EVALUATING THE IMPLICATIONS OF AUGMENTED TRANSPORTATION INFRASTRUCTURE ON THE OPERATIONAL DYNAMICS OF SKI RESORTS AMIDST CLIMATIC VARIATIONS

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Ski resorts, pivotal in tourism infrastructure, are notably susceptible to climate fluctuations. The Sixth Assessment Report (AR6) by the United Nations Intergovernmental Panel on Climate Change (IPCC) emphasizes the pressing need for comprehensive climate change strategies. Given the nexus between transportation accessibility and resort viability, it's imperative to adopt an approach that intertwines climate impact assessments with transportation infrastructure enhancements. This study scrutinizes 71 ski resorts in Hokkaido, Japan, renowned in Asia for skiing. We devised a logit model to gauge the repercussions of climate change on ski resort operational dynamics. Within this model, the operational status at ten-day intervals from 2006 to 2020 was the dependent variable, while a blend of meteorological data, socioeconomic metrics, and transportation indicators served as independent variables. Preliminary results reveal that each degree Celsius rise in temperature reduces the ski resort's operational likelihood by 40.35%, and every 1mm increase in precipitation decreases the operational probability by 6.95%.

Key Words : *Climate change, Ski resorts, Coupled model intercomparison project phase 6 (CMIP6), Representative Concentration Pathways (RCPs), Shared socioeconomic pathways (SSPs)*

1. INTRODUCTION

(1) Background

The tourism sector is instrumental in enhancing regional economies and fostering revitalization. However, many leisure infrastructures remain profoundly influenced by climatic shifts. Over the previous decade, observable phenomena have resonated with established climate change patterns. Rising temperatures in the Arctic, along with weakened Arctic westerlies and sustained temperature increases, combined with human-induced disruptions to microclimates, present challenges in snow retention and quality. The Sixth Assessment Report (AR6) [1)] by the United Nations Intergovernmental Panel on Climate Change (IPCC) underscores the critical necessity for proactive climate change mitigation and adaptive measures. Adopting prudent and sustainable strategies that encompass climate impact evaluations is crucial.

On a global scale, human-induced greenhouse gas emissions account for approximately 90% of observed climate warming. The Japan Meteorological Agency's data indicates a steady increase in the country's average annual temperature by 1.19°C every century. Notably, temperature rise

rates are more pronounced in higher latitudes compared to their lower counterparts. By the close of the 21st century (2070-2100), projections suggest Japan's average annual temperature will rise between 0.5°C to 1.7°C, and 3.4°C to 5.4°C under the distinct greenhouse gas concentration trajectories of RCP2.6 and RCP8.5 [Note1)], respectively. While current interdisciplinary studies shed light on various environmental impacts, there's an essential need for quantitative analysis highlighting how winter temperatures and other climate elements influence ski resort operations. For climate-sensitive establishments like ski resorts, understanding and projecting their functional periods is pivotal. This knowledge will enhance our ability to predict transportation needs for specific time frames, further solidifying strategies for future ground transportation planning and route development.

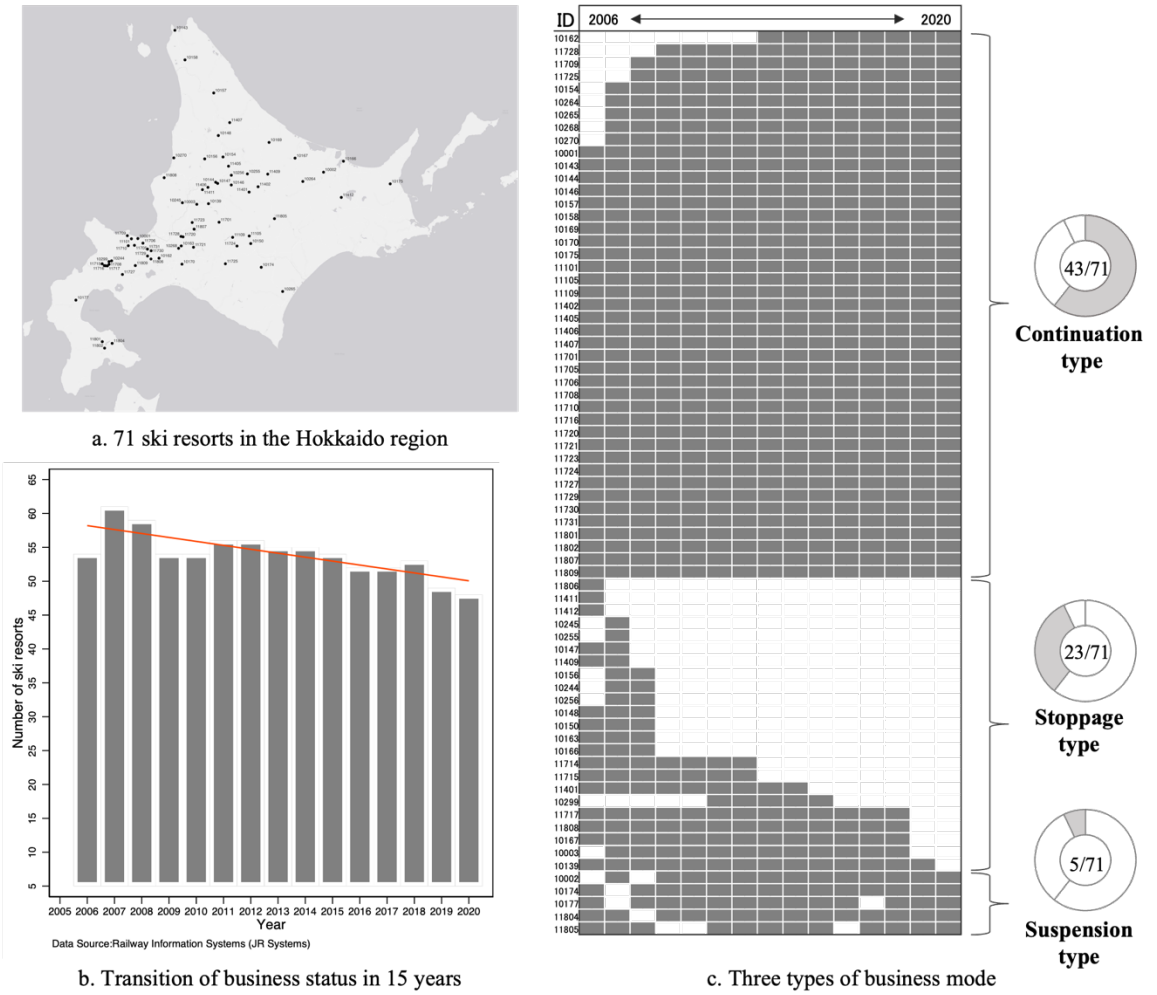
(2) Literature review

Climate change represents one of the most significant challenges to humanity in the 21st century and is anticipated to have major consequences for the climate-sensitive winter sports tourism sector. With its strong reliance on specific climatic conditions, the ski industry is regarded as the tourism market most directly and immediately affected by climate change.[3)] With rapidly expanding scientific literature and much speculation in the media, several authors [4)-14)] have stressed the need for critical reflection on the state of knowledge on ski tourism climate change risk and key information gaps to advance adaptation by industry and destination communities. The literature has expanded to include 27 countries with operating ski areas but remains concentrated (approximately 75% of publications) in five countries: Austria, Australia, Switzerland, the United States, and Canada.[3)-15)] The highest number of publications exists for Switzerland and Austria, where the ski industry's absolute (skier visits) and relative importance (skier visits per inhabitant) are very high.[3)] However, Japan as the fourth largest market remains notably underrepresented, as are other major markets with very limited available research (France, Italy, Sweden, Slovakia). Major gaps were found for Asia, Eastern Europe, and South America, regions that are also identified as underrepresented in the ski tourism literature.

In the early years, Kureha [17)] examines the regional pattern of lost and closed ski fields in Japan, analyzing the closing trend of all developed ski fields including those equipped only with T-bar lifts. Around 750 ski fields were opened between 1950 and 2003 in the whole country. However, nearly 37 percent of them were already closed or completely disappeared. This trend was dominant around 2000, involving owners' changes of lift companies. Most of the lost fields tend to be very small with one or two ski lifts. Fujimori [18)] estimated the influences of ambient temperature and precipitation changes on ski tourism. In recent studies, there are different opinions about the impact of social factors and climate factors on the ski industry. Tomoda [19)] provided results that show the annual change rate of skiing visitors due to the total factor, the one due to climate change, and the one due to other reasons are -2.95%, 0.46%, and -3.41% respectively for Nagano. These findings show that the decrease in skiing visitors in this term stemmed largely from social reasons other than climate change and that the weather mitigated slightly the decline. Matsunaga [20)] formulated the impact of social factors and climate factors that affect the number of visitors with case studies in Gifu prefecture. Due to the lack of a large number of accurate meteorological data, most of the preceding studies only remain at the level of case studies. Moreover, due to the limited data on snow depth, the selection of research objects can only be limited to a certain range. In this study, the new exploration of this issue will be focused on.

2. DATA COLLECTION

The primary purpose of this study is to construct a logistic regression model, utilizing panel data from 71 subjects spanning 15 years, to evaluate the extent of influence of diverse factors, including transportation accessibility, on the operational status of ski resorts. This analysis aims to offer insights into the prospective implications on ski resort operations and corresponding transportation demands in light of climate change risks. In this work, we carried out data collection from four aspects. The first is the basic attribute data of ski resorts, including the number of openings of 71 ski resorts in the Hokkaido region in each ski season from 2006 to 2020 [Note 2)], geographic location **(Fig. 1(a))**, elevation, number of lifts, the maximum slope of the piste, and other basic attributes provided by Railway Information System [21)], meanwhile, the change in the business statuses in the past 15 years is examined. From the perspective of the transition of business status shown in **Fig. 1(b)**, it is not difficult to find that although the number of ski resorts opened in the past 15 years has fluctuated in a small range, the overall trend is declining. Among them, the business mode can be roughly divided into three categories. As shown in **Fig. 1(c)**, the first type is regarded as the continuation type including the ski resorts that kept opening from the beginning of the first business year to the 2020 ski season without interruption. Those whose operations stagnated on or



a. 71 ski resorts in the Hokkaido region

b. Transition of business status in 15 years

c. Three types of business mode

Fig. 1 Research Objects

before the 2020 ski season are classified as stoppage type, and those who were suspended and resumed again are classified as suspension type. From the perspective of the operation time, the earliest opening time is early November, and the latest opening time is late May, which will be the basis for determining the time series of panel data used in this paper. Secondly, the transportation accessibility of the ski resorts is investigated: including public transportation (nearest railway station, nearest bus stop) and private transportation (nearest highway interchange, the number of parking capacities in the ski resort). In addition, because ski- ing activities have different audience groups in different periods, it is also easily affected by social trends at a certain time. For example, the Winter Olympic Games usually bring positive promotion, while the COVID-19 pandemic has hit various industries hard. As an indicator to measure social trends, we introduced the skiing population of the year according to leisure white paper provided by Japan Productivity Center [22] and the total population of Hokkaido ropeway transportation every year provided by the Hokkaido Ropeway & Ski Lift Association as a reference. Finally, the most challenging data collection work falls on the collection of meteorological data for the past 15 years.

As mentioned in the previous section, most of the existing studies use snow depth as an indicator to summarize the climatic conditions of ski resorts, which is undoubtedly reasonable and convincing.[19)23)] In this work, we also attempted to apply the same method. We examined the spatial relationship between 71 research objects and each AMeDAS observing station [Note 3)] by connecting each ski resort and its nearest observing stations. The spatial relationship is shown on the left side of **Fig. 2**. The distribution of their distances is shown on the right side. The violin plot in the middle shows the distribution of distances between 71 subjects and the nearest observing stations that include the snow depth data, the maximum value is reached at 84.848km; the violin plot on the right side shows the distribution of distances between 71 subjects and the nearest observing stations that only have 4 basic meteorological data to estimate snow depth. There is also a maximum value of 30.663km.

Considering this is far beyond the allowable error range, excluding some ski resorts far away from the

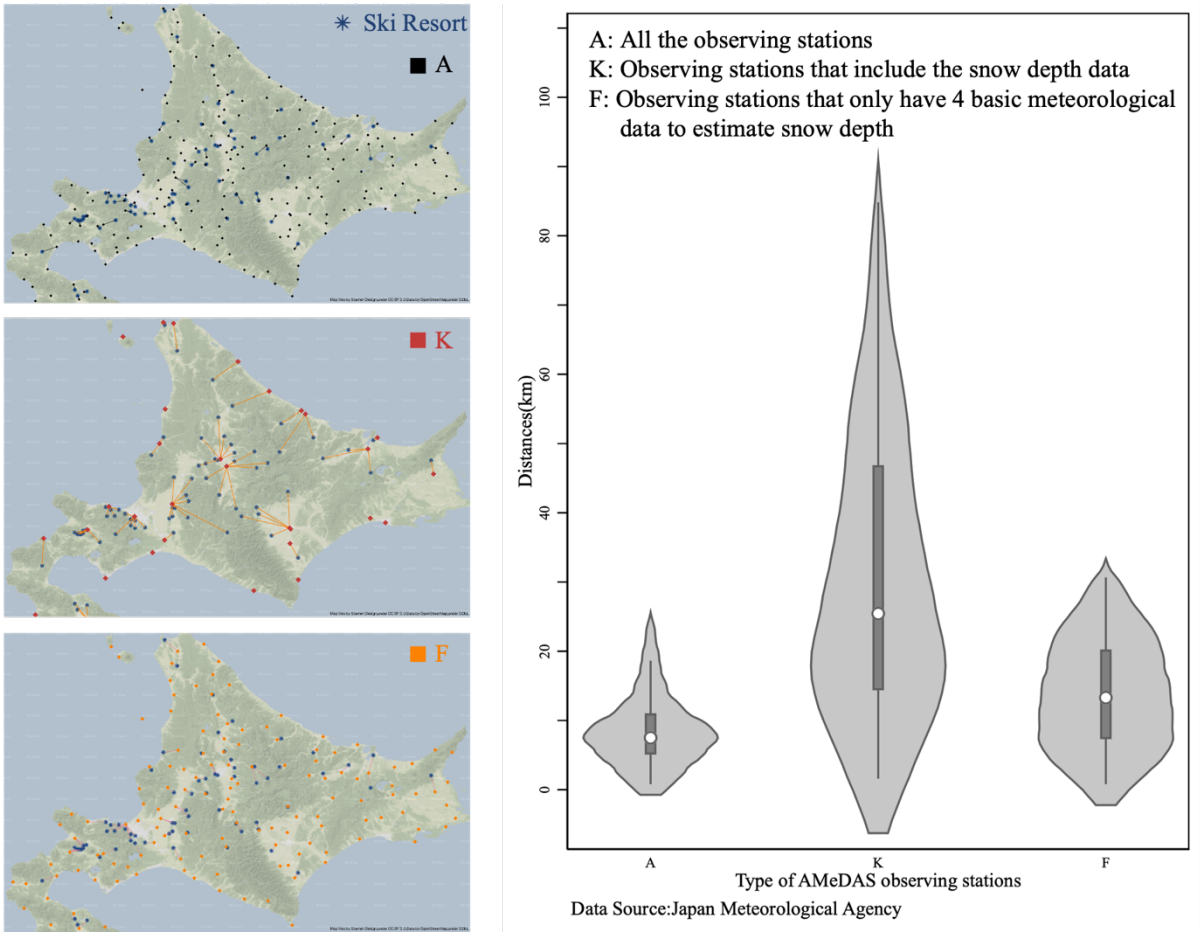


Fig.2 Distribution of the distances between ski resorts and their nearest observing stations

AMeDAS observing station from the study objects will be the only option. Indeed, in previous studies, the authors have made the same compromise.[19)23)] However, we did not want to limit the number of objects in this study, therefore we made the following reflections and attempts: Since snow depth is typically predicted using particular algorithms from basic meteorological data (such as temperature, rainfall, etc.) in a variety of scenarios, it is also thought reasonable to use simply basic meteorological data without also assessing snow depth in this study. Accordingly, eight variables under the bias-corrected climate scenarios over Japan based on the CDFDM method using CMIP6 [Note 4)], provided by the National Institute for Environmental Studies, Japan [24)] are collected in this work: Daily mean Temperature (◦C), Daily maximum temperature (◦C), Daily minimum temperature (◦C), Daily precipitation(mm/day), Global solar radiation (MJ/m^2/day), Wind speed(m/s), Surface relative humidity (%), and Downward longwave radiation(MJ/m^2/day). Regarding the storage forms of meteorological data, a further description is given here. Under the model MRI-ESM20, one of the five different general circulation models (GCMs) [Note 5)], daily data for the eight variables above-mentioned in Japan (122146°E, 2446°N, over land only) are available from 1900 to 2100 and stored in 1920 by 2650 grid with the form of dfCDA files. The corresponding grid coordinate number *(i,j)* can be obtained through each research object's latitude and longitude coordinates*(lan.lon.)*.

3. METHODOLOGY

Most statistical analyses are performed on so-called cross-sectional data, which is collected at one point in time. By contrast, panel data analysis extends statistical analyses of cross-sectional data over multiple time points by fitting panel regression models that account for both cross-section effects and time effects.[25)26)] The panel data set in this research is a balanced (complete) panel data which means comprises all observations for each individual measured at the same time points. It includes data collected on 71 individuals, business statuses, attribute data, meteorological data, social trend index, etc. over the same period, which is every ten days from 2006 to the 2020 ski season. The sample size is $71\ individuals * 3\ ten-day\ periods * 7\ months * 15\ years = 22365$.

We built a logit model to evaluate climate change's influence on ski resorts' business status. In this model, the business status every ten days was taken

as the dependent variable (dummy), and comprehensive meteorological and socioeconomic data were treated as independent variables. The general equation for a logit model under panel data can be given as:

$$ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \cdots + \beta_n X_{nit} + \mu_{it} + v_{it} + u_{it} \quad (1)$$

where:

– p: is the probability of "success", or the presence of an outcome.

– $\frac{p}{1-p}$: refers $\frac{p|success}{p|failure}$, is called odds ratio, and $\log\frac{p}{1-p}$ is called the *log odds ratio* or *logit*

– β_0: is the same across individuals and time.

– β_n: are different coefficients across individuals and time

– X_{it}: are observations (independent variable) on multiple subjects collected over time i and t are indices for individuals and time.

In panel analysis, the error term ε, which is in a normal regression model, is divided into three parts: μ_i, v_i, u_{it}

– μ_i: represents the unobservable individual (cross-section) heterogeneity

– v_i: denotes the unobservable time heterogeneity

– u_{it}: is the remaining random error term

The error ε includes μ_i, v_i, and u_{it} in panel analysis is very important. Assumptions about the error term determines the model choice from Pooled Regression Model, Random Effects Model, and Fixed Effects Model.

4. RESULTS

First of all, it is stated here that all regression models and graphs of the analysis results in this study were implemented by the statistical software Stata. Before constructing the model, we first tested the correlation between each independent variable. **Fig. 3** shows the correlation between the eight climatic factors described in the previous section. Among them, the daily mean temperature is positively correlated with the daily maximum temperature, daily minimum temperature, and downward longwave radiation. Thus, in the following model building, the daily mean temperature, daily precipitation, global solar radiation, wind speed, and surface relative humidity, five items will be imported into the model as independent variables of climate factors. Meanwhile, the correlation between other independent variables was also verified by the same method and the independent variables introduced into the model were finally determined.

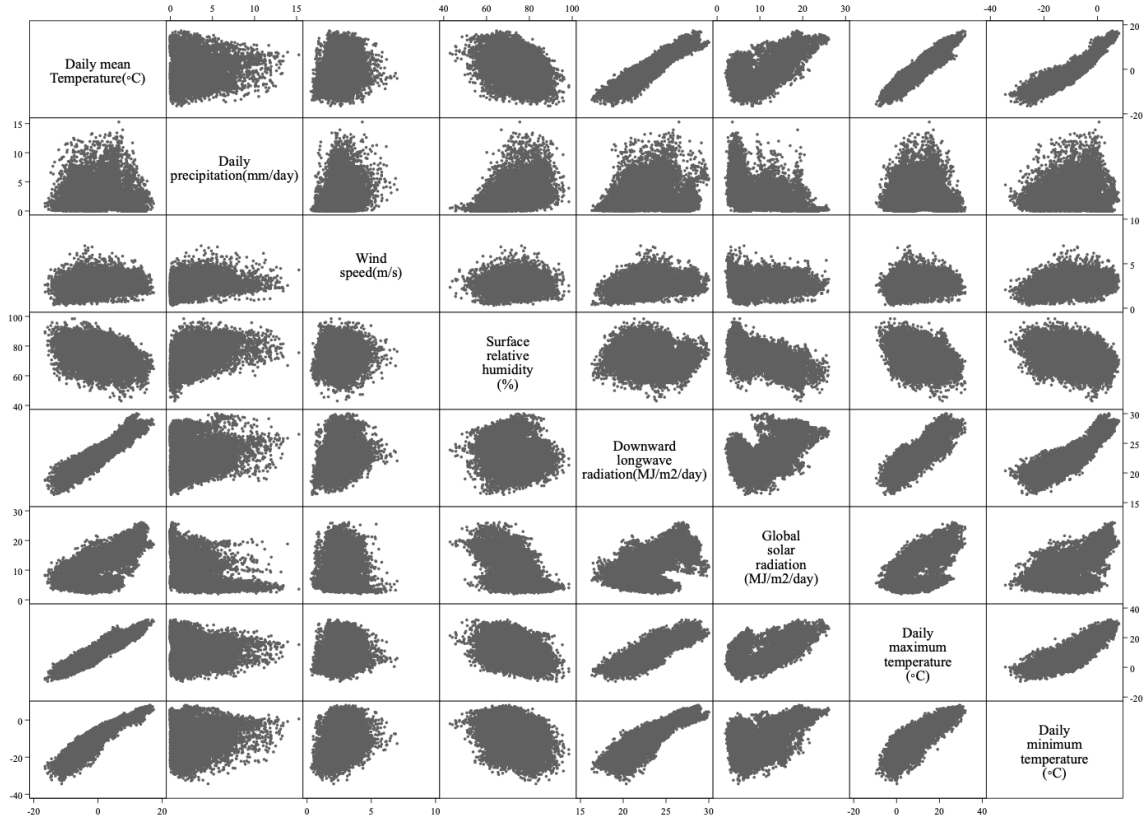


Fig.3 Correlation of climate factors

The results of the Pooled regression model are shown in **Table. 1**. Pseudo R^2 is 0.3820, which is considered a reasonable basis for the model in empirical studies. The likelihood ratio test is also relatively satisfactory. It is concluded that the model has sufficient explanatory power. Among the five climatic variables, except daily precipitation, p values are close to 0, and the absolute values of coefficients are between 0.02 and 0.44, which indicates that climatic conditions have a significant effect on the operation of ski resorts. Daily mean temperature shows a significant effect in either model. This means that a one-unit increase in daily mean temperature will reduce the probability of a ski resort opening by 40.35%, and a one-unit increase in daily precipitation will reduce the probability of a ski resort opening by 6.95%.

Beyond the considerations of weather conditions, the transportation infrastructure available to ski resorts is crucial in determining their operational efficacy. The distance from the resorts to the closest bus station provides a significant indication of the accessibility and utility of public transportation. Likewise, the capacity of parking areas and their proximity to major highway interchanges offer insights into the feasibility and attractiveness of self-driving options. In contrast, the relevance of tram station proximity appears to be less influential. To gain deeper insights, random interviews were conducted with visitors at

Table 1. Result of logistic regression of Pooled Regression Model

LR $chi^2(26)$ = 2329.97

Prob >chi^2 = 0.0000

Log likelihood = -1885.0327

Pseudo R^2 = 0.3820

Catagory	Variable	Coefficient	Std. err.	z	P>z	[95% conf.interval]	
Meteorological Items	Daily mean Temperature (◦C)	-0.341	0.013	-26.87	0.000***	-.3656	-.3160
	Daily precipitation (mm/day)	0.017	0.027	0.63	0.106	-0.005	0.053
	Wind speed (m/s)	0.436	0.036	6.94	0.000***	0.45	0.59
	Surface relative humidity (%)	-0.006	0.004	5.74	0.423	-.0198	-0.008
	Global solar radiation (MJ/m^2/day)	0.079	0.008	1.39	0.000***	0.063	0.094
	Artificial snowfall	0.747	0.111	5.93	0.000***	0.442	0.878
Transportation	Nearest railway station	-4.924	1.597	-8.12	0.000***	-6.094	-3.754
	Nearest bus stop	-0.000	0.000	-2.18	0.029**	-0.000	-0.000
	Nearest highway interchange	-0.389	1.052	3.70	0.000***	1.286	0.595
	Parkingcapacity	1.268	1.498	8.47	0.000***	0.975	1.562
Social Trend	Ropeway transportation volume	0.000	0.000	6.130	0.000***	0.000	0.000
	Ski population	0.000	0.000	-0.320	0.746	0.000	0.000
Appealing Points	Ski lessons	0.747	0.061	12.310	0.000	0.628	0.866
	Snowmobile	1.144	0.088	12.980	0.000***	0.971	1.316
	Heli-Skiing	-3.901	0.263	-14.850	0.000***	-4.415	-3.386
	Event	-0.283	0.069	-4.130	0.000***	-0.417	-0.148
Lift Diversity	Ropeway	0.566	0.140	4.040	0.000***	0.292	0.840
	Gondola	0.166	0.079	2.090	0.036**	0.011	0.321
	Quad lift	0.190	0.039	4.890	0.000***	0.114	0.266
	Triple lift	0.157	0.081	1.960	0.051*	0.000	0.315
	Pair lift	0.235	0.025	9.430	0.000***	0.186	-0.284
	Single lift	0.028	0.039	0.730	0.468	-0.048	0.104
Piste Condition	Number of ski piste	-0.036	0.009	-3.960	0.000***	-0.054	-0.018
	Maximum slope(◦)	-0.010	0.005	-1.850	0.064**	-0.021	0.001
Elevation	Maximum elevation(m)	0.001	0.000	3.450	0.001***	0.000	0.001
	Minimum elevation(m)	0.000	0.000	-4.940	0.000***	-0.001	0.000
	_cons	0.52	0.036	14.58	0.000***	0.45	0.59

z statistics in parentheses

*p<0.10, **p<0.05, ***p<0.010

the Niseko ski resort in Hokkaido in February 2023.

Utilizing buses, trains, and aircraft as modes of transportation presents an eco-friendly and efficient avenue for ski resort access. These methods tend to have a reduced environmental impact and often prove cost-effective, especially when resorts establish partnerships with transportation providers. However, these systems' fixed schedules and potential limitations in equipment storage can pose challenges for travelers.

On the other hand, personal vehicles offer an unmatched level of flexibility. Without the constraints of fixed timetables, drivers can adjust their plans based on various factors, including weather conditions. The ability to store equipment freely without size or cost restrictions is another notable advantage of this mode. Yet, drivers must navigate potentially challenging terrains, especially during adverse weather. Additionally, when considering costs such as fuel, tolls, and parking, expenses can add up, particularly depending on the travel distance and the geographical location of the ski resort.

The presence of snowmobiles and ropeway had a significant positive effect, on the contrary, the presence of heli-skiing and events showed a significant negative effect. This reflects that the diversity of ski resort activities will promote the business sustainability of ski resorts, but at the same time, the high cost of hardware configuration and the consumption of manpower and material resources required for event operation will also bring challenges to the operation of ski resorts. In addition, the number of quad lifts, triple lifts, and pair lifts [Note 6)] had a significant effect, while the number of single lifts did not. Skiing, as an outdoor recreational activity, tends to attract crowds of visitors. It is worth noting that whether the artificial snow machine is set up or not significantly affects the dependent variable, namely the business possibility of the ski resort.

Among the attribute variables, the capacity of the parking, the maximum elevation value, and the minimum elevation value show significant influence, which is derived from the understanding of the skier's traffic utilization mode. Most skiers approach the ski resort by self-driving [22)], which is different from other sightseeing facilities. The capacity of the parking will directly affect the opening status. For the result that the maximum elevation coefficient is negative and the minimum elevation coefficient is positive, and the absolute value of both coefficients is very low, it can be explained as follows: the natural conditions of the elevated areas are more likely to be more conducive to skiing, however, because the high elevation also means that there is a high probability of impassability due to extreme weather conditions, the resistance of ski resort users to reach the ski resort is also increased.

In terms of social trends, ropeway transportation volume as a reference index has a certain positive effect, but it is not very significant. At the same time, the total skiing population did not show a significant effect. This is related to the unique advantages of the Hokkaido region. This suggests that Hokkaido, as a well-known ski resort in Japan and Asia, may not be particularly affected by its business prospects even in less popular years.

5. CONCLUSION AND DISCUSSION

In this study, 71 ski resorts in the Hokkaido region were selected as the research objects. A logit model was built to evaluate climate change's influence on ski resorts' business status. Their business status every 10 days for 15 years was taken as the dependent variable, and comprehensive meteorological and socioeconomic data were treated as independent variables. Effects of Daily mean temperature and daily precipitation on business likelihood under the climate model MRI-ESM20 are quantified. However, there are still the following issues to be solved:

1. Due to the lack of data on the number of daily visitors of each ski resort, the ropeway transportation volume population of the Hokkaido region, and the annual nationwide ski population was introduced into the model as a reference indicator of social trends. This is undoubtedly reasonable, but it does not truly reflect the operation of each ski resort. Thereafter we plan to complete this collection by conducting further interview surveys at ski resorts in the Hokkaido region.

2. In the set of panel data, information imbalance among huge data sets seriously affects the deviation of panel data. In particular, it is still a challenge to collect and organize the data about the location environment transition of 71 ski resorts in the past 15 years, such as accommodation environment and traffic conditioning.

3. In this study, the model and analysis were conducted under the model MRI-ESM20, one of the five different general circulation models (GCMs). The comparative study under different climate models is also worth looking forward to.

To sum up, In future work, we look forward to improving the data collection work to further optimize the model. Finally, through the application of the model, the operation continuation of ski resorts in the future (2040~2080 and 2080~2100) will be predicted based on the coupled model intercomparison project phase 6 (CMIP6) and the shared socioeconomic pathways (SSP) scenario datasets. It is anticipated that the method of predicting the impact of climate change on

skiing will be expanded to other activities and that it will be applied nationwide through the development of data. There are high expectations for the nationwide deployment of traffic volume change forecasts due to climate change.

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NOTES

Note 1) A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the IPCC. Four pathways were used for climate modeling and research for the IPCC's Fifth Assessment Report (AR5) in 2014. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come.

Note 2) There will be two expressions about a year in this study: one is the ski season year, and the other one is the calendar year. For example, the 2016 ski season refers to form the end of the calendar year 2016 to the beginning of the calendar year 2017.

Note 3) The Automated Meteorological Data Acquisition System (AMeDAS) is a collection of Automatic Weather Stations (AWSs) run by JMA for automatic observation of precipitation, wind direction/speed, temperature, and humidity to support real-time monitoring of weather conditions with high temporal and spatial resolution. AMeDAS data play an important role in mitigating the risk of weather-related disasters. JMA began operating the AMeDAS system, which currently includes as many as 1,300 rain gauges at average intervals of 17 km nationwide, on 1st November 1974. Around 840 stations also observe wind direction/speed, temperature, and humidity in addition to precipitation, and snow depth is observed at about 330 manned and unmanned stations in snowy districts. [2)]

Note 4) CMIP6: Coupled Model Intercomparison Project Phase 6. The WCRP Working Group on Coupled Modelling (WGCM) oversees the Coupled Model Intercomparison Project, which is now in its 6th phase.

Note 5) A general circulation model (GCM) is a type of climate model. It employs a mathematical model of the general circulation of a planetary atmosphere or ocean.

Note 6) A chairlift is probably the most typical ski lift in ski resorts. It circles on a wire, the skier or boarder sits on it and then pulls down a safety rail to hold them in. They may seat from two to eight passengers and come in various degrees of complexity.

REFERENCES

1) IPCC: Sixth assessment report. (2021). https://www.ipcc.ch/assessment-report/ ar6/ (2021). Reference date: 2022/10/01
2) Japan Meteorological Agency. https://www.data.jma.go.jp/obd/stats/etrn/index. php. Reference date: 2022/10/01
3) Steiger, R., Scott, D., Abegg, B., Pons, M., Aall, C.: A critical review of climate change risk for ski tourism. Current Issues in Tourism 22(11), 1343-1379 (2019).
4) Abegg, B., Steiger, R., TrawoÃàger, L.: Resilience and perceptions of problems in alpine regions. In: R.W. Butler (ed.) Tourism and resilience, pp. 105-117. CABI, Wallingford (2017).
5) Scott, D., McBoyle, G., Mills, B.: Climate change and the skiing industry in southern Ontario (Canada): exploring the importance of snowmaking as a technical adaptation (2003).
6) Scott, D., McBoyle, G., Minogue, A., Mills, B.: Climate Change and the Sustainability of Ski-based Tourism in Eastern North America: A Reassessment. Journal of Sustainable Tourism 14(4), 376-398 (2006).
7) Scott, D., McBoyle, G., Minogue, A.: Climate change and Quebec's ski industry. Global Environmental Change 17(2), 181-190 (2007).
8) Steiger, R.: The impact of climate change on ski season length and snowmaking requirements in Tyrol, Austria. Climate Research 43(3), 251-262 (2010).
9) Scott, D., Steiger, R.: Vulnerability of the Ski Industry. Climate Vulnerability: Understanding and Addressing Threats to Essential Resources 4, 305-313 (2013).
10) Steiger,R.,StoÃàtter,J.:ClimateChangeImpactAssessmentofSkiTourisminTyrol. Tourism Geographies 15(4), 577-600 (2013).
11) BroÃànnimann, S., Diaz, H.F., Andrade, M.: Climate Change in the European Alps (2014). doi:10.7892/BORIS.61573.
12) Dawson,J.,Scott,D.: Managing for climate change in the Alpine ski sector.Tourism Management 35, 244-254 (2013).
13) Breiling, M., Charamza, P.: The impact of global warming on winter tourism and skiing: a regionalised model for Austrian snow conditions. Regional Environmental Change 1(1), 4-14 (1999).
14) Becken, S.: A review of tourism and climate change as an evolving knowledge domain. Tourism Management Perspectives 6, 53-62 (2013). doi:10.1016/j.tmp. 2012.11.006.
15) Tranos, E., Davoudi, S.: The Regional Impact of Climate Change on Winter Tourism in Europe. Tourism Planning & Development 11(2), 163-178 (2014).
16) Li, Y., Zhao, M., Guo, P., Zheng, J., Li, Z., Li, F., Shi, Y., Dong, S.: Comprehensive evaluation of ski resort development conditions in northern China. Chinese Geographical Science 26(3), 401-409 (2016).
17) Kureha, M.: Regional pattern of lost and closed ski fields in Japan. Journal of Ski Science 11(1), 27-42 (2014).
18) Yusuke, F., Noriatsu, O., Takehiko, F., Hideo, H.: Effect of ambient temperature and precipitation changes on leisure activities in case of ski tourism. Proceedings of Annual Meeting of Environmental Systems Research 29th, 323-330 (2001).
19) Tomoda,G.,Mori,R.,Morisugi,M.,Ohno,E.,Nakajima,K.,Sakamoto, N.:Statistical examination of the relationship between recent continuous decrease of skiing visitors and climate change. Journal of Japan Society of Civil Engineers, Ser. G (Environmental Research) 74(5), I_349-I_357 (2018).
20) Matsunaga,N.,Ono,Y.,Kato,H.:A forecast of changes in the

number of visitors to leisure facilities and that of access traffic volume due to climate change. Proceedings of infrastructure planning 53 (2021)
21) Railway information systems: Seasonal information service. https://www.jrs.co.jp/ service/product/season/
22) Center, J.P.: leisure white paper (2007-2021)
23) Otawara, N., Onishi, A., Sato, Y., Sao, H., Morisugi, M.: Effects on ski business in Toyama prefecture by decreasing of snowfall under the global warming. Journal of Japan Society of Civil Engineers, Ser. G (Environmental Research) 70(5), I_21- I_29 (2014). doi:10.2208/jscejer.70.I_21
24) N.Ishizaki: Bias corrected climate scenarios over Japan based on CDFDM method using CMIP, Ver.1.1, NIES. https://data.stats.gov.cn (2021).
25) Eric:IntroductiontotheFundamentalsofPanelData(2019).https://www.aptech. com/blog/introduction-to-the-fundamentals-of-panel-data/
26) Pillai N., V.: Panel Data Analysis with Stata Part 1 Fixed Effects and Random Effects Models (2016). https://mpra.ub.uni-muenchen.de/76869/

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