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Research on perception bias of implementation benefits of urban intelligent transportation system based on big data

Xiao Hu^{1*} and Zhenghua Deng²

Abstract

Providing convenient and comfortable transportation services for residents is an important part of urban construction, in which the intelligent transportation system (ITS) plays an important role. This study used the big data of urban public transportation in China and the evaluation of ITS in tourism e-commerce website to compare travelers' perception of urban intelligent transportation with the objective effects of ITS and analyzed the factors that affect the perception bias of urban residents about ITS. The conclusions are as follows: (1) there are regional differences in travelers' perception of ITS. The traveler's evaluation of ITS in the cities of East China is best in China, followed by cities in the central and southwestern regions. (2) The perception bias of urban residents from ITS is generally affected by the density of road network and travel radius. The influencing factors of perception bias are obviously different between provincial capital cities and non-provincial capital cities. (3) The use of digital maps, navigation, and intelligent road conditions in the travel process can improve travelers' evaluation of ITS.

Keywords: Intelligent transportation system, Big data, Perception Bias

1 Introduction

Intelligent transportation system (ITS) is a real-time, accurate, and efficient integrated traffic management system which plays an important role in a wide range and comprehensive traffic management. It effectively applies advanced electronic sensing technology, information technology, data communication transmission technology, network technology, and control technology to the entire traffic management system. By the information exchange and coordination of the core traffic elements, ITS helps to form an efficient collaborative environment for people, vehicles, and transportation. With the development of economy and the continuous expansion of urban scale, people rely more on motor vehicles in their daily life, which brings more and more serious problems to urban transportation, environment, and energy. Intelligent transportation systems can integrate

transportation infrastructure, traffic vehicles, transportation participants, and information services to solve these problems. Therefore, such systems have been enjoying rapid development. The acceleration of smart city construction process has promoted the rapid increase of investment in intelligent transportation projects. The Japanese government is working hard to develop autonomous driving and Internet of vehicles technologies to build the world's leading intelligent transportation system by 2020. The Dutch government invested nearly 70 million euros to promote the development of intelligent transportation system in 2016. In China, in 2012, the number of urban intelligent transportation projects with investment exceeding 10 million yuan was 235, and the total investment reached 6.81 billion yuan. By 2017, the number of them has reached 1087, and the total investment has reached 19.08 billion yuan, with the average annual investment about 17.48 million yuan.

Compared with the traditional transportation infrastructure construction projects, most of ITS projects rely on the development of emerging technologies. The

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design and implementation of it need to consider more comprehensive and complex issues, including the impact of economic level, social environment, geographical characteristics, and other factors. Although the construction of intelligent transportation industry has been valued in many countries, and the overall traffic situation has been improved to a certain extent, there are few studies on the perception of ITS by travelers and urban residents. At present, the research on the application effect of ITS mainly focuses on the travel quality and economic benefits. Wu et al. used connectivity as an evaluation index to measure the application effect of intelligent transportation system, and the study showed that ITS system could alleviate congestion and improve the speed of urban traffic [1]. Shi and Abdel-Aty found that a proactive real-time traffic monitoring strategy could be used to improve the system performance of urban expressways by reducing congestion and crash risk [2]. Zhou introduced spatial and temporal analyses separately to evaluate the mitigation of congestion under various traffic conditions and found that guidance messages made more significant contributions to improve the service level of congested roads [3]. Such research mainly focuses on improving traffic quality or evaluating of a function in the ITS system. Brand and Geis and Schulz evaluated the benefits of ITS projects and determined the screening, sequencing, and selection strategies for different ITS sub-projects [4, 5]. Mondschein et al. studied the impact of ITS on traffic accessibility [6]. Zong et al. evaluated ITS in terms of social benefit, individual benefit, and enterprise benefit from the perspective of macro application [7]. Zhang et al. evaluated ITS from the environmental point of view. They believed that the application of ITS data to emission management system could achieve dynamic air quality management [8]. Due to the complexity of ITS, the existing studies on ITS evaluation are mainly completed by constructing an index system and using subjective methods such as qualitative or fuzzy mathematics, with poor accuracy of the evaluation results.

Research on the application effect of ITS has important guiding significance to the development of ITS. Previous studies on the application effect of ITS are carried out on an external perspective. The essence of ITS application is to improve the living environment of urban residents. The potential of big data research makes it urgent to introduce new research methods and perspectives into the study on the application effect of ITS. Therefore, this research adopted text analysis method to analyze the emotional tendency of ITS implementation effect from the internal perspective and made a comparative analysis with the objective effect of it, so as to understand the subjective and objective differences of satisfaction of ITS and its influencing factors and provide a reference for traffic management.

2 Conceptual framework of its perception bias

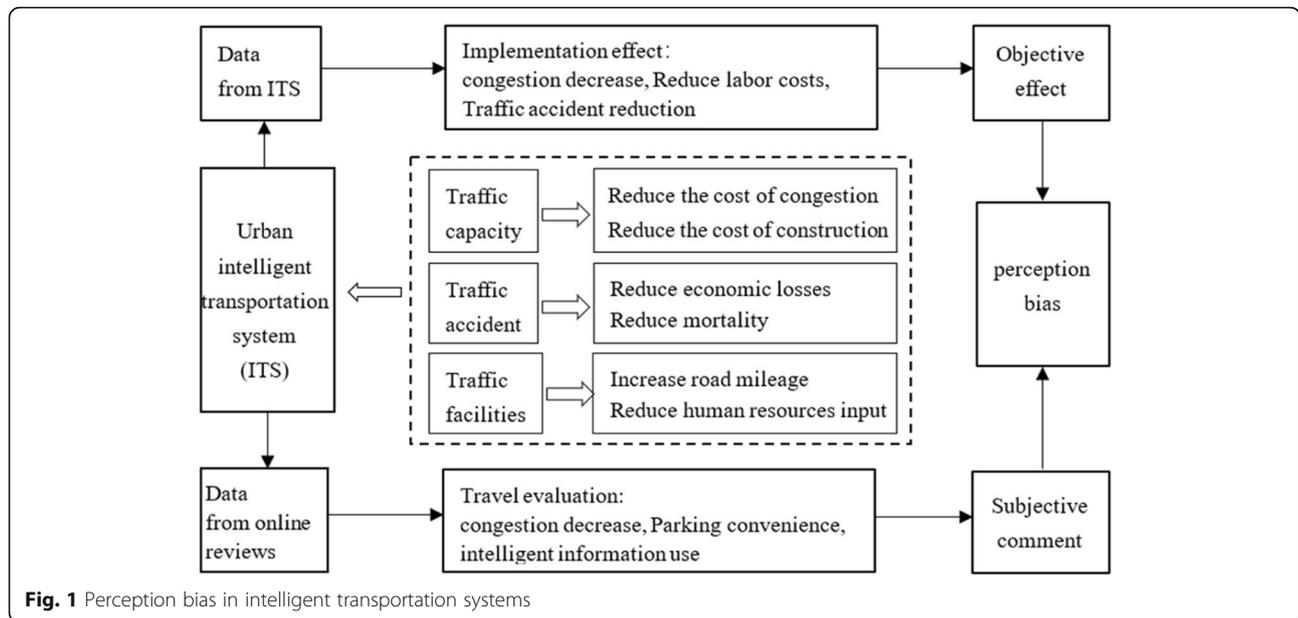
The implementation of urban intelligent transportation system aims to improve urban living environment, promote green travel, and build better urban space. Just as the utility of consumer goods is determined by factors such as commodity characteristics and consumption environment, urban residents' sense of transportation is determined by factors such as traffic characteristics and surrounding environment [9]. Urban residents' perception of traffic acquisition is the perception of traffic satisfaction, which is a type of subjective evaluation [10]. Urban residents' perception of traffic is their actual perception of traffic facilities, services, environment, and other elements in their living space. According to the design purpose, urban intelligent transportation system can provide more traffic information, save travel time, and improve the comfort of the traffic process. Generally, the use of urban intelligent transportation system will enhance the favorable impression of urban residents towards urban transportation.

For urban residents, their perception of ITS is closely related to travel. Residents acquire, filter, and store environmental information during their travel. This process accumulates and changes the perception of urban traffic [11]. In the process of travel, the function of ITS focuses on the comfort of travel, that is, whether to complete the round trip between the departure and destination in a stable time. At this time, the human brain's perception of the external environment can indirectly reflect the road environment and patency. This study on the implementation effect of ITS from the perspective of traffic participants is an important way to explore ITS construction, especially the peak demand. In the era of big data, the analysis of such data as traffic congestion data, traffic violation data, and ETC toll data can well explain the improvement of traffic after ITS is put into use [12]. Residents' perception is influenced by their living and traveling environment. It may not be consistent with ITS operational data. Whether the implementation of ITS has achieved the purpose of improving urban livability or not, the key is the consistency between travelers' feelings and traffic data. The conceptual framework of ITS perception bias is shown in Fig. 1. It can be seen from Fig. 1 that the evaluation criteria for ITS is not a single dimension. There may be differences in the conclusions from different perspectives. Figure 1 shows the process of generating perception bias for urban residents and travelers. The content inside the dotted box is a description of the content of the ITS construction.

3 Methodology

3.1 Measurement of ITS perception

The functions of intelligent transportation system cover a wide range, including traffic management, electronic



toll collection, road safety, and assisted driving. However, as the users of ITS, the scope of their feelings is limited to the part of their participation. In this study, we selected the travel events with the highest participation of urban residents in the intelligent transportation system to analyze and measure residents' perception of ITS.

By using the big data of urban tourism e-commerce websites, the text analysis can be used to realize the perception of urban residents and travelers on the use of ITS in the cities they live in. The reason for using the big data of urban tourism travel review is that ITS has a strong regional feature, while urban tourism BBS is a network space for travelers or residents to express their personal views on the city and exchange their impressions of the city. The reviewers' comments on the regional scope of the city are consistent with it of ITS. In order to construct the intelligent transportation perception evaluation model, we mainly refer to the emotional analysis model in Liu's research [13]. The emotion index of urban intelligent transportation is calculated to measure the perception of travelers and residents to the intelligent transportation system.

The measurement of emotional index of urban ITS includes three steps: constructing ITS-specific thesaurus, defining semantic discriminant rules, and adjusting emotional coefficient. The establishment of lexical database is the base of analyzing text emotion by lexical matching technology. In order to increase the credibility of evaluation results, this study uses the HowNet dictionary published by CNKI and delete the literary and uncommon words, as well as the specific words of describing the personality of the characters, and then extracts some words of intelligent transportation that are not included

in the dictionary by browsing reviews to build an intelligent transportation thesaurus. Secondly, adding semantic discriminant rules can make the text's emotional analysis more in line with the real feelings of urban residents [14]. Generally, the comment in BBS tend to be positive, so emotional coefficient should be added to adjust the score of comments to reduce the calculation error in order to accurately reflect residents' emotional tendencies towards ITS. Finally, the percentage of non-negative comments (including positive and neutral comments) in the total comments was used to represent the emotional index of intelligent transportation of each city, that is, the satisfaction degree of intelligent transportation [15].

Let E_{score} be the emotional value of each comment and E be the initial score of each comment. The initial score of E is 0. If a positive word appears in the comment, it will increase by 1 point; if a negative word appears, it will drop by 1 point at a time. Degree is the adjustment coefficient, which was divided into five grades, and the range of values is 1–3. Negative is the number of negative words, the value of Negative is -1 for odd number while 1 for even number. Adversative is the turning word, the value of the first category is -0.5 , and the second category is 2.

Then:

$$E_{score_n} = E_n \times degree_i \times Negative_j \times adversative_k \tag{1}$$

People will choose to be more active on social networks to gain a sense of social identity. In order to avoid the exaggeration of positive emotions and to ensure the

rationality of emotional characteristics evaluation, it is necessary to correct the number of negative vocabularies. When the comment is of negative, the value of $Escore$ is adjusted to four times [13].

The emotional index of urban ITS is as follows:

$$Index_m = 1 - Escore_{neg} \div Escore_{total} \quad (2)$$

where $Escore_{neg}$ is the number of negative comments and $Escore_{total}$ is the total number of comments of each city.

3.2 Implementation effect of ITS

Based on the above analysis of travel comments, it is found that the focus of city dwellers and travelers on urban traffic is congestion in the process of travel. The expectation of them to intelligent transportation system is also focused on solving traffic congestion problems, which is one of the important goals of intelligent transportation system design. We use the traffic big data of Auto Navi Map to measure the implementation effect from the perspective of travelers. The changes of time cost of city dwellers and travelers caused by traffic congestion are used to measure the effectiveness of intelligent transportation system.

3.3 Perception bias

Perception bias is the difference between the achievement of the intelligent transportation system design goal and the evaluation of it from travelers who participates in the traffic activity in the city with intelligent transportation system. In this study, we sorted the sentiment index and implementation effect of the intelligent transportation system in each city separately and defined the difference in the rankings of the city in the two different sorting results as perception bias. Perception bias reflects the deviation between ITS implementation effect and travelers' perception. When the difference is negative, it indicates that the traveler's satisfaction with the intelligent transportation system is lower than the achievement of the system's own goal. Then, there is a perceived under-deficiency, travelers are not fully aware of the benefits of ITS implementation. When the difference is positive, it indicates that the traveler's satisfaction with the intelligent transportation system is higher than the achievement of the system's own goal. Then, there is excessive perception bias; travelers overestimate the benefits of ITS implementation.

3.4 Influencing factors of perceptual bias

Individual perception of things depends on external perception and internal cognitive processes. Therefore, the reasons for the deviation of the perception and implementation effect of the intelligent traffic system by urban

travelers can also be analyzed from both internal and external aspects.

The intelligent transportation system is designed according to the development of urban traffic. The development of urban traffic determines the maturity of intelligent transportation system and directly affects the satisfaction of urban residents with it. The level of urban transport development in China has decreased from the eastern region to the western region. The transportation network in urban dense areas is highly covered, and the urban transportation development level of provincial capitals and main road intersections is also higher than in other areas. The ITS of these cities is more mature than in other cities with weak transportation. The design of the intelligent transportation system also takes into account the future development of the city's economy and transportation. But the prediction of economic and transportation in the future is based on historical data. When the future development of the city is not in line with the predictions when designing ITS, the implementation effect of the intelligent transportation system is limited by its design flexibility. The city's economy and major industries also affect the perception of urban residents about the intelligent transportation system. Urban transport development level, as a proxy variable for the maturity of ITS, can be measured by road network intensity, vehicle diversity, and intelligent travel. The economic development of a city can be measured by the growth rate of GDP.

Urban travelers' perception of ITS comes from their travel experience. According to the Travel Time Savings Model, the time value of resident's travel depends on the effectiveness of time and the specific context in which time is spent. The time value of travel consists of three factors: wage rate, travel expenses, and travel time [16]. The income level of the residents determines the type of transportation they can choose when traveling. When the choice of travel tools is limited by the financial constraints, the residents' travel experience will decline. Residents compare travel experience with travel expenses, and the worse the travel experience, the more likely they are to be dissatisfied with the cost of travel. The shorter the traveler spends on the vehicle, the less susceptible it is to other traffic factors. Then, the travel experience of the traveler is better, and the traveler's satisfaction with the implementation of ITS is increased. Therefore, income levels and road congestion are factors that influence travelers' perceptions of travel experiences.

3.5 Empirical model

The study used the above factors to establish an empirical model, which may influence the perception bias of ITS from urban residents and used Stata 13 for multiple regression. The regression model is as follows:

$$\begin{aligned}
 ED = & a_0 + a_1 \text{Density} + a_2 \text{Population} + a_3 \text{Growth} \\
 & + a_4 \text{Transport} + a_5 \text{ITI} + a_6 \text{Income} + a_7 \text{Congestion} \\
 & + a_8 \text{Radius} + a_9 \text{Pcapital} + a_{10} \text{Region} + \mu
 \end{aligned}
 \tag{3}$$

The variables are defined in Table 1.

In this study, we selected the intelligent traffic situation of 120 Chinese cities in 2017 as research samples. Because China's intelligent transportation industry has developed rapidly in recent years, many cities are building or improving the intelligent transportation system to facilitate access to data before and after ITS is put into use. One hundred and twenty sample cities include 28 provincial capital cities, 4 municipalities directly under the central government, cities listed as ITS model cities or urban data brains pilot cities, and some prefecture-level cities. After removing the cities with missing data, a sample of 93 cities was finally obtained.

We use the tourism e-commerce website with rich reviews of Chinese cities as the source of the comment data. It is to obtain a short commentary by the traveler about the traffic conditions within a certain city. Then, Baidu Travel Network (<https://lvyou.baidu.com>) was finally selected as the source of traffic comment data for this study. Because Baidu Travel Network has a large number of comments, it covers a wider geographical area, and the overall comments on a city are more comprehensive. Considering that the traveler's perception of ITS is lagging behind the ITS implementation, the

crawling time of the network commentary of the 93 cities through the web crawler was June 30, 2018, and a total of 3162 comments on intelligent transportation were obtained.

The data of population, growth, and income comes from the 2017 statistical yearbook of each province. The data of density and transport data are taken from the 2017 China Urban Construction Statistical Yearbook. The data of ITI, congestion, and radius comes from the data announcement of Gaode Map Traffic Big Data and Didi Travel Big Data in 2017.

4 Results and discussion

4.1 Perception bias of sample city

The average traffic intelligence index for all cities is 0.723. The cities with the top 5% of the index are Fuzhou, Shanghai, Guangzhou, Tianjin, and Nanjing. According to the distribution of urban areas, the average sentiment index of cities in eastern China is 0.786 that is higher than other cities, followed by cities in the central and southwestern regions. This shows that the traveler's evaluation of the intelligent transportation system in the cities of East China is best in China. In all cities, the average value of the intelligent traffic sentiment index of provincial capital cities is higher than it of non-provincial cities. The intelligent traffic sentiment index of Beijing is 0.714, the lowest among the four municipalities directly under the central government.

4.2 Descriptive statistics

Among all the samples, the proportion of travelers who are more satisfied with the intelligent transportation system than its implementation effect is 45.16%. While the proportion of travelers who are less satisfied with the intelligent transportation system than its implementation effect is 52.69%. Cities with no difference accounted for 2.15%. This indicates that the perceived bias of the traveler varies between different cities. From the perception bias of regional distribution, travelers in cities in East China and Northwest China are more satisfied with intelligent traffic than facts, while travelers in North China and Northeast China tend to have poor perception of intelligent traffic. Table 2 lists descriptive statistics for major variables.

4.3 Test results of full samples and analysis

Table 3 shows the standardized regression results. In each regression equation, the VIF values of the variables are lower than 10, and their mean is less than 5. There is no serious multicollinearity among variables. The full sample test shows that the coefficients of density, ITI, and radius are significantly positive. It indicating that perception bias of the traveler from the intelligent transportation system is negatively affected by the road

Table 1 Definitions of the variables

Variable	Definition
ED	Differences in the ranking of urban intelligent traffic sentiment index and implementation effect of the city
Density	Ratio of the total mileage of the road network to the area of the city
Population	The natural logarithm of the permanent resident population in the city
Growth	GDP growth rate
Transport	Summary of the categories of vehicles available to urban residents for daily travel
ITI	Intelligent travel index: use of digital maps, navigation and intelligent road conditions for urban residents' daily travel
Income	Natural logarithm of per capita disposable income of urban residents
Congestion	All-day congestion delay index: the ratio of actual velocity to free flow velocity throughout the day
Radius	Travel radius of the city
Pcapital	Virtual variable of whether it is a provincial capital, the value is 1 if it is; otherwise, it is 0.
Region	Virtual variable of whether the city is located in the economically developed area of the eastern coast of China, the value is 1 if it is; otherwise, it is 0.

Table 2 Descriptive statistics of variables

Stats	Mean	Median	Max	Min
ED	0.000	2.000	81.000	-74.000
Density	7.358	7.090	16.730	3.820
Population	6.435	6.482	8.123	4.331
Growth	0.076	0.079	0.110	0.021
Transport	3.484	3.000	6.000	3.000
ITI	27.504	20.400	100.000	2.400
Income	10.533	10.490	11.044	10.112
Congestion	1.507	1.503	1.717	1.260
Radius	16.729	15.000	31.700	6.000
Pcapital	0.323	0.000	1.000	0.000
Region	0.699	1.000	1.000	0.000

construction and travel experience, causing the traveler's perception to be excessive. When road network density and travel radius of the city increase, travelers have more routes to choose from. Then, the traveler's route decision becomes more complicated. The travelers require a high-quality urban traffic environment urgently. Travelers tend to choose intelligent travel tools that benefit travelers from the intelligent transportation system. It will cause them to overestimate the effects of the intelligent transportation system. There is no significant correlation between growth, income, and perception bias, which may be related to the lower difference in transportation costs between daily travel between cities.

4.4 Test results of grouped samples and analysis

Considering the differences in transportation construction between provincial capitals and non-provincial cities, the samples were divided into two groups: provincial capital cities and non-provincial capital cities. The results in

Table 3 Regression results of empirical model

Variable	Whole samples		Pcapital = 1		Pcapital = 0	
	Coef.	t	Coef.	t	Coef.	t
Density	-0.225**	-2.13	-0.282	-1.51	-0.233*	-1.96
Population	0.045	0.40	-0.528	-1.43	0.072	0.62
Growth	0.030	0.34	-0.164	-0.96	0.188*	1.83
Transport	0.086	0.60	-0.108	-0.38	0.268*	1.93
ITI	-0.450***	-2.72	-0.738**	-2.43	-0.426**	-2.17
Income	0.035	0.23	-0.342	-1.13	0.120	0.66
Congestion	-0.094	-0.81	0.072	0.41	-0.085	-0.65
Radius	-0.336*	-1.92	0.805*	1.82	-0.554***	-2.99
Pcapital	0.087	0.71	-	-	-	-
Region	0.080	0.71	0.316	1.33	0.002	0.02
Adj-R2	0.3537		0.3077		0.4399	
Num	93		30		63	

*p < 0.1, ** p < 0.05, *** p < 0.01

Table 3 show that the effects of four variables, density, growth, transport, and radius, on perception bias are different between the two groups. In the sample group of non-provincial capital cities, the regression coefficients of density and radius were significantly negative, while in the sample group of provincial capital cities, the coefficients of the two variables were not significant. The reason may be that compared with the provincial capital cities, the traffic congestion in the non-provincial cities is relatively light, and the urban road conditions are low in complexity, which induces urban residents to attribute the convenience of travel to the intelligent transportation system. In the sample group of non-provincial capital cities, the regression coefficients of growth and transport were significantly positive, while in the sample group of provincial capital cities, they were not significant. The possible reason is that the more per capita GDP growth, the higher the requirements for the urban living environment, and the greater attention to the travel convenience. The diversity of vehicles increases the difficulty of managing traffic with the intelligent transportation system. It leads travelers to believe that congestion is due to the unreasonable intelligent transportation system.

5 Discussion

The above analysis is based on considering urban residents and urban travelers as a whole of ITS users. In fact, the demand for intelligent transportation may vary among different groups of people. Although this does not lead to substantial differences in the conclusions, the study on the purpose of differentiated travel is one of the research directions worthy of further study in the future on the basis of this study. At the same time, the ITS system in this study specifically refers to the ITS of a certain city. With the development of information technology and future travel demand, the interconnection and the interconnection and collaboration of ITS among metropolitan areas is also a topic worth studying in the future.

6 Conclusion

This study compared the comments of urban intelligent transportation with the objective effects of ITS and analyzed the factors that affect the perception bias of urban residents about ITS. The conclusions are as follows: (1) there are regional differences in the cognitive bias of travelers to ITS in China. (2) The perception bias of urban residents from ITS is generally affected by economic development. The difference of perception bias between provincial capitals and non-capital cities comes from the impact of urban transport development levels. (3) There is a significant negative correlation between intelligent travel and perception bias. Intelligent travel can improve travelers' evaluation of ITS.

As a regional political and economic center, providing convenient and comfortable transportation services for residents is an important part of urban construction. Urban residents' satisfaction with ITS has an important impact on building smart and livable cities. Therefore, the study of urban residents' perception bias of intelligent transportation is of significance to the construction of intelligent city and the promotion of urban comprehensive transportation. It should be paid attention to in the process of urban construction how to avoid the negative perception brought by urban traffic. This study will help to understand the impact of ITS on the daily life of urban residents and provide a reference for the design and operation of ITS.

Abbreviation

ITS: Intelligent transportation system

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Availability of data and materials

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

XH conceived the idea. ZD conducted the analyses. All authors contributed to the writing and revisions. All authors read and approved the final manuscript.

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Competing interests

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