Research Article

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Correlation between travel experiences and post-COVID outbound tourism intention: a case study from China

Yilin SUN[1,2,3,4], Yinan DONG[1,5✉], Dianhai WANG[1,2], E. Owen D. WAYGOOD[6], Hamed NASERI[6], Kazuo NISHII[7]

[1]*College of Civil Engineering and Architecture, Zhejiang University, Hangzhou 310058, China*

[2]*Architectural Design and Research Institute, Zhejiang University, Hangzhou 310028, China*

[3]*Alibaba-Zhejiang University Joint Research Institute of Frontier Technologies, Zhejiang University, Hangzhou 310058, China*

[4]*Polytechnic Institute, Zhejiang University, Hangzhou 310015, China*

[5]*Center for Balance Architecture, Zhejiang University, Hangzhou 310028, China*

[6]*Department of Civil, Geotechnical, and Mining Engineering, Polytechnique Montréal, Montréal, H3T 1J4, Canada*

[7]*Department of Policy Studies, University of Marketing and Distribution Sciences, Kobe, 651-2188, Japan*

Abstract: The COVID-19 pandemic has devastated global tourism and recovery is proceeding very slowly. For many countries, tourism served as a major economic sector, so investigating how to recover is essential. As China was the largest source of outbound travelers before the outbreak, study of the factors influencing Chinese intentions to travel overseas in the post-COVID era is revealing. In Apr. 2022, among seven provinces (or cities) with the most outbound tourists from 2019 to 2021, 2450 individuals responded to a questionnaire on daily mobility, tourism experiences, and the shifts due to the pandemic. Light gradient boosting machine (LightGBM), a robust ensemble learning method, was adopted to quantify and visualize the impact of explanatory factors on outbound travel intention. In addition, the Optuna mechanism and Shapley additive explanation (SHAP) instruments were employed for tuning hyperparameters and interpreting results, respectively. Findings suggest neither one-day nor multi-day tours have resumed to pre-COVID levels. Higher frequency of multi-day tours with further destinations, less car utilization in daily shopping trips, and moderate pandemic restrictions can boost the intention to travel abroad. The concerns and desires of different age groups for overseas travel need different responses. This study reveals the factors affecting Chinese outbound travel intentions and provides suggestions for the recovery of tourism in the post-COVID period.

Key words: Outbound tourism; Touring behavior; Travel behavior; COVID-19; Ensemble learner

1 Introduction

Transport disruption, stalled economies, and hesitant tourists have all been triggered by the COVID-19 crisis since late 2019. Countries rushed to adopt restrictive measures in mobility, consequently paralyzing or significantly weakening the global tourism industry (Wen et al., 2021). Arrival restrictions and quarantine requirements discouraged many visitors or turned them to alternative destinations (DHS, 2020). The lack of international tourists has cast a thick gloom over the economic growth of some regions and countries, such as Spain (Donaire et al., 2021). Government support has never been more vital to the tourism industry than in this health crisis (Castanho et al., 2021). Moreover, COVID-19 has had a significant hit not only on national economies, but also on the United Nations Sustainable Development Goals for 2030 (Hocine et al., 2023). The recovery of tourism has been slow.

In 2019, China witnessed over 155 million outbound trips and more than 133.8 billion USD was spent abroad, accounting for about 20% of global tourism expenditure (CTA, 2020). As the largest source of foreign tourists and purchases before the outbreak, China has provided a strong impetus to the development of the worldwide tourism market. In contrast, with the virus continuing to spread in 2021 and 2022, only 20 million departures were recorded, along with over 90% decline in consumption (CTA, 2021b). Thus,

recalling the robust correlation between the tourism sector and global economic growth, insights into the factors influencing tourism recovery, especially Chinese outbound travel intentions, are pivotal (UNICEF, 2021).

Being one of the first countries impacted by the virus, China limited the spread and the number of infections through full-lockdown policies in Feb. 2020 (Ye et al., 2020). From then on, the pandemic continued to emerge from time to time in various regions and pushed people to make greater efforts for personal protection. Along with local shifts in travel such as working from home and obvious changes in daily activity patterns, tourism changed with fewer tour days and significant shifts in individuals' travel experiences (Caroppo et al., 2021; Rawat et al., 2021). For peripheral tourism zones, the provision of accommodation and the purposes of tourists have undergone significant changes (Castanho et al., 2020). The unprecedented challenges posed by the pandemic are evident in the destinations and mode choices made by domestic travelers (Grépin et al., 2021). In the context of substantial fluctuations in infections, China's domestic tourism market recovered to around 51% and 40% of 2019 levels in 2021 and 2022, respectively (CTA, 2021a; NBSC, 2023). The recovery is expected to be maintained since the withdrawal of domestic pandemic restrictions at the beginning of 2023, along with the restoration of normal living conditions and familiar travel experiences (Bayih and Singh, 2020).

With these changes and developments in mind, further exploration of outbound travel intentions is needed. Revealing the potential to stimulate and boost outbound travel from China would be beneficial to the recovery of international tourism in the post-pandemic period. Therefore, this study is designed to achieve the following: (1) examination of the variables in daily travel and touring experiences and the influence they have on outbound travel intentions post-COVID; (2) determination of the relationships among social and safety factors and outbound travel intentions. To fulfill these objectives, the light gradient boosting machine (LightGBM) model is constructed and optimized by the Optuna mechanism. Results are visualized and interpreted using the Shapley additive explanation (SHAP) instruments, to present a more elaborate approach.

The paper is organized as follows. A review of the COVID-19 pandemic and tourism is presented first. Next, the data and methodology parts demonstrate data acquisition, model establishment, and related analysis methods. The results are then given, where the effects of factors are discussed. Ultimately, conclusions coalesce, and implications and recommendations for future studies are presented.

2 Literature review

2.1 COVID and its impact on tourism

On Mar. 11, 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic. Tens of millions were infected and dead, and the number was still climbing swiftly (Gill et al., 2020). In response, countries deployed various approaches including social distancing policies, confinement measures, and mobility restrictions that have placed a significant hindrance on traveling for tourism (Paul et al., 2022; Shortall et al., 2022). For example, people were requested to stay at home more often (Hensher et al., 2021; Shibayama et al., 2021), mobility was restricted (Lu et al., 2021), transport mode choices shifted (Eisenmann et al., 2021), and health concerns were aroused (Parady et al., 2020). After a partial or full lockdown, the gradual withdrawal of domestic travel restrictions in many countries and regions has led to a general rebound of local trips for day-to-day travel. Metro use has witnessed significant recovery (Sharma et al., 2023), although many individuals who have switched to private transportation modes (car, bicycle, and walking) may have established new habits (Buehler and Pucher, 2021; Khaddar and Fatmi, 2021; Zhang JY et al., 2021). Participation in shopping trips remains one of the highest trip purposes, with the share of leisure trips continues to be at a lower level than in the pre-pandemic period (Molloy et al., 2021; Politis et al., 2021).

In contrast to local travel, the easing of international travel constraints has been much slower. From the initial stages of the pandemic, methods such as border closures, limiting or quarantining travelers from specific regions, and airline flight controls were widely implemented (Gkiotsalitis and Cats, 2021; Sun et al., 2021; Shortall et al., 2022). Shutting down airlines, an incredibly vital means of passenger flow among nations, was once recommended by WHO (2020). Few of these measures are still in effect (as of Mar. 2023).

According to the International Air Transport Association (IATA), there were 35.6% fewer international and domestic air passengers in 2022 compared to 2019 (IATA, 2023). With a lack of concrete estimates on the duration of the pandemic combined with concerns about long COVID disabilities, the full recovery of international traveling remains elusive (Raveendran et al., 2021). With the addition of vaccines and the ability to prove that one has been vaccinated, a substantial number of people have shown a strong willingness to rejoin cross-border travel (Tanrıverdi et al., 2020; Kim and Sohn, 2022). However, compared with domestic journeys, the obstacles, problems, and impacts faced by outbound travel are more complicated and require further exploration and research.

2.2 What is the global tourism industry seeking?

During the pandemic, the tourism industry has endured a dramatic decline and, in many areas, even paralysis. In some regions where international tourism is a pillar industry, such as Spain, the 12.8% gross domestic product (GDP) downturn brought a series of adverse effects (IMF, 2020; Donaire et al., 2021). According to the United Nations World Tourism Organization (UNWTO), international tourist arrivals have fallen by 58% to 78% in multiple scenarios in 2022. As one of the major economic sectors in many countries, the impact of the pandemic on tourism has had enormous implications for people's livelihoods (UNICEF, 2021).

Extremely vulnerable to fear, tourism industry has shifted the emphasis of research to protection and resilience following the first year of the pandemic (Prayag, 2020). Compared to the complex international tourism market, domestic travel has taken the lead in recovery (Duro et al., 2021). Plenty of countries are promoting community-based tourism with positive results in sight (Rogerson and Baum, 2020). Several service strategies, such as tailored advertising, special offers, and flexible cancellation regulations, have been implemented in many touring scenarios to promote domestic trips as well (Volgger et al., 2021). For peripheral destinations, such as the Azores region, the improvement of public infrastructure could be identified as the most efficient way to adapt to the new tourism paradigm (Sousa et al., 2022). Studies have suggested that vigorous boosts in domestic tourism and beneficial policies can compensate for the decline in foreign arrivals, but perhaps not sufficiently to be a replacement (de Sausmarez, 2007; Arbulú et al., 2021).

According to UNWTO, a nearly 100% upturn in global tourism was witnessed in 2022, as opposed to 2021. While the number of outbound tourists is recovering, it remains at 37% below the pre-pandemic year of 2019 (UNWTO, 2021). Exploring how to revitalize cross-border travel, studies conducted around the world are looking for the answers to the emerging issues: Are people as eager to travel abroad as they used to be? How significant are risk and safety factors in influencing travel intention? Does daily travel behavior impact the willingness to go on trips? Might recent travel experiences play a significant role (Sönmez and Graefe, 1998; Higgins-Desbiolles, 2021; Persson-Fischer and Liu, 2021; Rogerson and Rogerson, 2021; Zhang HY et al., 2021)? For instance, the tourism demand of Chinese arrivals to the USA and Australia was investigated through neural networks, and recovery time was estimated (Polyzos et al., 2021). Social distancing in daily life may contribute to sightseeing destination choices in the post-pandemic time among Italians (Corbisiero and Monaco, 2021). Analysis of travel and living experiences during the pandemic and psychological perception of risks, should deliver long-term correlations with touring behavior and intention, and further research on these internal mechanisms is indicated (Miao et al., 2021).

Chinese tourists were a significant share of the global tourism industry prior to the pandemic (Hung et al., 2021). Considering the new lifestyles developed during the pandemic and the relatively few studies of factors influencing overseas tourism intentions based on daily travel, this study aims to portray the outbound intentions of the Chinese in the post-COVID era and shed light on their inner connections.

3 Data

3.1 Data collection

Contextualizing the consequences of COVID-19 on daily life and the tourism industry, this study obtained the post-COVID outbound travel intentions of Chinese people via an online questionnaire. Two sets of questions were emphasized, personal & household attributes, travel & touring experiences over the past 30 d. Multiple features, such as perceptions about

travel during the pandemic and expectations for future trips, were also included. In total, 182 aspects were covered.

As the number of outbound Chinese tourists fell by a large margin after the outbreak, the target regions were the top provinces (or cities) with the most outbound travelers across the pre-COVID year of 2019 to the post-COVID year of 2021. Accordingly, five provinces (Fujian, Guangdong, Jiangsu, Shandong, Zhejiang), as well as two mega-cities (Beijing, Shanghai), were selected as the study areas. As the most representative regions, they contribute about 70% of Chinese outbound tourists with the leading positions in GDP as well (CTA, 2020, 2021b). From Apr. 15 to 21, 2022, the survey received 2450 valid responses with 350 from each province (or city). The composition of respondents was controlled to be as closely aligned with the census results as possible (NBSC, 2020). Moreover, this survey serves as a precursor of large-scale nationwide surveys and enables the accumulation of technique and experience for them.

Participants were recruited by fulfilling the guidelines as follows:

(1) Social media, online forums, and communities were utilized for questionnaire distribution.

(2) Each participant was rewarded with 20 CNY.

(3) Adult populations were the target group, and responses were filtered by IP addresses.

(4) Pre-set questions for cross-checking were used to review each answer sheet.

The post-COVID outbound travel intention was extracted as the dependent variable from the question "What is your intention to travel abroad when the risk and restriction measures of the COVID-19 pandemic are minimized?", measured by five categories:

Category 1: "Despite the receding risk and control measures, traveling abroad would still not be an option for me."

Category 2: "For me, travel plans tend to be more domestic while international travel is not preferred."

Category 3: "I still have no clear ideas or plans about traveling abroad, I tend to stay neutral."

Category 4: "Based on this, traveling abroad will be reconsidered as one of the preferred choices."

Category 5: "In this case, touring overseas would be my primary choice, and I would be very glad to go overseas for leisure trips as soon as possible."

As a result, Category 3 was interpreted as neutral, accounting for 39.9%. A nearly equal portion of people reported a strong desire to travel abroad (Category 4, 29.7%; Category 5, 8.0%). Only 22.4% of respondents chose Category 1 (5.2%) and Category 2 (17.2%), taking a wait-and-see or conservative attitude.

Considering the collection and utilization of personal data, this research was conducted in accordance with the Personal Information Protection Law in the target country, the People's Republic of China.

3.2 Descriptive analysis

The socio-demographic characteristics of the respondents are presented in Fig. 1. The labels and the shares of each attribute are indicated.
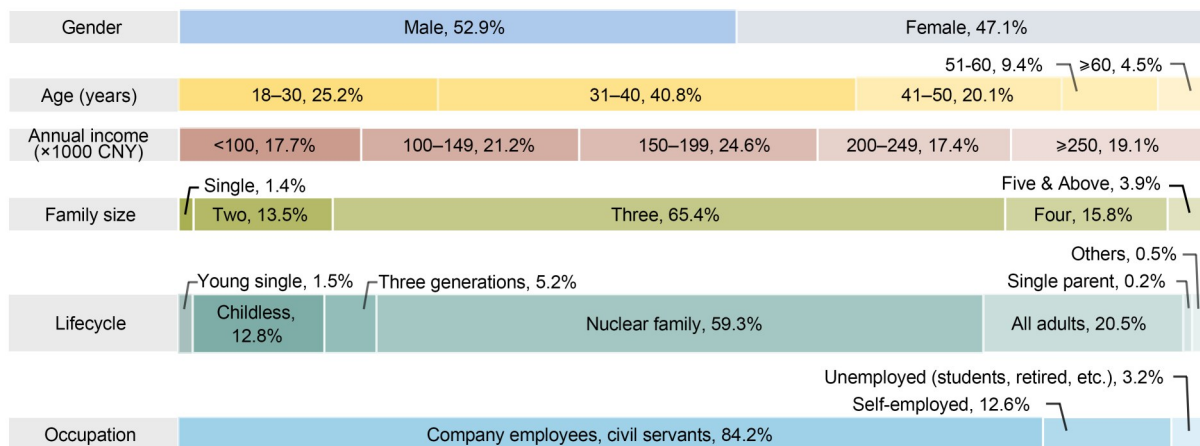

Fig. 1 Socio-demographic characteristics of the respondents

Five categories were merged in the age section, and the most prominent group is the 31- to 40-year-old segment. Higher percentages of working age groups correspond to greater shares of company employees or civil servants in the occupation statistics. A respondent's annual income (measured in CNY) is another variable strongly associated with travel intention and distributed somewhat evenly, around 20%. The nuclear family is the dominant household form and correlates firmly with the family lifecycle.

In Fig. 2, five categories of attributes are presented, which are observed in both one-day and multi-day tours. Compared to the pre-epidemic period, the shifts of attributes were classified as decreasing, almost unchanged, and increasing. Nine zones were thus constructed, with colors matching attributes, and digits indicating the number of people. The digits in the same color were summed to the total number of respondents. For instance, in the upper left zone, four persons reported a decline in the frequency of multi-day trips and an increase in the frequency of one-day trips; 17 persons reported more destinations in one-day tours, but fewer in multi-day tours.

Few participants reported increasing frequency of touring (top row and far right column in Fig. 2), and there was no apparent divergence in preference for one-day or multi-day trips. The upturn in travel intention is accompanied by an increase in private car usage. At the same time, demand for public transportation remains moderate in comparison, possibly due to shifts in daily travel habits during the pandemic.

While a substantial number of people have returned to the pre-pandemic status of destination choices and the duration of trips, most people still reported a decline in intentions of touring based on the attributes mentioned, indicating that tourism would only gradually recover.

4 Modeling

4.1 Model specifications

LightGBM is an improved version of the gradient boosting decision tree (GBDT) algorithm proposed by Microsoft (Ke et al., 2017). Addressing the trade-off between accuracy and efficiency when facing the mass of data that GBDT confronts, LightGBM introduces histogram-based algorithms to save computing power (Al Daoud, 2019). In the decision tree growth strategy, the leaf-wise approach with depth limitation replaces the level-wise method to locate the leaf node with the largest splitter gain, guaranteeing the model's efficiency and accuracy. LightGBM processes the data and features in parallel and performs a voting mechanism linking multiple learning machines, which boosts the search speed for the best split point and reduces the communication workload among machines (Sun et al., 2020). Recognizing its good compatibility and interpretability, LightGBM finds a wide variety of applications in diverse fields (Wang et al., 2018). Its operation schematic is shown in Fig. 3.
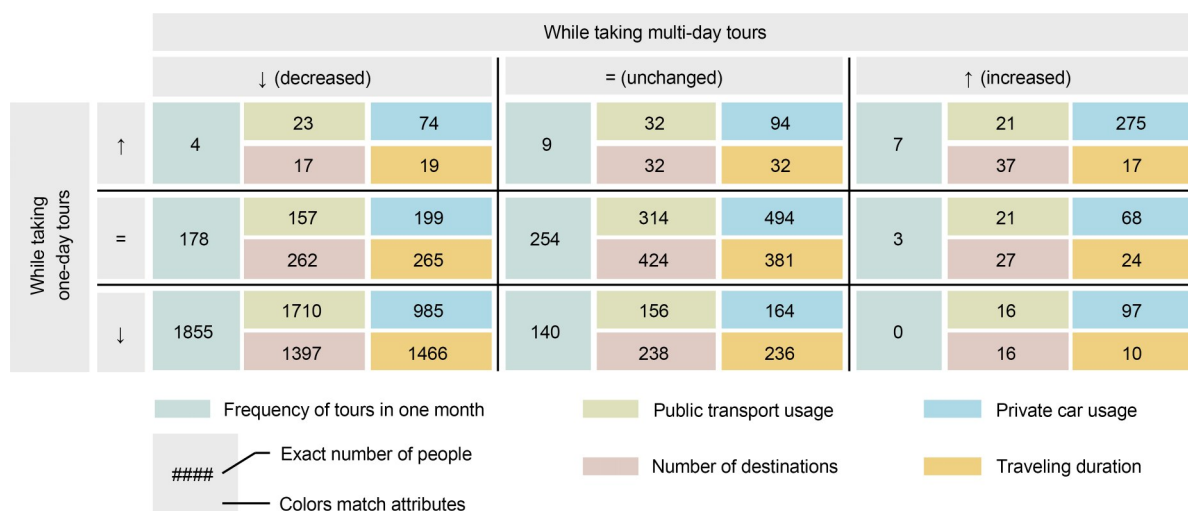

Fig. 2 Cartesian heat map of changes in various attributes of respondents' one-day and multi-day tours compared to the pre-epidemic period
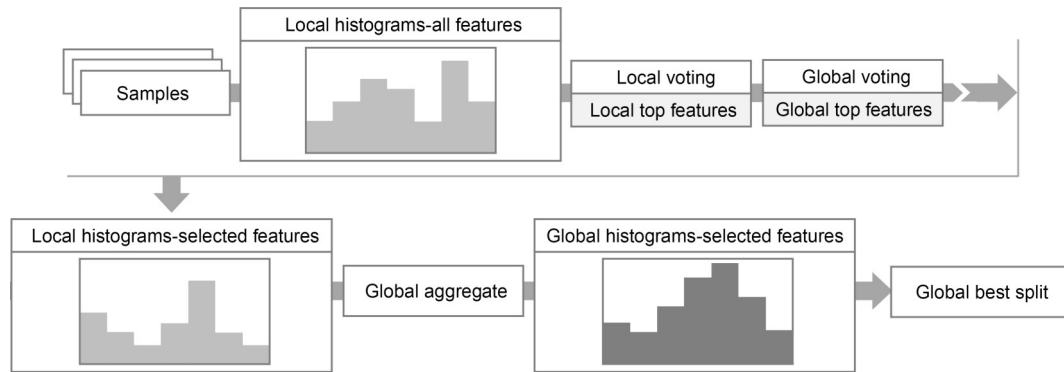
Fig. 3 Illustrations of the LightGBM modeling procedure

This study adopted the scikit-learn package (SciPy library) based on Python 3.8 to establish LightGBM models (Pedregosa et al., 2011). Five-fold cross-validation was utilized to generate subsamples for training and validation and improve model performance. Multi-round fitting process summoned the optimization of various hyper-parameters. In terms of empirical and practical approach, the following values were considered for LightGBM's hyper-parameters in order to maximize the prediction performance (Ke et al., 2017; Bentéjac et al., 2021):

(1) learning_rate, specifying the speed of iteration calculations, ranging: 0.001, 0.01, 0.05, 0.1, 1;

(2) n_estimators, controlling the number of iteration stages, ranging: 100, 500, 1000, 2500, 5000, 10000;

(3) early_stopping_rounds, the threshold that brings the iteration to an early end, matching n_estimators to locate the best calculation times, ranging: 100, 200, 500, 800, 1000;

(4) num_leaves, the number of leaves per tree, ranging: 6, 12, 30, 60, 200, 800;

(5) max_depth, defining the maximum depth of a tree, ranging: 3, 4, 5, 8, 10;

(6) num_class, the number of categories in the classification task, ranging: 5.

Each hyper-parameter comes with an array of values, and the optimization of complex configurations is time- and resource-consuming. To address this issue, Optuna, an open-source hyper-parameter optimization framework, was employed to obtain better performance with less computational cost. Optuna initiates with a random sampler and records the history to a set of hyper-parameter values and their corresponding target values (Akiba et al., 2019). Then, based on promising target values from past trials, the calculation process will generate a batch of hyper-parameter values for subsequent trials. Owing to its lightweight and efficiency, Optuna has gained wide application in various tasks (Agrawal, 2021).

4.2 Performance evaluation

Classification models can be evaluated through diverse approaches. When the classification task is completed, for one level of willingness to travel overseas, there are four conditions of samples: true positive (TP), false positive (FP), true negative (TN), and false negative (FN). In the dichotomous cases, accuracy, precision, and recall can exhibit the model results straightforwardly. But for multi-class issues, the F_1-score, a more comprehensive metric, is proposed and interpreted below:

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}}, \quad (1)$$

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}, \quad (2)$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}}, \quad (3)$$

$$F_1 = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}. \quad (4)$$

As the harmonic mean of precision and recall, the F_1-score integrates two perspectives about the predictive power for positive samples, thus offering a stronger and improved evaluation capability. F_1-score generally ranges from 0 to 1, with closer to 1 indicating better model performance. Thus, in this study, the F_1-score is applied for result evaluation.

4.3 Analysis methods

The path towards enhanced interpretability of machine learning models is already well established.

For example, the sklearn package used for modeling in this study provides essential interfaces for many models (Pedregosa et al., 2011). The importance values indicate the relative influence of features (i.e., input variables) on the response variable (i.e., output variables). They are proposed to explain the models. However, these indicators cannot escape many controversies, such as the inconsistent results of multiple fitting rounds and the apparent disturbance by noise. The SHAP was proposed by Lundberg and Lee (2017). Inspired by cooperative game theory, SHAP constructs an additive explanatory model in which all features are viewed as contributors. For each sample, the model generates a prediction value, where the SHAP value is the value assigned to each feature in the sample. A major benefit of a SHAP value is in revealing the effects of the impacts in each sample and demonstrating the positive and negative effects.

Assuming that x_i represents sample i, x_{ij} is the feature j of sample i, y_i equals the predicted value of sample i produced by the model, $f(x_{ij})$ is the SHAP value of x_{ij}, and y_{base} as the baseline of the model is generally set as the mean of the target features for all samples. The SHAP value obeys the following algorithm:

$$y_i = y_{base} + f(x_{i1}) + f(x_{i2}) + \ldots + f(x_{ik}). \quad (5)$$

Intuitively, $f(x_{i1})$ refers to the contribution of the 1st feature in the sample i to the final prediction y_i, onwards, and k refers to the number of features in the sample i. When $f(x_{i1}) > 0$, it indicates that the feature boosts the prediction power, namely a positive effect; on the contrary, the feature weakens the prediction value and renders a negative effect. For user-friendly visualization and swift implementation, this study establishes the SHAP value for model interpretation.

5 Results

Putting the concept of previous sections into practice, the LightGBM model was constructed. The best performance was achieved via multiple rounds of optimization search by Optuna, where key parameters were set as: learning_rate (0.01), n_estimators (5000), num_leaves (200), max_depth (8), num_class (5), early_stopping_rounds (500), metric (multi_logloss), boosting_type (gbdt), and objective (multiclass). The final model obtained a weighted F_1-score of 0.93, and the SHAP explainer was initialized for subsequent analysis.

For the dependent variable, post-COVID outbound travel intention, its five categories are summarized for a more concise presentation as: no such option (Category 1), stay domestic (Category 2), neutral (Category 3), reconsidering (Category 4), and primary choice (Category 5).

5.1 Feature analysis

A total of 88 features were fed into the model. Fig. 4 presents the SHAP summary plot where the top 15 features are listed according to their contribution to the model outcome. Five different colors correspond to the five categories of the dependent variable. The length of the bar indicates how strongly a feature is correlated to a particular category in the prediction results.

For Chinese people's outbound travel intention in the post-COVID periods, the current touring status and daily travel were the most important factors. Specifically, the frequency shift of multi-day tours per month in 2022 (compared to the pre-pandemic era) produced the highest impact on the model. This observation might be explained by most outbound trips being multiple days, and changes in frequency significantly impacting the positive side of attitude towards traveling overseas. Further, a statistical review of the collected data under the mobility restrictions at the time revealed that 76.3% of reported multi-day trips were within 50 km, and only 2% were over 300 km, which may pose adverse effects.

Shopping activities play a major part in daily travel and are also essential elements during tourism (Hung et al., 2021; Molloy et al., 2021). Car usage for daily shopping trips came in the 2nd place, which reflected the health concerns of the respondents, for cars can easily provide psychological and physical assurance of social distance although air quality within them can be a problem (Chan et al., 2002; Moreno et al., 2019). Compared to the pre-pandemic period, the change in shopping duration saw a decrease for 64.7% of respondents, with no change for 29.3%. Only 6.0% reported an increase.

Views on tourism at the time of the survey would directly inform people expected future travel (the
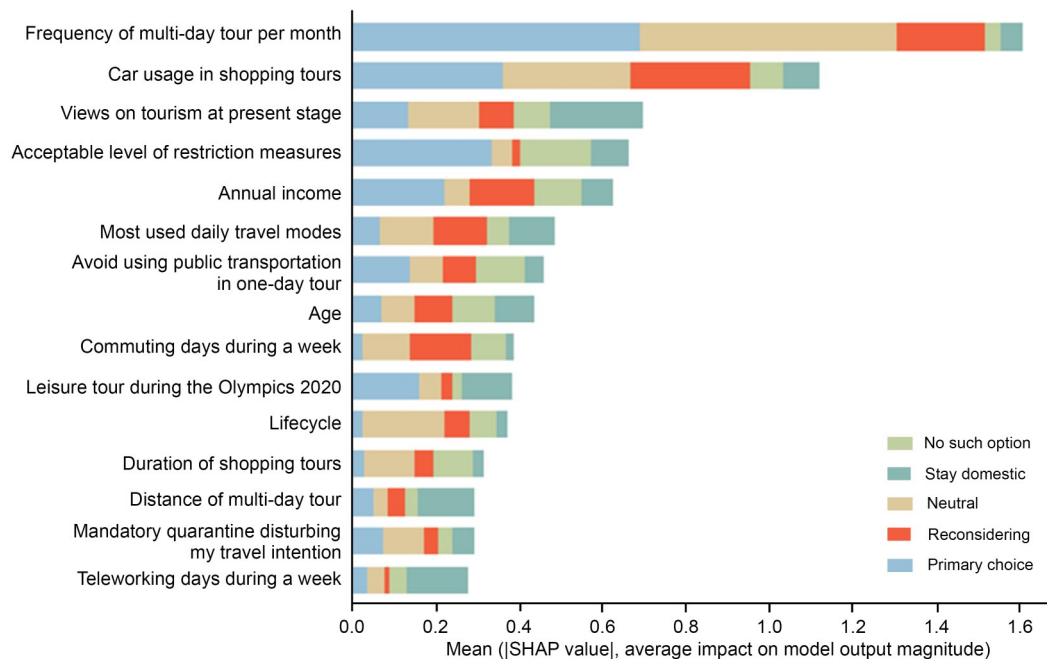
Fig. 4 SHAP summary plot

dependent variable) and seem to be more likely to lead to neutral and negative attitudes. Statistically speaking, 18.3% stated that they had minimized their travel activities, 32.2% tended to take less public transportation, 26.1% reported shortened stays at destinations, 25.2% had chosen to travel domestically instead of internationally, 59.2% agreed that they should keep a distance from others while traveling, and only 15.3% thought there was no major obstacle to traveling abroad at that time. This may guide how to develop policies focusing on tourism desire improvement. Regarding the acceptable level of restriction measures, the questionnaire provides seven classes of regulations, from lax to rigid, forming a remarkable connection with the intentions at both poles. At the time of the survey, individuals returning to mainland China were required to attend a mandatory quarantine for at least a week or two, and more than 91.2% agreed that this was one of the major impediments to travel abroad.

Stable and adequate annual income is the cornerstone of international mobility and was associated with a greater willingness to travel. Other socio-demographic attributes, like age and lifecycle, had a balanced and rather neutral effect on the intention levels, respectively. About 80.1% of respondents recalled traveling during the Beijing Winter Olympics, which were held about two months prior to the survey. Based on this

observation, recent experiences of leisure travel would determine the outlook on the future of travel with minimal restrictions.

The daily travel and work-related mobility variables are sporadically distributed on the *y*-axis. Among the most common travel modes on weekdays, respondents could pick multiple choices, with the car (52.1%) and active travel (walking and cycling, 47.8%) dominating, and public transportation (40.5%) in the 3rd place. This finding is validated by the 54.5% of those who would try to avoid public transportation on a one-day trip. Although many people rejoined public transportation, passengers with proper personal protection as the peak of the pandemic subsided, they tended to use it for short, brief trips (Dong et al., 2021). Though its SHAP values are significantly lower than the variables mentioned above, the rising number of teleworking days dampened the willingness to go traveling overseas. Possible explanations could be inconveniences from telecommuting and possibly acting as a proxy for anxiety about the growing viral infections that have reduced the appetite for leisure activities.

5.2 Feature dependency analysis

Dependency analysis is conducted to monitor shifts in SHAP values by fixing other variables at their mean values and changing a single feature in the

model. In Fig. 5, values of the feature are distributed on the *x*-axis and the SHAP values are projected on the *y*-axis. Considering the dependent variable, the intention to travel abroad is categorical, each subplot, therefore, corresponds to a specific category.

Fig. 5a illustrates the impact of multi-day trip frequency (*y*-axis) through the variation of multi-day trip distance (color scale). The change in color of the dots from blue to red represents the distance from short to long. Results are grouped by the individual's desire to travel abroad. When making relatively short multi-day trips with decreasing frequency, the possibility

of being neutral on outbound travel intention tended to grow. In other words, some respondents who made few multi-day trips or traveled in neighboring regions may have been ambiguous about the idea or plan of outbound travel and chose to be neutral instead. By contrast, the increase in distance and frequency of multi-day trips brought about a divergence of intentions. When the frequency of multi-day trips returns to pre-pandemic levels, the points for more distant destinations correspond to positive SHAP values, which can be concluded to be a significant boost to positive outbound travel intentions, with a stronger
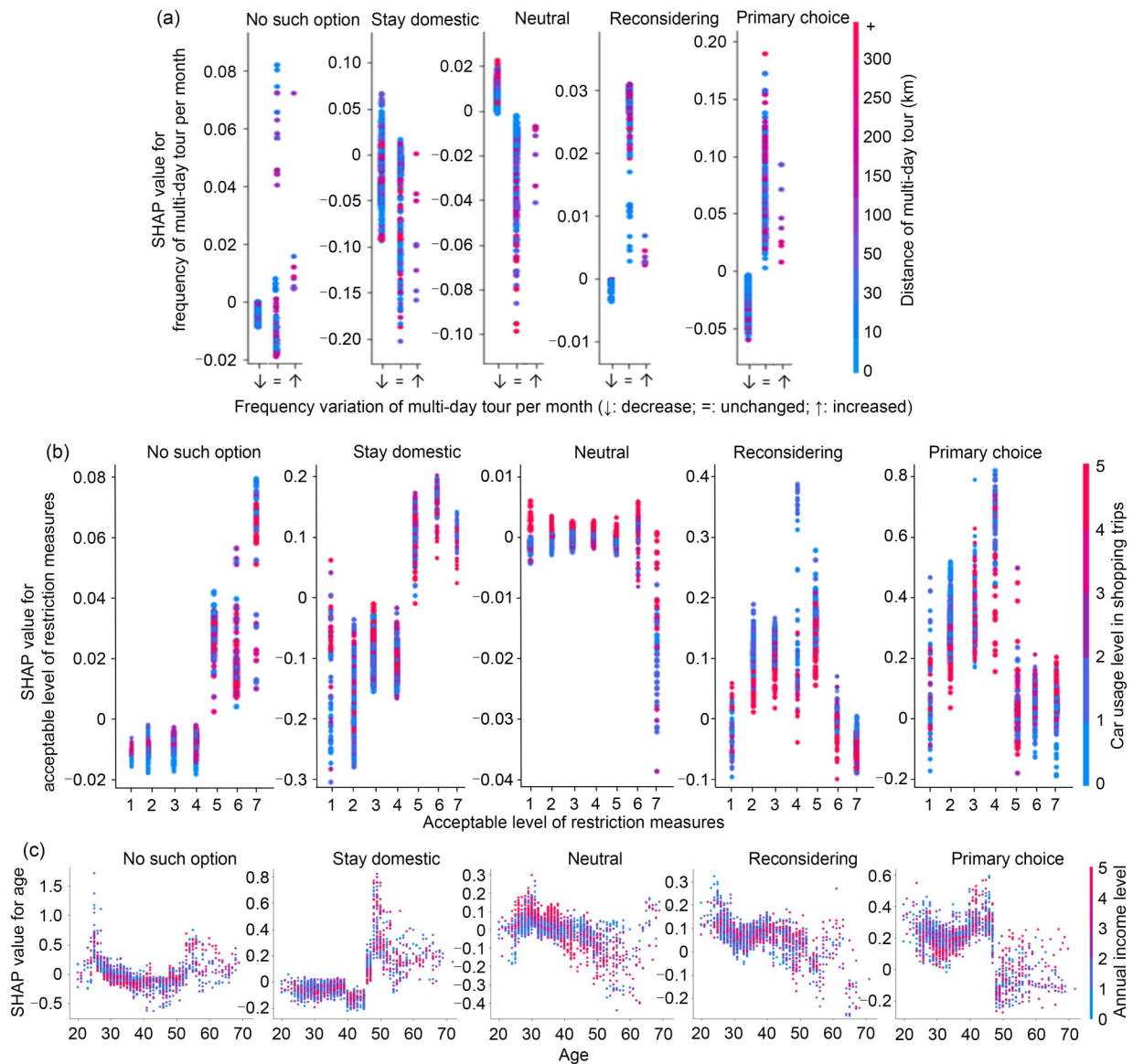

Fig. 5 SHAP dependency plots: (a) impact of frequency variation of multi-day tour and distance on model output; (b) impact of restriction measures and car usage level on model output; (c) impact of age and annual income level on model output

effect for Category 5 (primary choice). Similarly, in Category 1 (no such option), such a scenario turns out that SHAP values hover around negative values, showing an inhibitory effect on very negative intentions.

Focusing only on the SHAP value variation of the frequency and leaving the color aside for the moment, a few things can be noted. As frequency picks up, SHAP values switch from negative to positive, corresponding to a shift from pessimistic to solid outbound intentions. Multi-day trips tend to bring more mobility, and the increased flexibility of travel in the post-pandemic period enables greater confidence in tourism recovery. In terms of point density, fewer respondents reported more frequent multi-day trips than before the pandemic, perhaps due to quarantine policies and sporadic scattered infections, leaving constraints still in place.

Fig. 5b explores the impact of restriction measures on car usage on the results. In the questionnaire, the acceptable restrictions were defined in seven levels as follows: no restrictions; mask and social distance needed; health certificate required from time to time; limitations on large gatherings or parties; telework and reduced outings; essential trips only; prohibition of all mobility within an area, and lockdown in major places. The use of cars in shopping trips was then measured by five tiers, ranging from much less (blue) to much more (red), compared to the same period in 2019. Beyond some noise, the effects of increased car use on both Category 1 (no such option) and Category 2 (stay domestic) were primarily at levels 4 and 5 when the measures tended to be strict. The SHAP values were barely greater than zero for limits of level 4 and below, and the negative effect becomes more pronounced as car use decreased. In contrast, the opposite effect is observed for limits of level 5 and above. This suggests that stricter restraints were associated with greater car use (compared to public transport) and that in such conditions and feelings, people were not likely to want to travel abroad.

The subplot of Category 3 (neutral), with blue and red points separated above and below, is almost divided by the zero-line. The influence of the two variables on this group is rather subtle. For the two most positive attitudes Category 4 (reconsidering) and Category 5 (primary choice), lower car use and fewer restrictions were associated with more positive attitudes to foreign travel. This boosting effect was more substantial in Category 5 (primary choice) subplot. Meanwhile, it is worth observing that either more lenient or stricter policies could lead to lower SHAP values. In this regard, for the study area at the time the survey was conducted, policies similar to levels 3 and 4 would better depict the circumstances. For the lowest restriction level, Chinese residents might have felt concerned about an overly relaxed strategy as it might suggest that the authorities were failing to implement the proper health protection measures.

Ultimately, Fig. 5c demonstrates the role of age (*x*-axis) and annual income (color scale) on the intention to travel abroad. As age increases, people seem to have had a more cautious attitude towards outbound travel in the presence of this pandemic. For those who primarily wanted to do domestic tourism, a step change is observed at around age 46, where those older did seem open to traveling abroad. Amid this, the rise in income appeared to play no explicit role and the points of each color are distributed in an intermingled manner. In contrast, higher earnings spawned a divergence in attitudes toward neutral views between 20–40-year-olds and 40–70-year-olds. Among those eager to travel out of the country, there was a general inverse relationship, with SHAP values dropping from positive to negative with respondents getting older, especially after 50. Middle-income young people (23–46 years old) seemed to be more eager to travel abroad after the pandemic control measures have subsided. Higher income brought a slight decrease in SHAP value, but it remains beyond zero. Increased income generally led to conservative attitudes toward cross-country travel, but its effect varies across different age groups.

6 Discussion & conclusions

This study explores people's intention to travel abroad in the post-epidemic period from their daily mobility by integrating survey methods and ensemble learning tools. Data collection through online questionnaires provides a solid foundation for accuracy, reliability, and comprehensiveness. The collaboration of LightGBM and Optuna algorithms presents an unparalleled advantage in probing and visualizing the combined effects of complex factors compared to existing studies and traditional models. As one of the first

countries to bear the brunt of the virus, China took zero-COVID precautions to safeguard its citizens during the toughest periods. When this survey was conducted (Apr. 2022), despite some cities in the target provinces facing sporadic outbreaks, most of them were at nearly the same level of normal life as before the pandemic, which laid the foundation for acquiring outbound travel intentions in the post-pandemic era. In the seven provinces (or cities) with the highest number of outbound travelers, the questionnaire collected and reflected people's socio-demographic attributes, daily travel experiences, touring experiences and views, shifts in several factors compared to the pre-pandemic period, and more. Notably, the variations in the factors related to one-day and multi-day tours confirm the lack of confidence in travel at the time. Now that China's pandemic restrictions have been fully lifted (Mar. 2023), it is likely that longer, more elaborate, tours will gain popularity rapidly.

The analysis revealed that touring and travel experiences during the pandemic were the two most vital categories of factors influencing Chinese attitudes towards outbound travel. Among them, the frequency of multi-day tour per month and car usage in shopping trips demonstrated the highest positive effects. In multi-day trips, a similar frequency as before the outbreak and further away destinations would likely generate a keener desire to travel overseas. More flexibility in mobility management policies also bodes well for better outbound intentions. Nonetheless, with cars getting more engaged in shopping trips during the pandemic, and restriction measures tightening up, the intention for international sightseeing in the post-pandemic era decreases. Travel habits and mode preferences carried over from the pandemic period would maintain their roles in the willingness to travel during the post-COVID periods (Shortall et al., 2022).

Various age and income groups had different ways of coping with the pandemic, which was also reflected in their intention of traveling beyond borders. Data in this study indicate that older adults (separated between the ages of 40 and 50) with higher income, perhaps due to health, family lifecycle, and time considerations, are less positive about traveling to foreign countries even though the restriction policies are eased. Yet, from the survey results, it is encouraging to observe that people of all ages are inclined to reconsider or are already reconsidering outbound travel when the

opportunity arises. Only few respondents exhibit pessimism, a finding which would benefit the recovery of China's domestic and international tourism industry.

Amid the lingering consequences of COVID-19, international tourism, as a fragile sector, demands support and assistance from multiple quarters. The findings suggest that improving people's domestic travel experience and strengthening health measures for regular travel could boost tourism confidence and benefit the industry, as well as the economy. For instance, the approval of enhancing health measures (e.g., improved cabin ventilation, more contactless facilities, and disinfection reinforcement) in daily mobility methods, especially public transportation, could contribute to the recovery of tourism (Dong et al., 2022). Younger people seem to be more positive about travel abroad and thus might be a good target group to begin with. Additional attention to older groups could help increase the number of tourists (Peluso and Pichierri, 2021). And more concerns should be given to different population segments to make the recovery process more inclusive. Since the outbreak, Chinese tourists' preferences have evolved towards shorter weekend trips or slower, more in-depth, trips that emphasize extended durations and experiences. Based on daily travel experiences, having sufficient confidence in health protection measures when traveling in crowded transport vehicles has an undeniable impact on travel intentions. During the pandemic, more peripheral destinations and more diversified travel options grew in popularity, all serving the purpose of escaping the crowds (Wen et al., 2021). For destinations, proper social distancing measures, a wider variety of mobility options, and smart travel could enhance the travel experience to attract visitors (Wu and Wall, 2016; Butler, 2020).

Bearing in mind the limitations of this study, there is a need to include more diverse sources to cover broader populations, greater care for those who lack access to online surveys, and more consistency with the social and demographic structure. Also, more sophisticated data would contribute to the generalizability of the analysis. This is a "moment in time" study of opinions from Chinese, so future studies should examine other major population groups and consider how opinions are evolving. Further, global navigation satellite system (GNSS)-based trajectory recording, and digital travel logs would reduce the burden for individuals to report daily travel patterns (Sun et al., 2023).

Meanwhile, the protection of respondents' personal information and critical details during data collection and analysis is a major concern. Ultimately, characteristics of the built environment could also be integrated into the survey, and meticulous analysis of regional and population segments could be considered so as to predict the pandemic impact more comprehensively.

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Author contributions

Yilin SUN: investigation, writing–original draft, and funding acquisition. Yinan DONG: conceptualization, methodology, formal analysis, and writing–original draft. Dianhai WANG: conceptualization. E. Owen D. WAYGOOD: writing–review & editing. Hamed NASERI: writing–review & editing. Kazuo NISHII: survey design and investigation.

Conflict of interest

Yilin SUN, Yinan DONG, Dianhai WANG, E. Owen D. WAYGOOD, Hamed NASERI, and Kazuo NISHII declare that they have no conflict of interest.

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