enhance individuals' perceived diagnosticity, further promoting their trust and perceived resilience in the road transportation system. Moreover, as individuals' trust in the road transportation system increases, their perceived resilience increases. Additionally, passengers' time urgency negatively moderates the positive relationship between usage flexibility and perceived diagnosticity. Overall, this study enriches existing literature and provides practical implications for traffic management departments in mitigating uncertainty in the road transportation system.

1. Introduction

Traffic congestion is increasingly pervading cities, resulting in increased travel times, disruptions in road transportation systems, and heightened uncertainty. Given this challenge, it poses major hurdles to the resilience of road transportation systems. According to the "Traffic Analysis Report for Major Cities in China," approximately 62 % of cities across the country experienced an increase in traffic congestion (Amap, 2023). With the growth of cities and population, identifying effective solutions to alleviate the uncertainty of traffic congestion caused by various contingencies, such as weather and rush hours, and to ensure a swift recovery of road transportation systems has become the priority for transportation management departments.

Against this backdrop, many measures have been proven effective in alleviating traffic congestion. To our knowledge, policy instruments, such as vehicle restrictions, congestion pricing, and the utilization of alternative transportation modes, including bikesharing, light rail, and autonomous vehicles, have exerted certain control over loads of vehicles on the roads, further alleviating

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congestion (Basso et al., 2021; Fageda, 2021; Huang and Xu, 2023; Lin et al., 2022; Zhang et al., 2022). Additionally, corporate social responsibility ratings, "anywhere working," online-to-offline (O2O), and other measures have the potential to alleviate traffic congestion (Bakare et al., 2022; Hopkins and McKay, 2019; Niu et al., 2019). Notably, despite the objective alleviation of traffic congestion through these measures, people often fail to perceive congestion relief. In this case, in addition to implementing objective measures, improving citizens' perception of congestion relief is important. When individuals perceive a tangible reduction in congestion and a recovery of the road transportation system, they respond positively and derive great satisfaction from their travel experiences.

Ridesharing is increasingly emerging as a significant mode of the road transportation system globally (Cheng et al., 2020). The global ridesharing market size is estimated to reach USD 194.01 billion by 2030 (Market Research Future, 2024). As Dalia's survey indicated, nearly half of the region's smartphone-owning urban population has interacted with ridesharing apps or websites (Mordor Intelligence, 2023). Ridesharing platforms have implemented road congestion avoidance algorithms to provide drivers with optimal routes. They also display estimated waiting times for passengers, enabling them to consider alternative transportation options. Furthermore, these platforms offer privacy-protected communication methods between passengers and drivers, facilitating the ability to change pick-up locations. However, despite the extensive adoption and growing popularity of ridesharing platforms worldwide, a noticeable gap in our knowledge about individuals' perceptions exists. Previous studies provide limited analysis in terms of dissecting the ridesharing process and comprehending the mechanisms by which the service, at diverse stages of the ride, can impact individuals. As scholars have extensively noted, the process of calling and waiting for a ride is a significant component of passengers' travel time costs (Ke et al., 2020). Accordingly, investigating the perception of individuals shaped in the two above subprocesses of ridesharing service delivery regarding the transportation system's resilience to traffic congestion is crucial. Understanding which service cues provided by the platforms impact passengers' perception of congestion relief would greatly benefit the development of ridesharing platforms and perceived resilience of road transportation systems.

Employing a sequential mixed-methods design building on cue utilization theory, we dive deep into passengers' perception of the congestion relief service, which contributes to the perceived resilience of the road transportation system. The qualitative study aimed to identify the service cues introduced by ridesharing platforms to alleviate traffic congestion and explore passengers' perceptions and responses, while the quantitative study aimed to examine the hypotheses. This research enriches cue utilization theory in the context of ridesharing under traffic congestion and provides managerial insights for ridesharing platforms and traffic management departments.

The rest of this paper is structured as follows: Section 2 introduces the literature review. Section 3 presents the research design. Sections 4 and 6 provide the qualitative and quantitative analysis and results, respectively. Section 5 presents the model and hypotheses. Section 7 summarizes the findings, implications, limitations, and future directions.

2. Literature review

2.1. Perceived resilience of the road transportation system

Many similar concepts of resilience, such as reliability, robustness, and adaptability, have been investigated and applied in various domains, including psychology and engineering (Feng et al., 2023; Hollnagel et al., 2007; Liao and van Wee, 2017; Raetze et al., 2021; Wan et al., 2018; Zuo, 2021). In this sense, the resilience of transportation systems denotes the ability to recover swiftly from uncertain disruptions and return to a level similar to the previous state (Deveci et al., 2023). Some scholars have investigated the comprehensive role of transportation systems' resilience across diverse scenarios, including road, maritime, and airport systems, yielding valuable and insightful discoveries (Malandri et al., 2023; Wang et al., 2023; Yang and Hsu, 2018).

Within the road transportation system, prior studies acknowledge the significance of the resilience of the system and concentrate on resilience performance in diverse contexts, including short-term disruptions (e.g., earthquake), enduring disruptions (e.g., the COVID-19 pandemic), and frequent random disruptions (e.g., car accidents, traffic congestion) (Liu et al., 2023; Yin et al., 2023). Overall, indicators or measurement metrics could be classified as topological, functional, and economic (Yin et al., 2023). Indicators in time (e.g., speed to recover) and space (e.g., passenger volume) were also helpful in resilience evaluation (Lu, 2018; Reggiani et al., 2015). In the last decade, ridesharing, an innovative transit mode and on-demand sharing economy, has grown rapidly and played a crucial role in the road transportation system (Li et al., 2022). This developed transportation environment unceasingly requires evolving and contextualized measurement of resilience (Liu et al., 2023). Therefore, how to evaluate the resilience of this updated road transportation system remains salient. However, although user perception and behavioral intention could be utilized to examine the effectiveness of measures to improve perceived resilience of transportation systems, previous studies lack perceptive assessments from users' perspective (Downey et al., 2022). To tackle the presented gaps, this study intends to explore how users experiencing ridesharing perceive the resilience of the transportation system.

In contrast to the aforementioned quantitative measurement, perceived resilience of the transportation system signifies to what extent an individual perceives the transportation system's responsiveness and ability to rebound quickly from a negative experience (Park et al., 2015). In our study, we specifically focus on resilience performance in a frequent random disruption, e.g., traffic congestion, which is a common uncertainty in road transportation systems and can even lead to a breakdown (Ghadami et al., 2022). In this sense, we conceptualize perceived resilience as an individual's perceived capacity of the road transportation system to recover during traffic congestion.

Until recently, congestion in urban areas, especially in peak time, has long been troubling administrations and poses an inconvenience for citizens (de Palma et al., 2022). Abundant evidence substantiates that ridesharing is a promising way to ease traffic congestion (Agarwal et al., 2023). Understandably, ridesharing usage resulting in increased comfort or reduced travel time potentially fosters citizens' perceived resilience of the road transportation system. However, only a few studies explicitly disclose how ridesharing impacts users' perceived resilience of the road transportation system during congestion. To address this need, this study aims to find the relationship between ridesharing and the perceived resilience of the road transportation system. We subsequently review ridesharing and its subprocesses to gain a rich understanding on when ridesharing users possibly perceive high resilience during congestion.

2.2. Ridesharing usage during traffic congestion

Enabled by smartphone technology and embedded with GPS tracking systems, the ridesharing platform is an intermediary to match the supply from idle drivers and real-time demand from passengers (Pan and Qiu, 2022). Moreover, equipped with path planning and matching algorithms, ridesharing can lower the total amount of travel time and miles traveled by consolidating routes to the same destinations through carpooling (Chen et al., 2019). Ridesharing satisfies demands from isolated and remote areas through online information sharing and covers the last mile to public transit systems with the help of smartphones, thereby prompting a portion of drivers to substitute their usage of private vehicles with ridesharing. These facts potentially reduce traffic volume and partly alleviate congestion (Rhee et al., 2023). In addition to general implications, certain services offered by ridesharing platforms can additionally exert an impact on users' perceived resilience of the transportation system, particularly in the context of traffic congestion (Fig. 1) (Zhang et al., 2023). For instance, disclosure of information on congestion and path planning informs passengers about congestion condition and may ease their anxiety caused by congestion.

Given the effects of ridesharing on congestion mitigation and users' perception, the understanding of when ridesharing service delivery influences users' perceived resilience of the road transportation system during congestion is warranted. Therefore, we dissect ridesharing usage during traffic congestion into subprocesses, as depicted in Fig. 2. The service cues in calling and waiting for a ride are expected to improve passengers' perceived resilience, which is the focus of this study (Ke et al., 2020).

Surveys have indicated that passengers get stuck in the process of calling and waiting for a ride, resulting in increased travel times (Tech.China, 2023). Congestion could be reflected in on-demand ridesharing platforms as the lack of drivers for service delivery. Consequently, passengers must wait in line when calling for a ride. Even after the order is accepted by a driver, the passenger possibly continues to wait for a ride. Cohen et al. (2022) stated that long waiting times in ridesharing use for congestion would frustrate passengers and further dissipate users' re-transaction intention and actualize reduced service completion. Moreover, satisfaction and

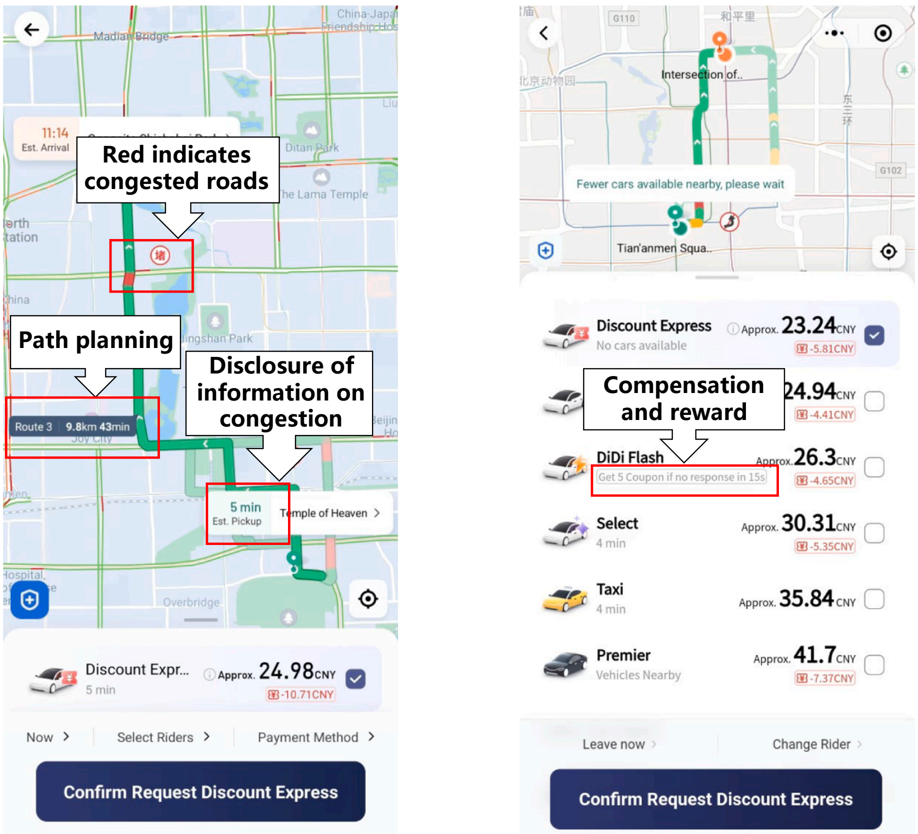

Fig. 1. Screenshots of some congestion relief services on a ridesharing platform.

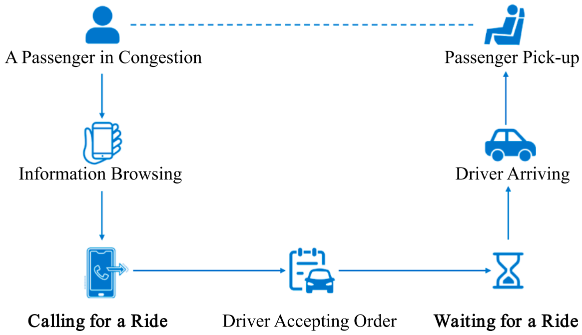

Fig. 2. Process of ridesharing usage.

perceived usefulness are disclosed to be determinants of the continuance intention of ridesharing platforms, yet could be hurt by the congestion (Si et al., 2022).

To mitigate the negative effects of congestion on passengers and retain users, ridesharing platforms tend to boost demand through monetary stimuli, such as discounts and consumer vouchers. However, the users' choices and evaluation of ridesharing usage in congestion are far from predictable. Individual characteristics, such as sensitivity to the compensation, are proposed to moderate the effects of monetary stimuli on congestion perception (Saha et al., 2021). To explore and validate the mechanism by which ridesharing platforms' efforts influence users' perceived resilience, we lend support from cue utilization theory.

2.3. Cue utilization theory

Cue utilization theory posits that a product or service consists of some cues that are indicators of product quality (Jang et al., 2021; Kakaria et al., 2023; Longstreet, 2010; Zou et al., 2024). Derived from cognitive psychology conditions, cue utilization theory provides a way to process information by utilizing intrinsic and extrinsic cues in sophisticated and uncertain environments (Olson and Jacoby, 1972; Visentin and Tuan, 2021). The theory suggests that the extent to which these cues can be utilized to address uncertainty is determined by their perceived diagnosticity, which refers to the extent of the perceived reliability and availability to support the decision-maker's judgment (Wang et al., 2016). When an individual finds it difficult to evaluate the intrinsic cues, salient extrinsic cues help (Kakaria et al., 2023). On ridesharing platforms, users are confronted with various service types and suffer from uncertainty in decision-making (Jang et al., 2021). Extrinsic and intrinsic cues are utilized by ridesharing users simultaneously for perceived diagnosticity and service evaluation (Langan et al., 2017; Szybillo and Jacoby, 1974).

Given the significance of cue utilization theory in evaluating service and products, it has been widely applied to many scenarios, including transportation (Chi et al., 2021; Sturman and Wiggins, 2019; Ünal et al., 2013; Ye et al., 2020; Zou et al., 2024). The positive evaluation based on cue utilization further boosts trust in the service provider and even transaction intentions (Huang et al., 2023). Specifically in transportation, cue utilization theory has been utilized to evaluate drivers' performance and ridesharing service quality. Ünal et al. (2013) proposed and substantiated that the arousal level of drivers serves as a cue for evaluating their driving performance. Furthermore, cues related to ridesharing services, such as driver reputation, ridesharing platform reputation, relative price, and ridesharing offer duration, are considered pivotal in influencing travelers' demand for ridesharing services (Sturman and Wiggins, 2019; Ünal et al., 2013).

However, only a few studies explored how the public evaluates the road transportation system in terms of resilience and what cues take effect. Given the potential of ridesharing in alleviating congestion and enhancing perceived resilience, this study aims to address the gap by probing cues related to ridesharing and constructing the mechanism by which ridesharing users utilize cues. Gleaned from previous work, boundary conditions, such as user characteristics, frequently impact the utilization of cues (Kukar-Kinney and Xia, 2017; Lee and Lou, 1995). Therefore, this study also intends to investigate key user characteristics that function as boundary conditions and those that matter in cue utilization but are not yet clear.

Overall, prior studies have primarily analyzed the transportation systems' measurable resilience but have not yet investigated the public's evaluation and perception. This study primarily emphasizes the significant role of ridesharing in enhancing perceived resilience. It aims to investigate which ridesharing cues are utilized by the individuals and how these cues are used to evaluate their perceived resilience of the road transport system. Consequently, this study contributes to the sustainable development of the transportation system.

3. Research design

According to Venkatesh et al. (2013), we employed a mixed-methods approach to mitigate the biased interpretations arising from purely qualitative research and the nascent understanding of specific contexts from quantitative research. Many extant studies have demonstrated that the mixed-methods approach is conducive to triangulate the findings (Chen et al., 2020; Fraedrich et al., 2019; Liya et al., 2024). The current research context is on ridesharing usage during traffic congestion and its impact on the road transportation system's resilience. Fig. 3 illustrates the research design. In Phase 1, we conducted a qualitative study, involving semi-structured interviews with 40 participants who had experience using ridesharing during traffic congestion. The findings were analyzed and coded with theoretical foundations and existing literature to identify service cues. On the basis of cue utilization theory, the research motivation, and the interview results, a research model was established, and empirical hypotheses were developed. In Phase 2 (a quantitative study), we conducted a structural equation modeling (SEM) analysis of 353 valid anonymous questionnaires to test the proposed hypotheses.

4. Phase 1: Qualitative in-depth interviews

4.1. Data collection

In Phase 1, we conducted semi-structured interviews to collect qualitative data from participants who had experience using ridesharing during traffic congestion. We posted the recruitment notice on social networking platforms, outlining the research purpose (i.e., to optimize ridesharing services during traffic congestion), requirements (i.e., having a high frequency of ridesharing usage and experience using ridesharing services during traffic congestion), and monetary reward. Finally, our sample comprised 40 participants with 18 males and 22 females, averaging 24 years of age. Their education includes senior high school and below and bachelor's, master's, and doctoral degrees; their monthly income involves 1500–2999, 3000–4999, 5000–6999, 7000–8999, and 9000 RMB or higher. Moreover, the sample is distributed in 21 different provinces across China, indicating sample diversity and low bias.

We scheduled interviews with the participants at mutually agreed-upon times, and each interview continued for approximately 30 min. During the interviews, we followed a pre-designed interview guideline (Table 1) and posed questions accordingly. When participants raised new viewpoints, we probed further by asking related follow-up questions. All verbal content was transcribed into text for organization and analysis. In summary, our focus was on the participants' experience of using ridesharing services during traffic congestion and their perceptions and responses to the road transportation system. First, we encouraged the participants to provide detailed descriptions of their experiences and feelings when using ridesharing during traffic congestion. Second, we inquired about the measures or services introduced by ridesharing platforms to alleviate traffic congestion during the process of calling and waiting for a ride. Third, participants were encouraged to elaborate on the impact of the traffic alleviation services introduced by ridesharing platforms on the road transportation system, as well as their own perceptions and responses to these service cues. Finally, an open-ended question was provided to allow participants to supplement any additional information they deemed relevant.

4.2. Analysis and results

In line with Miles and Huberman (1994), this study employed an inductive approach to analyze interview data. First, phrases or sentences relevant to the research questions were identified and labeled as initial codes "I-*x*" (e.g., "I-1" indicates the first participant), which were then organized on the basis of the same or similar meanings. Second, these initial codes were classified to create a list of keywords, guided by the theoretical foundation. Third, on the basis of theories and existing research, the content within the keyword list was identified as higher-level constructs. Meanwhile, through an iterative review of the interview data, a storyline was developed to establish connections between the constructs, facilitating an improved understanding of the service cues related to ridesharing during traffic congestion and passengers' perceptions and responses to the road transportation system. We took two measures to avoid the bias of the responses introduced by five participants who had work experience at ridesharing platforms. We revisited all the interview data and scored the materials ("Do you feel there is emotional bias in the material due to the interviewee's work experience at the ridesharing platform?" measured on a seven-point Likert scale where 1 = very low and 7 = very high). First, the results showed that the mean and maximum values of five participants with ridesharing platform's work experience are 1.7 and 3, respectively. Second, we compared five participants' responses with others and found no significant difference ($t = 0.947$, $p > 0.05$). The identified constructs are presented below, including information transparency (80 %), usage flexibility (72.5 %), compensation and reward (27.5 %), time urgency (67.5 %), perceived diagnosticity (50 %), trust in the transportation system (27.5 %), and perceived resilience

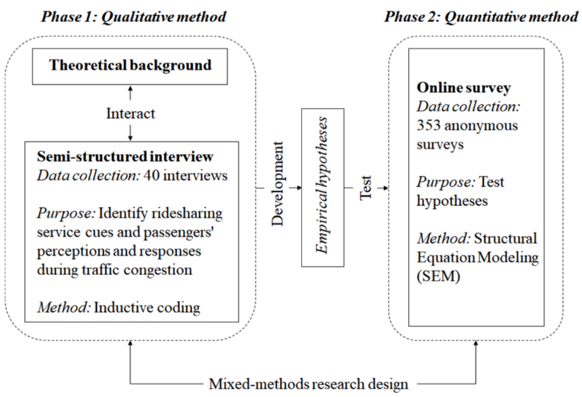

Fig. 3. Research design.

Table 1
Interview guideline.

Interview topic	Question description
Experience of taking ridesharing	1.1 Please provide a detailed description of your entire process and experience of taking ridesharing during traffic congestion (e.g., before, during, and after the ride). 1.2 When you take ridesharing during traffic congestion, what are your feelings during the following processes: 1) the process of calling for a ride, and 2) the process of waiting for a ride? Why do you have these feelings?
Ridesharing service cues during traffic congestion	2.1 Do you think ridesharing platforms have introduced services specifically targeting traffic congestion? Why? Please provide examples of such services. 2.2 What are your opinions and evaluations regarding the services introduced by ridesharing platforms targeting traffic congestion? Why? 2.3 Which services introduced by ridesharing platforms or other factors during the process of calling and waiting for a ride can impact the alleviation of traffic congestion? Why?
Passengers' perceptions and responses	3.1 Do you think the services introduced by ridesharing platforms alleviates traffic congestion? What impact do they have on the resilience of the road transportation system? Why? 3.2 How do the congestion-alleviating services introduced by ridesharing platforms change your perception of ridesharing platforms? Why?
Open-ended question	4.1 Do you have any other content to add?

Note: Prior to the interview, we informed the participants of the need for them to recall their personal experience of ridesharing usage during traffic congestion and provide authentic answers based on their own experience.

of the transportation system (75 %). The percentage in brackets indicates the frequency of participants who mentioned a specific construct in the total number of participants.

4.2.1. Information transparency

The coding results demonstrate that during the process of calling a ride in traffic congestion, ridesharing platforms provide intrinsic cues (i.e., information transparency) to passengers, such as the degree of disclosure of queue length, traffic volume, road congestion status, carpooling options, and surge pricing for distant dispatches when passengers request a ride. Several participants indicated that some ridesharing services could enhance information transparency.

"*The platform's map will display the locations nearby where cars are available, marked with icons. Additionally, the platform will provide an estimated waiting time for calling a ride, allowing passengers to assess the convenience of getting a ride*" (I-2).
"*Passengers can view many congestion-avoiding routes planned by the platform. Drivers will also send information to them based on the traffic conditions*" (I-3).

4.2.2. Usage flexibility

During the waiting process, the platforms offer intrinsic service cues (i.e., usage flexibility), such as the ability for passengers to cancel or modify their orders freely and communicate with drivers to determine the pick-up location. Several participants reported the usage flexibility of ridesharing platforms.

"*Passengers and drivers can communicate with each other through private messaging or phone calls to discuss specific pick-up locations, as well as any relevant changes*" (I-10).
"*Ridesharing platforms allow passengers to change their pick-up location and facilitate communication with the driver via phone calls. By coordinating with the driver and selecting less congested areas for pick-up, it is possible to alleviate congestion*" (I-13).

4.2.3. Compensation and reward

In our research context, the construct of compensation and reward refers to the platforms' provision of compensation for delays or free ride coupons, which is considered extrinsic cue due to its presence in the processes of calling and waiting for a ride. This cue has an impact on passengers' perceived diagnosticity, influencing their perceptions of the ridesharing platform's effectiveness in alleviating traffic congestion. Several participants indicated that they received compensation or reward of ridesharing during congestion.

"*Ridesharing platforms often launch compensation and reward. For example, if users choose to be picked up at specific locations recommended by the platform, they may receive a no-threshold discount coupon worth two or three yuan*" (I-10).
"*After passengers have waited in the queue for a certain time, the app will display waiting compensation in the form of discounted coupons*" (I-16).

4.2.4. Time urgency

The coding results also indicate that apart from the service cues provided by the platforms, passengers' time urgency is an important construct. During traffic congestion, passengers often have a sense of time urgency, i.e., the frequent concern with the time, which affects their expectations and needs regarding the ridesharing service (Waller et al., 2001). Participants mentioned that time urgency can affect their experience during the ride.

"*During the morning rush hour when I call for a ride, I am often frustrated if I cannot get a ride due to time pressure*" (I-21).

"*The waiting process is quite stressful, and if the traffic jams continue, I may feel a bit angry, bored, and anxious*" (I-24).

4.2.5. *Perceived diagnosticity*

Individuals' perceived effectiveness of congestion relief is conceptualized as perceived diagnosticity in our study. It denotes the perception of the ability of individuals to receive information that helps them understand and evaluate a specific object (Jiang and Benbasat, 2007). Participants anticipated that some of the services provided by the ridesharing platform would be significant in reducing congestion.

"*The measures introduced by ridesharing platforms aim to enhance route planning for reaching the destination and provide efficient solutions during traffic congestion*" (I-3).
"*The map indicates congested road with red circles, providing people with a clear understanding of the congestion situation in the area of their current location*" (I-30).

4.2.6. *Trust in the transportation system*

Passengers' trust in the road transportation system is crucial after experiencing the ridesharing platforms' services for alleviating traffic congestion. Participants indicated that the reduction of uncertainty regarding congestion would contribute to their trust in the transportation system.

"*The service provided by ridesharing platforms can alleviate congestion, improve traffic efficiency, and enhance the quality of urban transportation environments. This, in turn, increases people's trust in the urban transportation system*" (I-11).
"*I will have greater trust in the transportation system. I believe that it has the ability to recover quickly from traffic congestion*" (I-24).

4.2.7. *Perceived resilience of the transportation system*

In the context of our study, the traffic congestion caused by multiple uncertainties can pose a threat to the transportation system. Congestion relief facilitates the recovery of the transportation system. In addition to trusting the transportation system, participants emphasized that ridesharing could improve the perceived resilience of the transportation system.

"*I think ridesharing has enhanced the perceived resilience of the transportation system. It is a flexible solution that, to some extent, breaks down information barriers, allowing passengers and drivers to have better communication*" (I-9).
"*The service introduced by ridesharing platforms to alleviate traffic congestion is also beneficial for enhancing the perceived resilience of the transportation system*" (I-10).

5. Theoretical framework and research hypotheses

In this stage, we explicate our theoretical framework and research hypotheses for conducting a quantitative study based on the qualitative findings and relevant literature. Our research model and proposed hypotheses, as shown in Fig. 4, were initially developed by cue utilization theory and ridesharing usage in congestion and were adapted to the identified extrinsic and intrinsic cues and boundary conditions. Generally, our model explains how congestion relief services provided by ridesharing platforms impact users'

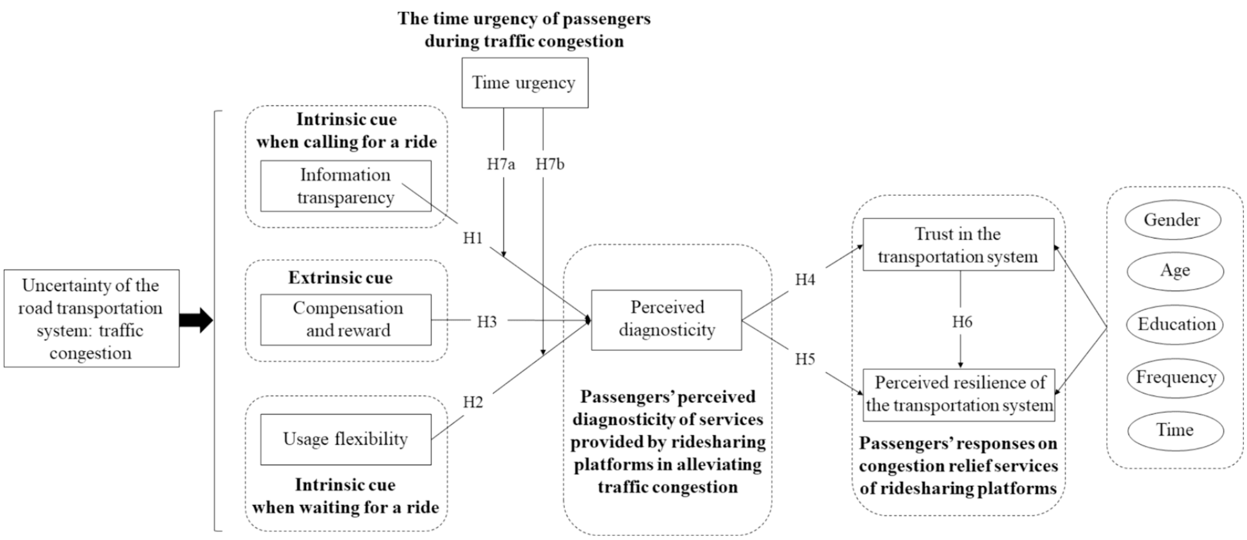

Fig. 4. Research model.

perceived resilience and trust in the transportation system from a cognitive perspective (Bhattacherjee and Hikmet, 2007; Prakash and Das, 2021).

5.1. Extrinsic and intrinsic cues

In line with cue utilization theory, an abundance of intrinsic and extrinsic cues could be utilized to assess ridesharing platforms (Longstreet, 2010). Extrinsic cues, such as price and discount regarding ridesharing services, are not inherent and easy to change. They are of high confidence value that indicates the extent to which ridesharing users believe in their ability to observe and utilize the cues (Longstreet, 2010). Intrinsic cues are inherent and relate tightly to the ridesharing platform (Richardson et al., 1994). Compared with extrinsic ones, intrinsic cues are more difficult to observe due to information asymmetry but are of high predictive value that depicts the degree to which users link the cue with the platform. Albeit the difference, all the cues consistently impact users' evaluation through diagnosticity, which signifies how reliable the cue is to support the judgment (Wang et al., 2016). Each cue contributes to diagnosticity to varying degrees (Ullah et al., 2022).

In terms of the process of ridesharing usage, congestion produces two inefficiencies during calling and waiting for a ride. Cues utilized by users to evaluate the platform in congestion possibly surfaced in the two subsections. As analyzed in Phase 1, information transparency when calling for a ride and usage flexibility when waiting for a ride were recognized as intrinsic cues.

Given the inherent specific information about congestion, including the number of users who call for a ride, estimated waiting time, and available substitute options of higher expense, users acknowledge information transparency that is fundamental to the platform (Namasudra and Sharma, 2022). Moreover, compared with the platform that discloses scant information, the elevated information transparency enabled by more vivid information better assured users' confidence in its ability to diagnose and predict the capacity of the platform to alleviate the congestion (Buell and Norton, 2011). Hence, we propose the following hypothesis:

H1: Information transparency when calling for a ride positively relates to the passengers' perceived diagnosticity of the services provided by ridesharing platforms in alleviating traffic congestion.

Another identified intrinsic cue is usage flexibility when waiting for a ride. Usage flexibility indicates the degree to which the user could flexibly adjust the ride, for instance, communicating with drivers or directly canceling the ride on the platform to change their own plans. In congestion, users can avoid a jammed journey by negotiating with the driver and changing the pick-up location. When the driver is far away, the user can re-call a closer driver by withdrawing the current order. Such kind of usage flexibility is recognized as a reflection of the ability of the platform to ease congestion (Lygnerud and Nilsson, 2021). This observation is consistent with a statement by respondent (I-9): "*I believe that ridesharing represents a highly flexible option that dismantles information barriers to some extent, thereby enabling passengers and drivers to engage in more effective communication.*" Hence, we propose the following hypothesis:

H2: Usage flexibility when waiting for a ride positively relates to the passengers' perceived diagnosticity of the services provided by ridesharing platforms in alleviating traffic congestion.

When congestion hinders the fluent use of ridesharing services, the platforms try to retain users through discounts, compensation, and rewards (Saha et al., 2021). As confirmed in Phase 1, the compensation and reward services as extrinsic cues help users diagnose the ridesharing service: "*When traffic congestion becomes inevitable, the ridesharing platforms introduce targeted initiatives for passengers, such as providing free upgrades and issuing discount coupons.*" (I-27). Moreover, during congestion, the supply of high-end ridesharing services is relatively abundant compared with regular economy services. Some ridesharing platforms allocate these high-end resources to upgrade the services of some users for free. Similar to free product sampling, either less expenses or higher quality of ridesharing service motivates users to choose the ridesharing service during congestion (Shi et al., 2023). Given the high likelihood that users turn to ridesharing services during congestion, users are more likely to experience the objective measures aimed at reducing congestion provided by ridesharing platforms. Then, users gain an in-depth understanding of ridesharing's potential in relieving them from congestion and perceive high diagnosticity of service in alleviating traffic congestion provided by ridesharing platforms. Hence, we posit the following hypothesis:

H3: Compensation and reward positively relate to the passengers' perceived diagnosticity of the services provided by ridesharing platforms in alleviating traffic congestion.

5.2. Evaluation of transportation systems

Cue utilization theory helps explain the effect of diverse cues on cognition and behaviors (Ye et al., 2020). Notably, trust, as an outcome of cue utilization, simultaneously bridges cues and behavioral intentions of service users (Yang et al., 2020). Trust indicates that one party is willing to be influenced by the actions of another party and expects that the trustee tends to behave in a manner that matters (Mayer et al., 1995). Empirically, cues were validated to assist users in assessing trust (Hu et al., 2010). In Phase 1 of this research, the trust of users in the road transportation system was said to be affected by the cues regarding ridesharing in the context of congestion. "*These features provided by the platform will inspire my trust, as these measures can effectively solve traffic congestion and save time.*" (I-3).

In addition to trust, we focus our attention on perceived resilience, which depicts the innate ability to tolerate and absorb external changes and preserve the performance as ever efficiently (Ullah et al., 2022). Considering that ridesharing, renowned for its flexibility, is conducive to the resilience of the road transportation system, we examined the perceived resilience when using ridesharing in congestion (Cheng et al., 2024; Markolf et al., 2019). We found that cues about ridesharing services indicated capability in alleviating congestion and enhanced the perceived resilience of the road transportation system. As reported by respondent (I-22), "*The optimization of algorithms for ridesharing platforms have assisted in reducing traffic congestion… Regarding the flexibility of the transportation* *system, its recovery speed and response time are both relatively rapid.*".

According to Purohit and Srivastava (2001), how cues, either intrinsic or extrinsic, are utilized to which extent depends on their varied diagnosticity. The accumulated diagnosticity demonstrates that extrinsic and intrinsic cues jointly influence the evaluation (Szybillo and Jacoby, 1974). Given that the cues were identified and confirmed to influence the dependent variables, i.e., trust in and perceived resilience of the road transportation system, the collective diagnosticity could impact these two variables. Hence, we hypothesize the following:

H4: Perceived diagnosticity positively relates to the trust in the transportation system.

H5: Perceived diagnosticity positively relates to the perceived resilience of the transportation system.

Additionally, trust has been demonstrated to influence individuals' attitudes, intentions, and even behaviors (Yang et al., 2020). Trust was attested to influence the perceived resilience of the whole organization (Pavez et al., 2021). Moreover, the trust of users was evidenced to bolster the resilience of the technology-based system (Dubey et al., 2020). Considering the potential interaction between resilience and trust, we postulate the following hypothesis:

H6: Trust in the transportation system positively relates to the perceived resilience of the transportation system.

5.3. Moderating role of time urgency

In the process of cue utilization, boundary conditions have been noticed for their biasing effect on the relationships between cues and diagnosticity (Wang et al., 2016). For example, individuals' knowledge of the product was demonstrated to impact the utilization of cues when assessing the products (Lee and Lou, 1995). Moreover, personal characteristics are proposed to influence the utilization as boundary conditions potentially (Kukar-Kinney and Xia, 2017). In our study, in addition to intrinsic and extrinsic cues, time urgency was frequently mentioned and manifested as anxiety. When analyzing interview data, we found that time urgency emerged as a moderator affecting the efficacy of cues that enhance perceived diagnosticity. Specifically, when ridesharing users with time urgency are calling or waiting for a ride, the impact of information transparency and usage flexibility on individuals' perception is poor. As reported by respondent (I-3), "*I am anxious when hailing a car and constantly worried while waiting for the driver because it feels like everything is unknown, even though it shows the current driver's distance from me.*" This moderating effect is consistent with Easterbrook (1959), which indicated that negative emotions (e.g., anxiety) arguably and potentially inhibit the utilization of cues and further mitigate the performance of cues in diagnosing the focal object. We thus hypothesize the following:

H7a: Time urgency negatively moderates the relationship between information transparency and perceived diagnosticity.

H7b: Time urgency negatively moderates the relationship between usage flexibility and perceived diagnosticity.

6. Phase 2: Quantitative survey

The qualitative analysis conducted in Phase 1 provided us with a comprehensive understanding of how individuals utilize cues while using ridesharing services during congestion. In Phase 2, we aim to investigate the impact of these cues on individuals' perceived diagnosticity, trust, and perceived resilience.

6.1. Data collection and measurements

We conducted a survey using credamo.com, a professional questionnaire collection platform, to gather data from participants who have taken ridesharing during traffic congestion. Participants were asked to recall their experience of using ridesharing services during

Table 2
Demographics of participants.

Category	Item	Sample (N = 353)
Gender	Male	45.61 %
	Female	54.39 %
Age (years)	18–25	42.78 %
	26–30	26.91 %
	31–40	25.50 %
	>40	4.82 %
Education	Senior high school and below	3.40 %
	Associate degree	11.61 %
	Bachelor's degree	71.67 %
	Master's degree	10.76 %
	Doctoral degree	2.55 %
Frequency of taking ridesharing	Rarely	2.83 %
	Occasionally	24.65 %
	Frequently	57.79 %
	All the time	14.73 %
Years of taking ridesharing	<1	3.40 %
	1–3	29.75 %
	3–5	34.84 %
	>5	32.01 %

traffic congestion and answer related questions. We employed three measures to process the data: (1) removing data with duplicate IP addresses, (2) removing data with repetitive or regular responses, and (3) removing data with insufficient completion time. The regular responses indicate that participants did not carefully read the questionnaire items and instead provided the same responses for different questions, potentially leading to the invalid questionnaires. Finally, we obtained 353 valid samples from 27 provinces, municipalities, and autonomous regions across the country, indicating sample diversity and low bias. Table 2 provides the demographic information.

In this regard, this study used existing scales to ensure the questionnaire's quality. The questionnaire design used a five-point Likert scale. All items were translated into Chinese and revised to fit this study. The content of the scale is provided in Table 3. Demographic variables, such as gender, age, education, frequency of taking ridesharing, and years of taking ridesharing, were also included in the questionnaire.

6.2. Data analysis and results

Following a two-step analytic approach, we first performed confirmatory factor analysis to evaluate the model and then used SEM to test the empirical hypotheses (Anderson and Gerbing, 1988). As shown in Table 4, the Cronbach's α values, composite reliability (CR), and average variance extracted (AVE) for all constructs exceeded the acceptable thresholds of 0.7, 0.8, and 0.5, respectively, indicating satisfactory results (Fornell and Larcker, 1981; Nunnally, 1967). Additionally, the factor loadings for each item exceeded the threshold of 0.7 (Fornell and Larcker, 1981). These results suggest acceptable internal consistency, reliability, and convergent validity of the model. We also obtained the variance inflation factor (VIF), and all values were below 5, suggesting the absence of multicollinearity issues. Moreover, we employed Harman's single-factor test to examine potential common method bias (CMB) (Podsakoff et al., 2003). The results obtained from SPSS indicate that the variance explained by the first and largest factor is 30.73 % (<50 %), suggesting the absence of CMB problem in our study.

Furthermore, the square root of each construct's AVE value exceeds its correlations with other constructs (Table 5) (Fornell and Larcker, 1981). Table 6 presents the heterotrait–monotrait (HTMT) values, all of which were below 0.85, indicating good convergent validity (Benitez et al., 2020).

Bootstrapping with 5,000 iterations was used to evaluate the parameter estimates. The SRMR value of 0.053 (<0.08) indicates an acceptable model fit (Hu & Bentler, 1999). The model explained 37.4 %, 24 %, and 47.2 % of the variance in PD, TTS, and PRTS, respectively. Table 7 and Fig. 5 reveal the path analysis results. Specifically, IT, UF, and CRD were positively associated with PD; PD was positively associated with TTS and PRTS; and TTS was positively associated with PRTS. Therefore, H1–H6 were all supported.

Table 3
Scale development.

Constructs		Question	Source
Information transparency (IT)	IT1	The traffic congestion information presented on ridesharing platforms (such as real-time traffic conditions, queue length, estimated time, etc.) is transparent.	(Venkatesh et al., 2016)
	IT2	The ridesharing platforms will provide me with deep access to traffic congestion conditions.	
	IT3	The ridesharing platforms will provide me with in-depth knowledge on traffic congestion conditions.	
Compensation and reward (CRD)	CRD1	I expect to receive compensation and reward (e.g., timeout compensation fees or free tickets) in return for my use of ridesharing in traffic congestion.	(Kankanhalli et al., 2015)
	CRD2	It is important for me to get compensation and reward in return for my use of ridesharing in traffic congestion.	
	CRD3	It is important for me to relieve traffic congestion through compensation and rewards provided by the ridesharing platforms.	
Time urgency (TU)	TU1	I find myself in a rush to wait for the ridesharing even when there is an ample amount of time.	(Mohammed and Nadkarni, 2011)
	TU2	People familiar with me agree that I tend to wait for the ridesharing in a hurry.	
	TU3	I often feel very pressed for time while waiting for the ridesharing.	
Usage flexibility (UF)	UF1	Ridesharing platforms will flexibly respond to traffic congestion.	(Mithas et al., 2008)
	UF2	Ridesharing platforms will allow passengers to use the ride-hailing service flexibly (such as canceling orders within a certain time limit) rather than stick to original terms if there was traffic congestion.	
	UF3	Ridesharing platforms will make continuous adjustments to cope with traffic congestion.	
Perceived diagnosticity (PD)	PD1	It is helpful for me to evaluate the situation of calling for a ride.	(Jiang and Benbasat, 2007)
	PD2	It is helpful for me to understand the situation of calling for a ride.	
	PD3	It is helpful for me to evaluate the situation of waiting for a ride.	
	PD4	It is helpful for me to understand the situation of waiting for a ride.	
Perceived resilience of the transportation system (PRTS)	PRTS1	Ridesharing platforms are well prepared to respond to traffic congestion in the road transportation system.	(Park et al., 2015)
	PRTS2	Ridesharing platforms have relevant measures to handle traffic congestion in the road transportation system.	
Trust in the transportation system (TTS)	TTS1	I trust the road transportation system to be reliable.	(Srivastava and Chandra, 2018)
	TTS2	I believe the road transportation system to be trustworthy.	

Table 4
Reliability and validity results.

Constructs	Item	VIF	Factor loading (>0.7)	Cronbach' α	AVE	CR
Information transparency (IT)	IT1	1.459	0.809	0.737	0.656	0.851
	IT2	1.448	0.801			
	IT3	1.474	0.819			
Compensation and reward (CRD)	CRD1	1.503	0.828	0.784	0.698	0.874
	CRD2	1.682	0.832			
	CRD3	1.831	0.846			
Usage flexibility (UF)	UF1	1.438	0.827	0.725	0.644	0.844
	UF2	1.362	0.749			
	UF3	1.503	0.829			
Perceived diagnosticity (PD)	PD1	1.499	0.791	0.731	0.554	0.832
	PD2	1.422	0.740			
	PD3	1.400	0.717			
	PD4	1.417	0.726			
Trust in the transportation system (TTS)	TTS1	1.891	0.916	0.814	0.843	0.915
	TTS2	1.891	0.921			
Perceived resilience of the transportation system (PRTS)	PRTS1	1.445	0.875	0.714	0.778	0.875
	PRTS2	1.445	0.889			
Time urgency (TU)	TU1	4.573	0.920	0.930	0.830	0.936
	TU2	3.752	0.987			
	TU3	3.357	0.819			

Table 5
Fornell–Larcker criterion.

	AVE	IT	CRD	UF	PD	TTS	PRTS	TU
IT	0.656	**0.810**						
CRD	0.698	0.204	**0.835**					
UF	0.644	0.545	0.214	**0.802**				
PD	0.554	0.379	0.356	0.435	**0.744**			
TTS	0.843	0.572	0.257	0.562	0.458	**0.918**		
PRTS	0.778	0.587	0.164	0.607	0.446	0.637	**0.882**	
TU	0.830	−0.16	0.038	−0.244	−0.038	−0.110	−0.188	**0.911**

Note: The values of the diagonal represent the square roots of the AVE.

Table 6
HTMT values.

	IT	CRD	UF	PD	TTS	PRTS	TU
IT							
CRD	0.275						
UF	0.747	0.296					
PD	0.511	0.472	0.591				
TTS	0.739	0.325	0.730	0.587			
PRTS	0.811	0.225	0.840	0.613	0.835		
TU	0.199	0.037	0.273	0.078	0.133	0.193	

Additionally, the moderating effect of TU on the relationship between IT and PD was not significant. By contrast, TU significantly and negatively moderated the impact of UF on PD. Thus, H7a and H7b were rejected and supported, respectively.

Furthermore, we conducted the mediation analysis following the existing instructions (Zhao et al., 2010). Table 8 depicts the results, whereby P_1, P_2, and P_3 refer to the effect of the independent on the mediator variable, the mediator on the dependent variable, and the independent on the dependent variable, respectively. In addition, $P_1 \bullet P_2$ and P_3 refer to the indirect and direct effects, respectively. When indirect effect (i.e., $P_1 \bullet P_2$) is significant, the mediation exists; otherwise, no mediation occurs. In this case, the partial mediation is present if direct effect (i.e., P_3) is significant; otherwise, full mediation occurs.

7. Conclusions and discussion

7.1. General conclusions

Given the contextual novelty of this study, we draw on cue utilization theory and adopt a mixed-methods approach to explore and confirm the mechanism by which users assess the resilience of transportation systems. We also explain how ridesharing usage enhances the perceived resilience of the transportation system in congestion from an individual's cognitive perspective. We offer the main

Table 7
Structural model results.

Hypotheses	Paths	Effect	P	Supported?
H1	IT → PD	0.190**	0.004	Yes
H2	UF → PD	0.427***	0.000	Yes
H3	CRD → PD	0.216***	0.000	Yes
H4	PD → TTS	0.401***	0.000	Yes
H5	PD → PRTS	0.187**	0.004	Yes
H6	TTS → PRTS	0.530***	0.000	Yes
H7a	TU * IT → PD	−0.039	0.627	No
H7b	TU * UF → PD	−0.248*	0.048	Yes
	Gender → TTS/PRTS	−0.071/0.032	0.455/0.686	No/No
	Age → TTS/PRTS	0.064/0.190***	0.095/0.000	No/Yes
	Education → TTS/PRTS	0.031/−0.009	0.547/0.831	No/No
	Frequency → TTS/PRTS	0.135*/0.030	0.019/0.557	Yes/No
	Time → TTS/PRTS	0.040/−0.053	0.453/0.244	No/No

Note. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

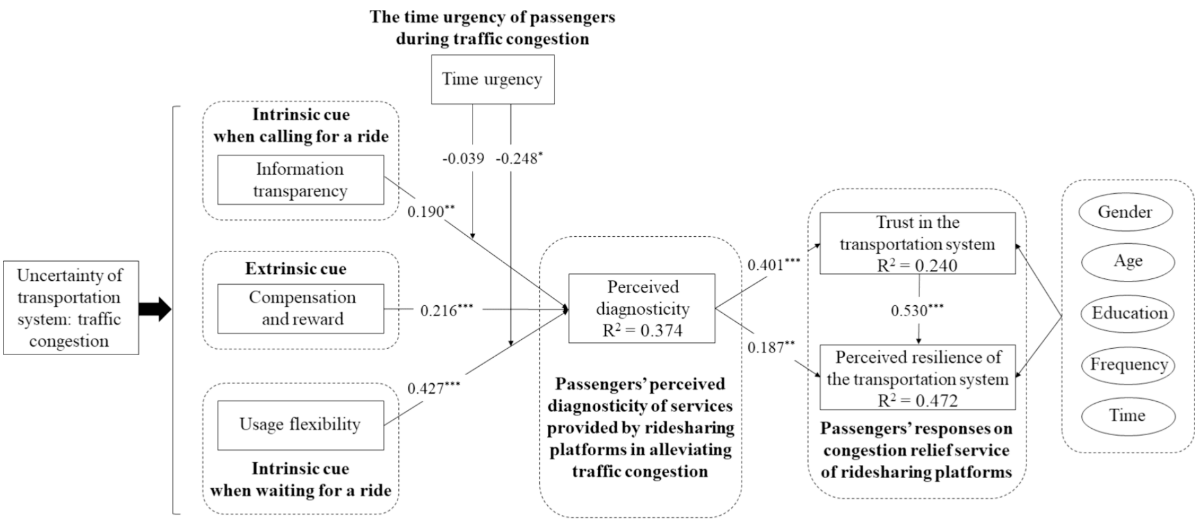

Fig. 5. Structural model results.

Table 8
Mediation testing results.

Mediator variable	Independent variable	Dependent variable	Is $P_1 \bullet P_2$ significant?	Is P_3 significant?	Type of mediation
PD	IT	TTS	Yes	Yes	Partial mediation
		PRTS	No	Yes	No mediation
	CRD	TTS	Yes	Yes	Partial mediation
		PRTS	Yes	Yes	Partial mediation
	UF	TTS	Yes	Yes	Partial mediation
		PRTS	Yes	Yes	Partial mediation

findings as follows (Fig. 6):

First, we identified cues utilized by ridesharing users in congestion to evaluate the transportation system through qualitative interviews. In the first inefficiency of ridesharing use (i.e., calling for a ride), information transparency was reported as an intrinsic cue to help evaluation. In the second inefficiency (i.e., waiting for a ride), usage flexibility emerged as a second intrinsic cue. In this process, the construct of compensation and reward functions as an extrinsic cue to diagnose the ability of the ridesharing service to alleviate congestion.

Second, on the basis of SEM, we found positive relationships between identified cues (i.e., reward and compensation, information transparency, and usage flexibility) and perceived diagnosticity of ridesharing service in alleviating congestion (H1–H3). These relationships imply the predictive power of ridesharing cues in congestion mitigation. Passengers' perceived diagnosticity of services cues in alleviating traffic congestion enhances their perceived resilience and trust of the transportation system. High trust relates to high perceived resilience of the transportation system (H4–H6). Understandably, ridesharing users experiencing effective cues, either

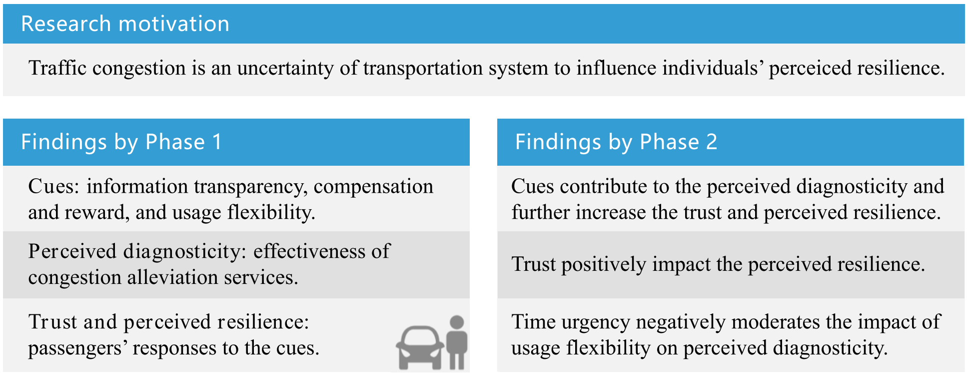

Fig. 6. Research findings.

intrinsic or extrinsic, are likely to perceive high resilience of the transportation system during congestion. We also found the negative moderating role of time urgency in the relationship between usage flexibility and perceived diagnosticity (H7b). However, the moderating effect of time urgency on the effect of information transparency was not supported (H7a). Apparently, time urgency poses varied influences on different functions in ridesharing services, and ridesharing users use different cues when they are pressed for time.

7.2. Implications

Our study bears theoretical and practical implications. Theoretically, we extend cue utilization theory from consumer and marketing research to the field of ridesharing and transportation (Visentin and Tuan, 2021; Wedel and Pieters, 2015). The qualitative study guided by the overarching theoretical framework (i.e., cue utilization theory) provides a fine-grained understanding of crucial cues for transportation evaluation. Second, we explore the boundary condition of cue utilization theory. Despite the proposal that personal characteristics potentially influence cue utilization and the broad use of the theory, only a few studies investigate critical and concrete personal factors (Kukar-Kinney and Xia, 2017; Lee and Lou, 1995). In the context of congestion, time urgency amplifies users' negative arousal and thus potentially hampers cue utilization, negatively moderating the positive relationship between information transparency and perceived diagnosticity of ridesharing services in alleviating congestion (Easterbrook, 1959). Third, although ridesharing contributes to the resilience of transportation systems, studies disclosing the users' cognitive processing mechanism are surprisingly scant (Chen et al., 2019). We are among the first to ascertain the effect of service in ridesharing platforms on the perceived resilience of transportation systems through perceived diagnosticity, particularly during the calling and waiting for a ride.

Practically, given that we have confirmed the potential of ridesharing services in congestion, traffic management departments are encouraged to pay increased attention to the role of ridesharing in enhancing perceived resilience. When constructing the road transportation system, managers are suggested to improve the distribution of ridesharing pick-up points at crowded places, such as train stations. When implementing traffic restrictions, they are also suggested to consider providing additional privileges for ridesharing vehicles similar to those of taxis. Second, managers are advised to evaluate and manage ridesharing platforms according to the cues derived from them. In terms of enhancing intrinsic cues, ridesharing platforms are requested to have high information transparency and flexibility of use, allowing users to contact drivers, browse path information, cancel orders, and change routes during congestion. In terms of reinforcing extrinsic cues, if ridesharing platforms cannot provide timely service, such as failing to find a driver for the use within the expected wait time, platforms should be required to provide corresponding compensation to the users. Third, under the consideration that time urgency negatively offsets the effect of usage flexibility on the evaluation of the transportation system, the ridesharing platform could start up a new fast service to deal with urgent demands with increased expenses. When congestion is heavy and vehicle speeds are low, ridesharing platforms can push soothing alerts at regular intervals to stabilize the user's mood or use dynamic path planning to recommend other fast travel options for the user.

7.3. Limitations and future work

Our study still has a few limitations. First, our dataset is derived from China, presenting a Chinese context of the perceived resilience of the transportation system during traffic congestion. However, demographic characteristics, traffic conditions, and the usage patterns of ridesharing platforms across nations and regions have significant differences. Future studies should collect globally diverse data and evaluate them comparatively within distinct contexts, including different urban settings and varied demographic groups. Second, as ridesharing and transportation systems continue to improve and new technologies (e.g., generative artificial intelligence) develop, utilized cues may evolve and differ from now. Potential negative cues from ridesharing and other moderating factors deserve further investigation. Hence, future research can focus on the emerging context and develop the theoretical model.

CRediT authorship contribution statement

Xusen Cheng: Writing – original draft, Supervision, Resources, Methodology, Funding acquisition, Conceptualization. **Shuang Zhang:** Validation, Software, Investigation, Data curation. **Yanyue Ran:** Visualization, Investigation, Formal analysis. **Baojun Ma:** Writing – review & editing, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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