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Comprehensively Evaluating Higher Education in North America Based on a Weighted Hierarchical Indicator Model: Specific to Different Study Abroad Students

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Abstract: Receiving higher education abroad has become a promising way for international students to increase competitiveness. Despite the global outbreak of COVID-19 in recent years, still a large number of international students are inclined to study abroad, especially regarding North America as their first choice. University rankings recommended by distinct institutions are commonly considered as a useful guide to evaluate the quality of higher education, which is critical for international students to determine the target university for their further study. However, major problems identified in existing university ranking systems include insufficient integration of potential facets, weak measurement and quantification, and lack of taking personal demands and preference into account. To tackle these challenges, this study proposed an integrated conceptual model based on a hierarchical index system for comprehensively evaluating higher education in North America. This model attempts to improve the current university ranking philosophy by incorporating both subjective and objective weights using statistical and geospatial techniques, providing a theoretical basis for comprehensive evaluating higher education in North America as well as a personalized guide of selecting universities for different international students. Finally, results were effectively visualized on an interactive web-based platform with users' personalized preference as the input weights.

1. Introduction

In the context of accelerated economic and cultural globalization, studying abroad for higher education has become an effective way for international students to improve their competitiveness and to gain competitive advantages [1,2]. In particular, students in developing countries prefer to pursue their undergraduate or graduate programs in developed countries due to the abundant education resources and high-quality intelligent training in those countries [3,4]. Despite the global outbreak of COVID-19 in recent years, the number of international students who prefer to study abroad is still on the rise, among which Chinese students account for the largest proportion of

international students [5,6]. The key factors that motivate students to go abroad for pursuing a degree mainly include career advancement, immigration qualification, accumulation of research experience, and broadening horizons [7,8]. Since university rankings are commonly considered as a useful guide to assess the quality of higher education, how to comprehensively and quantitatively evaluate different universities or colleges in North America is critical for potential overseas students to make a prudent decision of choosing the most suitable university or college for their further study [9].

In general, scholars highlighted that choosing universities for studying abroad is mainly influenced by multiple aspects including academic reputation, cost, curriculum provision, campus safety, educational attributes, campus geographical conditions, and so on [10,11]. Early in 1973, Bowers and Pugh [12] pointed out that academic reputation can greatly affect how students choose a proper university for further higher education, which was subsequently resonated with by a series of similar studies indicating that academic reputation of a university can significantly contribute to the future career advancement [13-15]. In addition, the expense of studying abroad has long been another essential aspect of concern for those outbound students [16,17]. Also, there is considerable consensus within the scientific community that curriculum provision and diversity of disciplines are recognized as the main selection criteria with both "practical" and "financial" attributes that influence the applications for admission [18,19]. This is consistent with Shanka et al. [10] who holds a similar view that the availability of course variety and the high standard of facilities together determine the selection of an ideal university, which can further stimulate students' interest and passion for higher education [20]. Moreover, geographical conditions [11], socioeconomic circumstances [16], campus security [21], language proficiency (e.g., TOEFL, IELTS, SAT and GRE) have also been taken into considerations when it comes to apply for a suitable university [22].

Since multiple domains collectively demonstrate profound relevance to university choice or comprehensively evaluate higher education in North America, a number of studies have been conducted to focus on the international students' decision processes including their primary motivations, sources of information, and ways of higher education assessment, which can further explain according to what criteria students choose an education destination in the North America [10,23]. Given that a variety of commercial institutions have conducted some marketing analysis of overseas higher education based on statistical data, students can gain some recommendations to guide their decisions of choosing the target universities of colleges in North America [24,25]. However, because students in different backgrounds may have different perception of ranking the influential factors to their education destinations. It is possible that certain factors slightly affect some students 'decision but highly impact others' choice.

Therefore, major problems identified in existing university ranking systems include insufficient integration of potential facets, weak measurement and quantification, and lack of taking personal demands and preference into account. To tackle these challenges, this study proposed an integrated conceptual model based on a hierarchical index system for comprehensively evaluating higher education in North America. This model attempts to improve the current university ranking philosophy by incorporating both subjective and objective weights using statistical and geospatial techniques, providing a theoretical basis for comprehensive evaluating higher education in North America as well as a personalized guide of selecting universities for different international students. Finally, results were effectively visualized on an interactive web-based platform with users' personalized preference as the input weights

2. Methodology

In order to comprehensively quantify and analyze the patterns and distributions of higher education in North America, this study establish a theoretical conceptual model with four fundamental

dimensions of evaluation (Figure 1). Those four domains have been the major focus of students who would like to apply an education destination abroad. Then we use a hierarchical index system to calculate the multi-level indicators within different domains of the conceptual model. The candidate evaluation indicators can be more flexibly selected for the model according to the actual needs of different study abroad groups. Since traditional global university rankings provided by different commercial institutions are merely based on statistical data to calculate the priority order of university in the list. However, this schema put more attention to the objective information of the target universities with assigning constant weight for each domain instead of taking personal preferences or individual needs into consideration. Therefore, to cope with the aforementioned challenge, we adopt both objective linear weighting and subjective interactive weighting to calculate the evaluation index at different levels of the model, which can ultimately provide a comprehensive and effective evaluation of North American universities by considering different subjective requirements.

To test the feasibility of the hierarchical evaluation model, we focused on the higher education destinations in North America including both the United States and Canada. North America is a recognized aggregation of prestigious universities and colleges in the world, and every year a number of international students are attracted to pursue undergraduate or graduate programs in North America for its high quality of teaching, strong academic reputation, reasonable curriculums, abundant scholarships, and optimistic career prospects. However, given the increasing crime rate, climate changes, racial issues, and the high cost of universities the selection and applications of universities or colleges in North America have been affected to some extent. In particular, with the global pandemic of COVID-19 over the past few years, the public awareness of epidemics as well as the prevention and control measures also discouraged many international students. In this study, the target higher education destinations of this study are the common 82 institutions of the top 200 universities or colleges in North America recommended by four major rankings (QS, THE, U.S.News, and CWUR). Research data consists of statistical data, remote sensing data, and vector data.

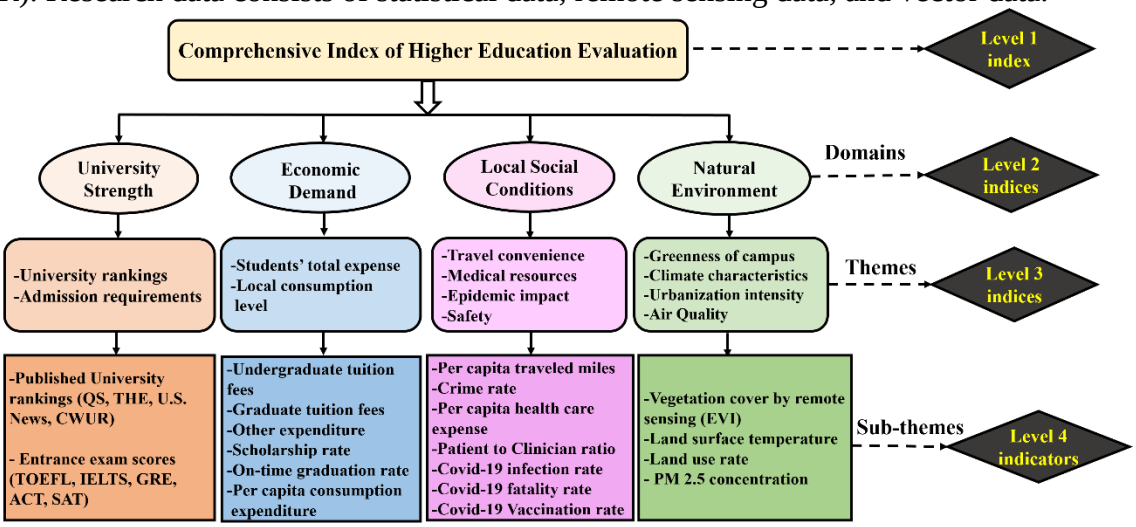

Figure 1: The framework of the comprehensive model to evaluate higher education at different integrated levels

2.1. Quantification of different indicators

A Since the original research data was acquired in different units of measurements, it is necessary to conduct data normalization and standardization before being applied in the subsequent index calculation. After identifying the positive or negative attributes of each measurement, the correction of direction was implemented respectively based on Formula (1) for positive measurement and

Formula (2) for the negative one.

$$y_i = \frac{x_i - \min(x)}{\max(x) - \min(x)} \quad (1)$$

$$y_i = \frac{\max(x) - x_i}{\max(x) - \min(x)} \quad (2)$$

For objective weight calculation, we adopted Critic Weight Method, which includes four steps: indicator variability calculation, indicator conflict reduction, information assessment and objective weight assigning. Since the final evaluation and selection of the target education destination is of great influence from individual subjective preference and demand among the multifaceted factors in making choice of the university or college application, in this study incorporating a subjective weight provided interactively by users is proposed when calculating the final comprehensive evaluation index which is the most critical index to determine the final education destination for different undergraduate or graduate students. The subjective weights ultimately will be interactively input by individuals through the Web platform, which will be further illustrated in the result section. The calculation way is shown by Formula (3) and (4).

$$W_i = \frac{\sum_{i=1}^{n} x_i \times S_i}{10} \quad (3)$$

$$\sum_{i=1}^{n} x_i = 10 \quad (4)$$

Where S is the score set of level 2 indices, i is the score of the i-th index, n is the number of the level 2 indexes, x_i is the evaluation value of the i-th index entered by the study abroad group, W_i represents the weight of the i-th index. In this study, it is stipulated that the sum of the evaluation values entered by the study abroad groups is 10.

2.2. Remote Sensing Data Processing Methods

As one essential type of data source, satellite imagery can provide useful information of neutrality, objectivity, and technical proficiency for measuring evaluation indicators. Besides, online free downloaded remote sensing data can helpfully reduce the cost of indicator measurement. After previewing all available MODIS (Moderate Resolution Imaging Spectroradiometer) data for the geographic area of North America from the National Aeronautics and Space Administration (NASA) official online archive, we acquired the EVI (enhanced vegetation index) product (2011-2021) for characterizing vegetation cover, land surface temperature product (2011-2021) and land use product (2011-2020). Also, we obtained PM2.5 concentration products (2000-2018) from Washington University in ST.Louis Atmospheric Composition Analysis Group. All of those data serve as input measurements to quantify the indicators at Level 1 and further calculate the indices at Level 2 and Level 3 for the domain of natural environment. Given the large variability among different remote sensing products in terms of spatial and temporal resolutions, we preprocessed each product and established a buffer zone to calculate the temporal and spatial average value. Then we utilized the Remote Sensing Euclidean Distance Method to obtain the weights of each product corresponding to the level 3 indices.

In order to effectively quantify the indices which are used to geographically characterize the status of each target university, we applied a buffer zone with a radius of 5 km of the target university as the centre of the circle, and assumed the value in each pixel within the buffer all contribute to the index calculation. So we extracted the mean values of the different data sets within the buffer and used them to yield the indices at different levels of the target universities.

3. Results

3.1. Spatial distributions of indices at different levels for the target universities

Based on a hierarchical colouring method we mapped the number of target universities in each state or province of North America shown in Figure 2, which can further prove that the states (provinces) with more target universities are located almost on the more developed east and west coasts of North America. In contrast, less universities distribute in the inland areas which are relatively economically undeveloped. This tells that the spatial distribution of the prestigious universities in North America are highly associated and consistent with the geographical and economic conditions.

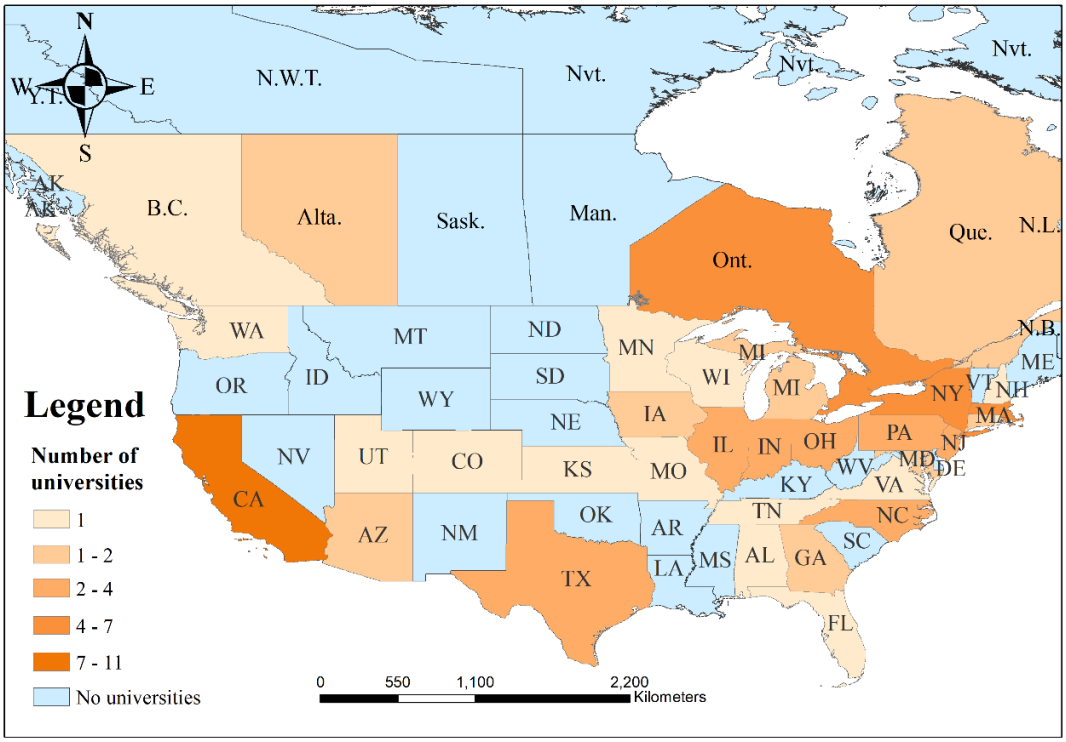

Figure 2: The geographical distribution of the target universities in different states (provinces) in North America

Also, to obtain a quantitative measurement of the geographic distribution of those target universities in North America, we also derived a heat map based on the latitude and longitude of each university using the kernel density method (Figure 3 (a)), and a clustering map using the DBSCAN clustering method (Figure 3 (b)). The heat map shows very high heat values along the eastern coast of North America, higher heat values along the western coast, and low heat values in the central region. In similar, the clustering map exhibits the similar characteristic patterns of the aggregation in the eastern and western coast compared to the central region.

Based on kernel density method we derived the heat map for Level 2 indices. We also yielded the clustering maps for those indices using SCAN method with the minimum cluster size of 2, and the minimum sampling number of 2 in Euclidean distance. The heat map shows that the values of *University Strength Index* on the eastern coast (New York, Boston, and Philadelphia) and on the western coast (Los Angeles, San Francisco) are significantly high, signifying an agglomeration of prestigious education destinations with high admission requirements in those two specific regions in North America (Figure 4 (a)). In addition, the clustering maps demonstrate that New York,

Philadelphia on the eastern coast of North America, Los Angeles, San Francisco on the western coast, and the Chicago area have relatively high *University Strength Index* values; the Boston area, Lowa state, and Houston area have relatively unsatisfactory *University Strength Index* values (Figure 4 (b)). In general, it implies the entrance requirements (e.g., TOFEL, IELTS, GRE, ACT, SAT, etc.) of the education destinations are strict in those areas mainly involving New York, Philadelphia, Los Angeles, and San Francisco.

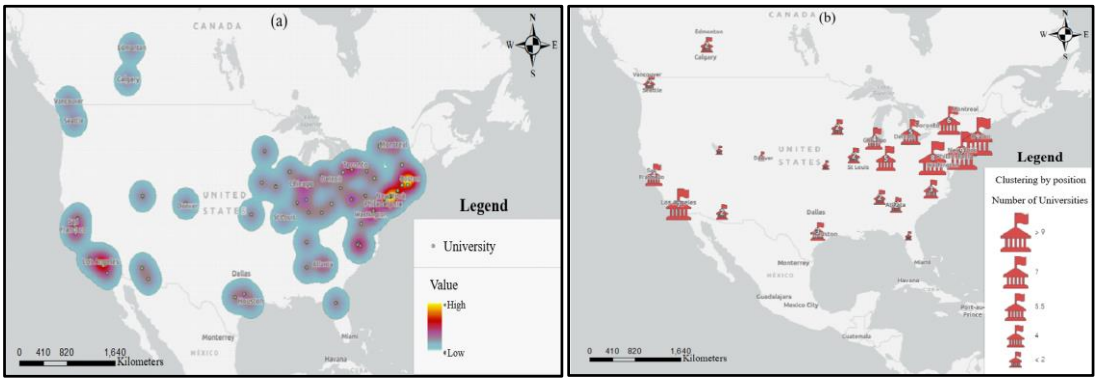

Figure 3: (a) is a heat map of the target universities (b) is a clustering map of the target universities

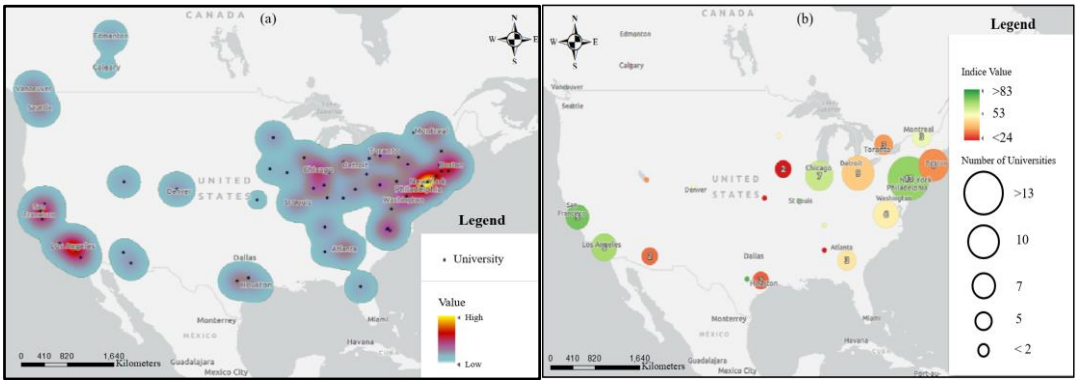

Figure 4: (a) is a heat map of *University Strength Index* values (b) is a clustering map of *University Strength Index* values

3.2. The web-based visualization of interactive evaluation

Based on the calculated indices at different levels of the comprehensive evaluation model, we applied the spatial technique to develop a web-based visualization platform for displaying the spatial maps by incorporating the subjective weights from the users. The web-based platform provides an efficient and convenient way to present the research results with different study abroad groups. Users can input different subjective interactive weights according to their own preferences or demands to obtain the evaluation results of education destinations, and finally choose the most suitable university or college for studying abroad. In this platform, different input subjective weights for Level 2 indices can derive different result maps. Users can view specific information of each target university on the result map which can further assist users to determine their final education destinations. The core interfaces can be shown by Figure 5 and Figure 6.

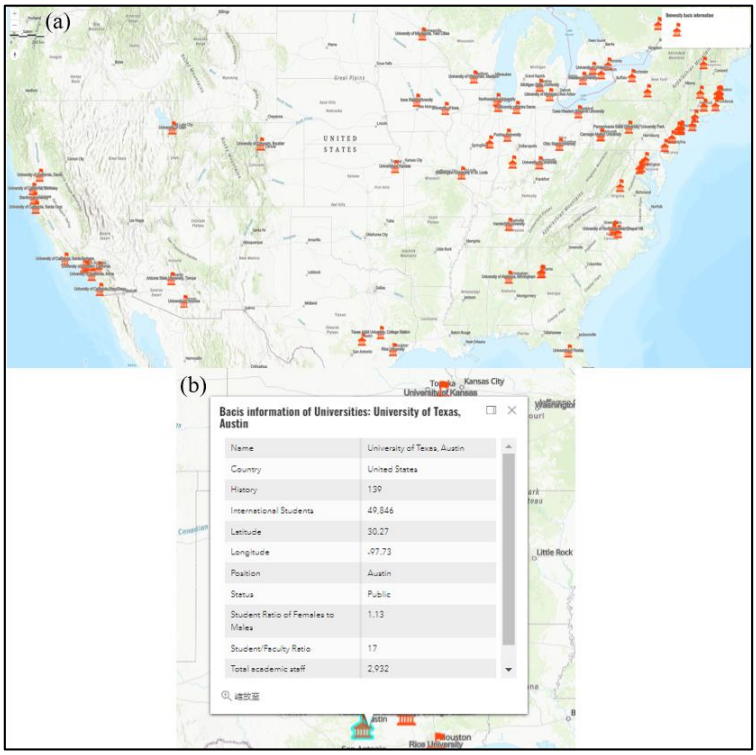

Figure 5: (a) is the fundamental information page of the target education destinations (b) is the pop-up window of the target education destination

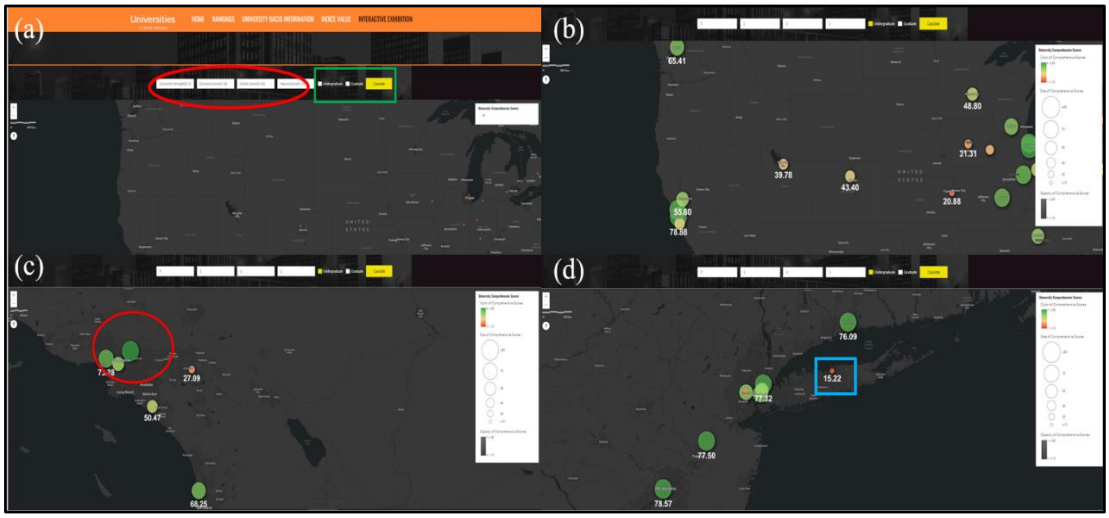

Figure 6: (a) is the interaction page in need of users' input subjective weights; (b) is the example web map of Level 2 indices; (c) is the location that has the highest Comprehensive Index value; (d) is the spatial location of the university that has the lowest Comprehensive Index value

4. Discussion

As a preliminary and multidiscipline study of evaluating higher education, this research proposed a comprehensive model based on a hierarchical index evaluation system. Multiple data sources consisting of statistical data, remote sensing data, and vector data were applied to quantify the index measurement. Both objective and subjective weights are incorporated into the index calculation in

different levels of the model. The higher education evaluation model developed in this study covers the most fundamental domains pointed by abundant published literature. However, as an open concept framework, the selection of specific evaluation indicator in different levels can be flexibly adjusted according to the actual requirements and scientific principles for widely applications. In addition, this comprehensive model can provide guiding information for different study abroad groups including both undergraduate and graduate students relatively reasonable and reliably.

Furthermore, to facilitate the visualization of comprehensive evaluation results and provide an interactive parameter inputting function for users of different study abroad groups, a web-based visualization platform was developed based geospatial techniques. The platform primarily visualizes the basic information of the target education destinations and different Level 2 indices of the comprehensive evaluation model. It is worth noting that different study abroad groups can set their own subjective weights and finally get the information of potential target universities.

There are three main innovations in this thesis: firstly, a comprehensive model based on a hierarchical index evaluation system is proposed with multiple data source as measurements; secondly, both objective and subjective weights are used to calculate the different indices of the model, which are more suitable for the practical applications; thirdly, a spatial visualization platform is built to display the final result map of target universities for different study groups. However, there are several limitations in this study. First of all, due to the research funding, data availability, and time restrictions, data used in this study might not precisely and accurately quantify the proposed indicators. Moreover, we applied the CRITIC weighting method only to the statistical data processing and more weighting methods need to come up with a comparative validation of the result accuracy. Last but not the least, there is still much room for optimization of the spatial visualization platform, such as improving the response speed, providing stronger interactivity, and offering richer visualization methods.

For further research, we can extend the model to global study or narrow the study to a certain individual country or even a certain region. The selection of indicators and measurements should be adapted accordingly for evaluating a specific type of discipline or major because international students may care more about the subjects or the specific research program they will be involved in.

5. Conclusion

University rankings recommended by distinct institutions are commonly considered as a useful guide to evaluate the quality of higher education, which is critical for international students to determine the target university. This study proposed an integrated conceptual model based on a hierarchical index system for comprehensively evaluating higher education in North America. This model attempts to improve the current university ranking philosophy by incorporating both subjective and objective weights using statistical and geospatial techniques, providing a theoretical basis for comprehensive evaluating higher education in North America as well as a personalized guide of selecting universities for different international students. Finally, results were effectively visualized on an interactive web-based platform with users' personalized preference as the input weights.

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