Hindawi
Discrete Dynamics in Nature and Society
Volume 2022, Article ID 8056897, 14 pages
https://doi.org/10.1155/2022/8056897

Research Article

Development and Application of a Model Measuring Public Safety in Taiwan

Zhi-Ping Lin,[1] Song-Chia Hsu,[1] and Z. H. Che[2]

[1]*College of Management, National Taipei University of Technology, 1, Sec. 3, Zhongxiao E. Rd., Taipei 106, Taiwan*
[2]*Department of Industrial Engineering and Management, National Taipei University of Technology, 1, Sec. 3, Zhongxiao E. Rd., Taipei 106, Taiwan*

Correspondence should be addressed to Z. H. Che; zhche@ntut.edu.tw

Received 9 June 2022; Revised 10 September 2022; Accepted 3 October 2022; Published 20 October 2022

Academic Editor: Tapan Senapati

Public safety-related problems exist in all countries, causing the public to fear for their personal safety and that of their property. Maintaining public safety, providing citizens with safe living environments, and realizing sustainable social development are issues that concern not only the public but also local and central governments. Accordingly, this study proposed a measurement model that combines the analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) to obtain public safety ratings. First, this study used the AHP to analyze the contributions of public safety-related criteria, and the relative weights of the criteria were calculated. Subsequently, TOPSIS was used to calculate the relative closeness coefficients between public safety performance and positive-ideal solutions to evaluate public safety performance. The measurement model proposed in this study was used to rate the public safety performance of 22 cities and counties in Taiwan. The results showed that the criterion weights matched the perceptions of the public, and Lienchiang County, Taitung County, and Penghu County had the best public safety performance. The applicability of the proposed measurement model has been confirmed using real-world data. Thus, it can be used to help decision-makers make complex public safety-related decisions.

1. Introduction

Public safety events threaten property and human lives. When such events are serious, they may even endanger economies. Appropriate protective measures must be employed to prevent public safety events from negatively influencing the daily operations of vulnerable industries, such as the restaurant, entertainment, and tourism industries. For a society to naturally and culturally develop, its people must be free from fear and be able to live in peace. Recently, governments worldwide have made sustainable development a focus of governance policies, with economic development, social harmony, and environmental protection established as key goals. Social harmony concerns people's basic needs, and the goals of social harmony include promoting people's health, improving people's quality of life, reasonably distributing social resources, and facilitating community reconstruction. Public safety has crucial effects on people's quality of life, and national leaders and regional heads must address public safety goals. Public safety is a challenge that all countries must address, and strengthening and maintaining social safety, ensuring social stability, and preventing violent crimes are sustainable development goals that Taiwan must achieve. To realize social justice and stable social development, freeing people from fear and creating favorable living environments in which people can thrive are major tasks related to the creation of sustainable societies.

Taiwan's highly democratic political environment, liberal economy, diversified social development, and rapid advances in technology such as information technology have created various social problems and methods through which crimes can be committed. Crime types have become more diverse, and social crimes have become increasingly serious. Often, public safety is associated with politics, and public safety-related incidents are frequently discussed in political settings. The public usually considers public safety-related incidents as a measure of a government's governance results and the police force's law enforcement efficiency. To elevate governance results, governments commonly refer to statistical data when formulating and testing policies. To measure public safety, Taiwan uses criminal case-related statistics as basic data. Such statistics reflect major crime types and trends and can be used to assess law enforcement results; police units can reference these data when formulating appropriate crime prevention policies and crime investigation strategies. According to general criminal offense-related statistics compiled by the National Police Agency of the Ministry of the Interior, from 2017 to 2021, the number of crimes was over approximately 294,000, 285,000, 268,000, 260,000, and 243,000, respectively, showing a decreasing trend but persistently high crime numbers. These statistics make the public worry about their personal safety and that of their property. The public hopes that police units can protect their personal safety and property and devise and implement more efficient crime prevention strategies to solve social safety issues. Thus, strengthening and improving public safety should be a key focus of central and local governments.

The Taiwanese government previously used the number of crimes solved or the number of criminals captured as a measure of police enforcement efficiency, and no comprehensive model for measuring the public safety of each region had been constructed. In 2002, the National Police Agency proposed the National Public Safety Improvement Project, which measures the public safety of each city and county by calculating the number of cases of violent crimes and thefts that have occurred and have been solved. Objective and subjective indicators are used to assess public safety. The objective indicators include the number of cases of violent crimes and thefts solved, whereas a subjective indicator is the public's satisfaction with public safety. The objective indicator is based on the average number of crimes committed and solved per quarter, which account for 30% and 70% of the overall score, respectively. Violent crimes and thefts account for 50% of such crimes, respectively. To enhance public safety and deter criminal activity, Taiwan promulgated the 2020 Policy Guidelines of the Ministry of the Interior. Additionally, to eliminate transnational crimes and effectively fight crime, Taiwan continues to collaborate with other countries and improve its technology-oriented crime detection and prevention approaches.

The aforementioned indicators, which only analyze the number of criminal offenses that have occurred and been solved, do not distinguish between major and minor offenses. Additionally, the use of only violent crimes and thefts to represent public safety is insufficient. Furthermore, the weights assigned to these indicators are not objective and do not reflect the public safety of Taiwanese cities and counties, which leads the government to believe that no improvements to public safety are required. Therefore, a measurement model was developed in this study to systematically assess the public security of cities and counties. Multicriteria decision-making (MCDM) methods have been applied to solve problems in various domains [1–3]. Because public safety concerns in cities and counties involve multiple criteria, an MCDM model was used in the present study. In addition, the analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) have been widely explored and employed by researchers and decision-makers. As such, in the present study, the AHP and TOPSIS were used to develop a public safety measurement model. In the proposed model, the AHP is used to obtain criteria weights, and the TOPSIS is used to determine the public safety of Taiwanese cities and counties. Objective rankings according to the public safety ratings of cities and counties were obtained and served as references for relevant decision-making. The main contributions and originality in this paper are as follows: (1) developing a public safety measurement method that integrated the AHP and TOPSIS and systematically measured the public safety ratings of cities and counties in Taiwan. To the best of our knowledge, no study has developed a comprehensive model to assess local public safety; (2) determining the key criteria that affect the public safety of cities and counties and using the AHP to measure the relative criterion weights and gain insight into their importance; (3) using TOPSIS to rank the public safety of cities and counties; and (4) employing the proposed model to help cities and counties determine their public safety ratings and provide specific, objective measurement results for relevant units to formulate policies.

This paper is organized as follows: Section 2 presents a review of the public safety, crime, and MCDM-related literature. Section 3 introduces the public safety rating-related methodology adopted in this study. Section 4 describes the data import approach and the data analysis results. Section 5 provides the results of sensitivity analyses on the main dimensions. The final section offers conclusions and recommendations for future studies.

2. Literature Review

Diversified social development and social structure changes have created increasingly serious social problems; public safety is the most crucial of such concerns. Although crimes cannot be fully prevented, governments have primary responsibility for maintaining public safety, protecting the public's personal safety, property, rights, and well-being. Both governments and police officers devote themselves to integrating resources and breaking down organizational barriers and jurisdictional boundaries to maintain social harmony and ensure that the public lives in a comfortable environment. Safety involves the avoidance of dangerous situations and frees individuals from feelings of anxiety, restlessness, and fear. Fay [4] indicated that safety entails actively or passively offering protection and maintaining safe environments to enable individuals or organizations to remain unhindered as they engage in activities.

Effective police force allocation is an important measure in crime fighting. Simply increasing the number of police officers is not a favorable solution. Instead, governments should adopt systematic methods to organize and integrate police agencies and plan their police force allocation to achieve low-cost and highly efficient results. Most governments worldwide enact legislation to protect citizens' rights.

Because safe living environments are basic survival needs, maintaining public safety is a critical goal. In countries that maintain public safety, citizens are confident of their safety and even attract people from other countries to travel to or live there. Winterdyk [5] indicated that public safety problems cannot be solved by fighting crimes alone; mechanisms that prevent crimes should also be incorporated to minimize crime and ensure public safety. In the Uniform Crime Reports (UCRs) of the United States, crimes most directly related to public safety include thefts, general harm, intimidation for financial gain, violent crimes, and fraud. Hamill et al. [6] referenced these UCR classifications and employed a multiple linear regression model to analyze the incidence of homicide and other violent crimes. McCormack et al. [7] used UCRs and the National Incident-Based Reporting System to identify crime hotspots in the United States. Pandey & Mohler [8] analyzed crimes that took place in Los Angeles from 2009 to 2014 by using the non-negative matrix factorization model to examine seven crime types in the UCRs. They collected 5,000 pieces of data as a sample for each crime type, culminating in 35,000 pieces of crime-related data for analysis. Thomas & Barbara [9] noted that in the United States, the crime index is used as a key indicator to measure social quality in political jurisdictions. They investigated the weight and influence of the crime index in related jurisdictions. Kwan et al. [10] researched and analyzed the crime index of Hong Kong by using the Thurstone scale to compare the relative severity of 15 crime types, and they calculated the weight of each crime type. They then developed a time series-based weighted crime index of crime severity. Silva et al. [11] proposed using the MCDM method to analyze major theft and violent crimes in Brazil, and they presented the analysis results to relevant units to be used as a reference when formulating crime-fighting and prevention policies.

The MCDM involves using the decision support methods to help decision-makers solve complex decisions. Because of the nature of MCDM problems (i.e., they often involve multiple goals or multiple measurement properties), determining the correct decision to be made is critical [12]. The MCDM assigns weights to criteria according to the decision-making goals and finds solutions during the decision-making process. The solutions in the final results are generally ranked. The MCDM is used in many studies and applications, such as evaluating energy storage systems for grid applications [13], identifying the optimal site for a solar power plant [14], assessing the sustainability of end-of-life alternatives for waste plastics [15], selecting solar panels [16], analyzing waste-to-energy management strategies [17], choosing sustainable materials for construction projects [18], assessing the sustainability of energy sectors [19], and selecting sites for solar photovoltaic systems [20].

The AHP, the most widely used MCDM method [21, 22], primarily involves making preference-based decisions by considering multiple conflicting attributes and selecting an option (or an alternative) out of all options [23]. The AHP can be used for individual and group decision-making [24]. Developed by Thomas Saaty in the 1970s, the AHP decomposes decision-making into a systematic, hierarchical structure of goals, criteria, and alternatives. The AHP creates hierarchical structures for decision-making under the basic concept of relevance; that is, all factors at any level should be related to the corresponding factors at a higher level. Thus, the effects of factors can be quantified by assessing their relative importance at their respective levels [25]. The AHP has become a commonly used tool among those who must make complex decisions. It simplifies complex decision-making into a series of pairwise observational comparisons, and comprehensive results are achieved. The AHP can help decision-makers quickly define goals and make optimal choices [26].

The AHP is a technique for determining weights in multiattribute decision-making problems [27, 28]. When using AHP, decision-makers measure the relative importance of factors by using their data, experiences, opinions, and intuition. On the basis of weights, decision-makers choose the optimal attribute among multiple attributes. The AHP calculation process is not complicated. If judgments made about the relative importance of attributes are reasonable, AHP calculations produce results that match such judgments. Additionally, AHP uses the consistency ratio (CR) to verify whether decision-makers' judgments contain decision biases. Lower CR values indicate higher consistency in decision-makers' judgments. Usually, a CR value of less than 0.10 is acceptable, and a CR value greater than 0.10 suggests inconsistency in the decision-maker's judgments [29]. Some researchers have set an acceptable CR of 0.2 [30, 31]. The AHP integrates all the judgments made by all experts. Therefore, it is reliable and directly determines the relative weights of attributes [32, 33]. The AHP can transform qualitative attributes into quantitative measures, making it useful in the fields of science and sociology. Saaty [29] cited numerous studies to illustrate the applicability and importance of AHP.

Because of the intuitiveness of the AHP and the ability of the AHP to solve complex problems, Balt [34] proposed an AHP method that assisted engineers in selecting mining options. Subramanyan et al. [35] used the AHP to develop a model for assessing the risks associated with construction projects. Ali & Al Nsairat [36] used the AHP to build a green building assessment tool to determine green building assessment criteria and weights. Lai & Yik [37] used the AHP to identify the indoor environmental quality of high-rise residential buildings; they used the AHP to reveal the importance and weights of indoor environmental quality-related attributes. Alwaer et al. [38] constructed a sustainability assessment model on the basis of the AHP to help decision-makers choose the most appropriate indicators for smart buildings. Wakchaure & Jha [39] used the AHP to solve bridge maintenance problems in a scenario involving resource limitations. Tran et al. [40] used the AHP to develop transportation livability-related indicators; these indicators provided a green urban road rating system for Taiwan. They also identified key barriers to applying these indicators in Taiwan's urban road systems. The objective was to measure and promote the sustainability of road projects by using rating system indicators. Researchers have used the AHP-related applications to decide technology transfer factors and choose alternative plans [41], select software for engineering education [42], explore factors that influenced students' school-choice decisions [43, 44], assess environmental conditions [45], and evaluate wetland parks [46].

Proposed by Hwang & Yoon [23], TOPSIS is an MCDM ranking method that has favorable performance in assessing criteria. TOPSIS is used in MCDM to identify positive-ideal solutions (solutions with the largest benefit criteria) and negative-ideal solutions (solutions with the smallest benefit criteria) to calculate their integrated performance value (measured in terms of the distances between decision criteria and positive- and negative-ideal solutions). Subsequently, the solutions are ranked and assessed. Escolar et al. [47] stated that TOPSIS is a simple, reasonable, and easy-to-understand concept that employs intuitive logic, conforms to the basic principles governing human choices, and is easy to apply. TOPSIS is widely used in various fields. Sharma & Singhal [48] applied TOPSIS to solve urban planning problems. Falqi et al. [49] used TOPSIS to assess silicon materials; they were able to extend the service life of concrete and thereby reduced costs and identified a means of achieving sustainable construction development. Khabir et al. used TOPSIS to develop a vehicle theft index; they analyzed the overall vehicle theft patterns and property thefts in 82 regions of Peninsular Malaysia. Zhao et al. [50] used a TOPSIS-based hybrid method to evaluate electricity development in 11 countries. Awasthi et al. [51] used TOPSIS to determine the optimal locations for distribution centers in cities. Kampf et al. [52] used TOPSIS to apply a decision-making approach to identify optimal locations for public logistic centers. Li et al. [53] used TOPSIS to develop five criteria (i.e., transportation, communication, candidate land area, candidate land value, and freight transportation) for logistic center selection. Freeman & Chen [54] used TOPSIS to select optimal suppliers. Other TOPSIS-related applications include managing human resources [55], assessing e-commerce service quality [56], and selecting projects [57]. However, no study has combined the AHP and TOPSIS to measure national public safety. Additionally, a systematic, objective public safety assessment mechanism has yet to be introduced in Taiwan. Because the AHP and TOPSIS have been widely used in various domains for decision-making, this study used the AHP and TOPSIS to build a public safety rating model.

3. Methodology

In comprehensive analyses, the weights assigned to each decision-making dimensions and criterion are crucial because the results outputted are largely based on said weights. The AHP is an MCDM method that involves processing quantifiable and nonquantifiable criteria; it provides fast and precise results in a cost-effective manner. The AHP uses numerical scales to represent personal preferences, and pairwise comparisons are made between dimensions and criteria to convert individual preferences into ratios. TOPSIS assesses alternatives by primarily considering alternatives' geometric distances to positive- and negative-ideal solutions (i.e., those closest to positive-ideal solutions and furthest from negative-ideal solutions are ideal). In this study, 22 cities and counties in Taiwan were used as alternatives to analyze the public safety ratings of cities and counties. The researchers of this study referenced the crime data of cities and counties provided by the National Police Agency, adopted the AHP theory, used studies and expert opinions to determine the hierarchical structures that may contain factors (e.g., dimensions and criteria) influencing decision-making, and performed pairwise comparison analyses (analyses among dimensions and among criteria) to determine the relative importance of factors in decision-making problems. Subsequently, this study followed the principle of TOPSIS (i.e., solutions selected should be closest to positive-ideal solutions and furthest away from negative-ideal solutions) to measure the public safety performance of each city and county. This performance was then ranked. The AHP-TOPSIS procedure is as follows:

Step 1. Build a hierarchical decision-making structure.

All public safety rating-related dimensions and criteria are defined to develop the necessary hierarchical structure. This step is markedly critical, and all expert opinions must be referred to account for all possible standards and alternative plans, ensuring the completeness of assessments.

Step 1.1. Establish alternatives as follows: $A = \{A_1, A_2 \ldots A_P\}$; P is the number of alternatives.

Step 1.2. Set the assessment dimensions and criteria.

Dimension $C = \{C_1, C_2, \ldots, C_X\}$; X is the number of dimensions; criterion $C_x = \{C_{x1}, C_{x2}, \ldots, C_{xY}\}$; and Y is the number of criteria in dimension x. The hierarchical structure of public safety rating-related dimensions and criteria is presented in Figure 1.

Step 2. Create pairwise comparison matrices.

Through the building of a hierarchical structure according to Step 1, the relationships between dimensions and criteria can be defined. Next, pairwise comparisons between dimensions and criteria are conducted to build judgment matrices. Setting reasonable dimension and criterion weights is crucial to the accuracy of comprehensive assessment results, and questionnaire results are used to derive the numerical values of the aforementioned matrices. Subsequently, experts rate the pairwise comparisons between dimensions and criteria on a scale of 1–9. The ratings represent the differences in decision-makers' preferences, where a value of 1 indicates that the dimensions/criteria are equally important, and a value of 9 indicates that the dimensions are markedly more important than the criteria. Subsequently, experts' judgment values are used to build pairwise comparison matrix D, where $D_{ij} = w_i/w_j$, i and j are the weights of criteria (or dimensions) w_i and w_j, the value of the upper right triangle is the relative importance between criteria/dimensions, the bottom left triangle is the reciprocal of

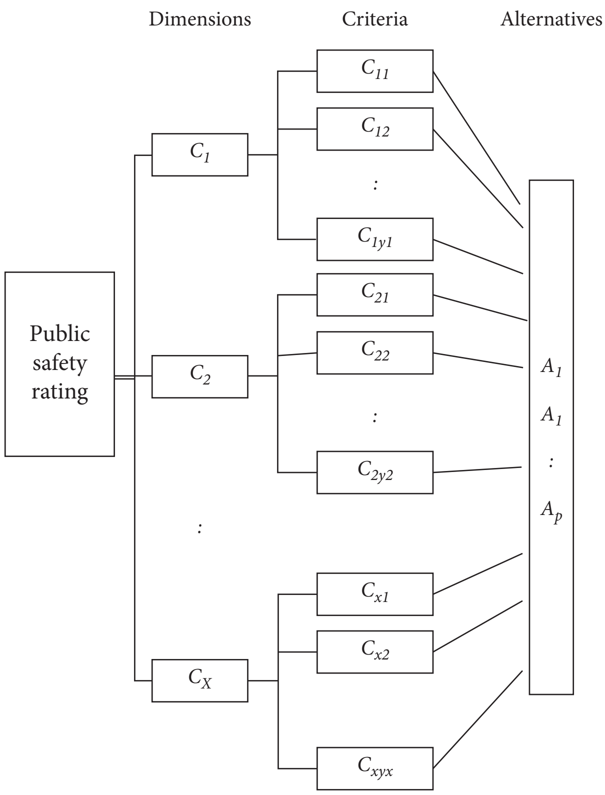

Figure 1: Hierarchical structure of public safety rating-related dimensions and criteria.

the upper right triangle, and the diagonal value (D_{ii}) from the upper left corner to the bottom right corner is 1.

$$D = \left[D_{ij}\right] = \begin{bmatrix} D_{11} & D_{12} & \dots & D_{1J} \\ D_{21} & D_{22} & \dots & D_{2J} \\ \vdots & \vdots & \vdots & \vdots \\ D_{I1} & D_{I2} & \dots & D_{IJ} \end{bmatrix} = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_J} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_J} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_I}{w_1} & \frac{w_I}{w_2} & \dots & \frac{w_I}{w_J} \end{bmatrix}. \quad (1)$$

Step 3. Normalize the geometric mean and calculate the relative normalized weight (W_j) of each criterion.

$$\overline{w_i} = \frac{\left(\prod_{j=1}^{N} D_{ij}\right)^{1/N}}{\sum_{i=1}^{N}\left(\prod_{j=1}^{N} D_{ij}\right)^{1/N}}. \quad (2)$$

Step 4. Perform consistency tests.

The maximum eigenvalue ($\lambda_{\max}$) and consistency index (*CI*) are calculated. The *CI*, which must be less than or equal to 0.1, is used to determine whether experts' answers are consistent. The *CI* and random index are used to calculate the *CR* of each level; this ratio must be less than or equal to 0.1. Failure to meet this condition signifies weak relationships between the criteria and indicates that all assessment criteria and their relationships must be re-evaluated.

$$\begin{aligned} D\overline{w} &= w^{\#}, \\ \overline{w} &= \left[\overline{w_1}, \overline{w_2}, \dots, \overline{w_i}\right]^T, \\ \lambda_{\max} &= \frac{1}{N}\sum_{i=1}^{N}\left(\frac{w_i^{\#}}{\overline{w_i}}\right), \\ \mathrm{CI} &= \frac{\lambda_{\max} - N}{N-1}, \\ \mathrm{CR} &= \frac{\mathrm{CI}}{\mathrm{RI}}. \end{aligned} \quad (3)$$

Step 5. Build the alternative evaluation matrix. e_{pq} is the rating of the p^{th} alternative of criterion q.

$$e = \left[e_{pq}\right] = \begin{bmatrix} e_{11} & e_{12} & \dots & e_{1Q} \\ e_{21} & e_{22} & \dots & e_{2Q} \\ \vdots & \vdots & \vdots & \vdots \\ e_{P1} & e_{P2} & \dots & e_{PQ} \end{bmatrix}. \quad (4)$$

Step 6. Normalize the evaluation matrix.

$$\delta_{pq} = \frac{e_{pq} - \min_p e_{pq}}{\max_p e_{pq} - \min_p e_{pq}}. \quad (5)$$

Step 7. Calculate the weighted and normalized evaluation matrix.

$$\varphi_{pq} = \overline{w_q}\delta_{pq}. \quad (6)$$

Step 8. Decide on positive-ideal solution A^+ and negative-ideal solution A^-.

$$\begin{aligned} A^+ &= \left\{\varphi_1^+, \varphi_2^+, \dots, \varphi_Q^+\right\} = \left\{ \begin{array}{l} \left(\max_p \varphi_{pq} | q \in Q'\right), \\ \left(\min_p \varphi_{pq} | q \in Q''\right), \\ \text{for} \, p = 1, 2, \dots, P \end{array} \right\}, \\ A^- &= \left\{\varphi_1^-, \varphi_2^-, \dots, \varphi_Q^-\right\} = \left\{ \begin{array}{l} \left(\min_p \varphi_{pq} | q \in Q'\right), \\ \left(\max_p \varphi_{pq} | q \in Q''\right), \\ \text{for} \, p = 1, 2, \dots, P \end{array} \right\}, \end{aligned} \quad (7)$$

Here, Q' is a benefit-related criterion, and Q'' is a cost-related criterion.

Step 9. Calculate the distance between each alternative and the positive-ideal (S_p^+) and negative-ideal solutions (S_p^-).

$$S_p^+ = \sqrt{\sum_{q=1}^{Q} \left(\varphi_{pq} - \varphi_q^+\right)^2}, \quad p = 1, 2, \ldots, P,$$
$$S_p^- = \sqrt{\sum_{q=1}^{Q} \left(\varphi_{pq} - \varphi_q^-\right)^2}, \quad p = 1, 2, \ldots, P. \tag{8}$$

Step 10. Calculate the relative closeness coefficient (CO_p^+) between the alternative and positive-ideal solutions.

$$CO_p^+ = \frac{S_p^-}{S_p^- + S_p^+}, \quad p = 1,\ 2, \ldots,\ P. \tag{9}$$

Step 11. According to the order of CO_p^+, decide the rankings of alternatives.

4. Results and Discussions

This study referenced the UCR classification system proposed by the FBI to derive 3 major dimensions (i.e., violent crimes, property-related crimes, and other crimes) and 12 criteria for assessing and ranking the public safety of 22 cities and counties in Taiwan. Prior to MCDM analyses being performed, these dimensions and criteria were utilized to reconstruct a hierarchical model for assessing public safety in the aforementioned cities and counties. Figure 2 shows the public safety rating-related dimensions and criteria, where the first and second levels contained three dimensions and 12 criteria, respectively.

4.1. Violent Crimes (C_1). Violent crimes, which include homicide and sexual assault, are crimes against individuals that seriously endanger public safety. Governments worldwide focus on fighting violent crimes. The criteria under the "violent crimes" dimension include intentional homicide, rape, robbery, and serious assaults.

4.2. Property-Related Crimes (C_2). Property-related crimes, which include general and vehicle (e.g., scooter) thefts, arson, and burglary, are related to private property. Property-related crimes are those that involve money, property, or other forms of financial gain. The crimes under the "property-related crimes" dimension include arson, burglary, general thefts, and vehicle thefts.

4.3. Other Crimes (C_3). Other crimes are serious crimes that are not violent or property related. Such crimes include drug possession, gambling, drunk driving, and forgery.

This study referenced the expert questionnaires distributed and adopted the AHP to calculate the weights of dimensions and criteria. Crime dimensions or indicators that were more important were assigned higher weights to ensure that they were separated according to their level of importance. Data analyses revealed that among the first-level dimensions, violent crimes had the highest weight (0.74), followed by property-related crimes (0.16) and other crimes (0.10). Among violent crimes, intentional homicide and rape had the highest weights at 0.37 and 0.26, respectively. Among property-related crimes, arson had the highest weight (0.10), and burglary, general thefts, and vehicle thefts had weights of 0.02, 0.03, and 0.01, respectively. Among other crimes, possession of drugs had the highest weight (0.04). The weights of all the criteria in the dimensions are presented in Table 1.

This study used normalized data for data comparisons and analyses. The values were scaled to range from 0 to 1. Figure 3 shows the normalized public safety data of cities and counties, and Figure 4 presents the normalized data matrices after weights had been assigned. After determining the positive- and negative-ideal solutions, the researchers calculated the distances between alternatives and positive-ideal (S_p^+) and negative-ideal solutions (S_p^-). For example, the S_p^+ and S_p^- of New Taipei City were 0.357 and 0.144, respectively, whereas those of Taitung County were 0.014 and 0.467, respectively. The distances between the alternatives and the positive- and negative-ideal solutions of all the cities and counties are shown in Table 2. Subsequently, the relative closeness coefficients (CO_p^+) between the alternatives and positive-ideal solutions for each city and county were ranked. For example, New Taipei City had a CO_p^+ of 0.2876 (21st place), whereas Taitung County had a CO_p^+ of 0.9704 (2nd place). The relative closeness coefficients and rankings of all the cities and counties are displayed in Table 2. The top 10 cities and counties in terms of public safety are listed in descending order as follows: Lienchiang County (1.0000) ≻ Taitung County (0.9704) ≻ Penghu County (0.9224) ≻ Hsinchu City (0.9133) ≻ Kinmen County (0.9042) ≻ Miaoli County (0.8621) ≻ Hsinchu County (0.8585) ≻ Yunlin County (0.7988) ≻ Pingtung County (0.7874) ≻ Chiayi County (0.7827).

This study used the proposed hybrid MCDM model to evaluate and rank the public safety of cities and counties in Taiwan; areas with room for improvement were identified according to their overall rankings. The researchers first asked current police officers to develop a public safety rating framework and made pairwise comparisons between the dimensions and criteria to obtain original data. Next, the researchers performed AHP calculations to derive the optimal weights of various crime types; the weights of the dimensions "violent crimes," "property-related crimes," and "other crimes" were 0.74, 0.16, and 0.1, respectively. Violent crimes being assigned a weight exceeding 0.5 indicated that police officers believed violent crimes to have greater effects on public safety than property-related crimes and other crimes. Among violent crimes, intentional homicide and rape had a total weight of 0.63. Because of the nature of violent crimes, which cause obvious and serious bodily harm to victims, they are the crimes that the general public is most afraid of. Thus, the fact that they have a higher weight is

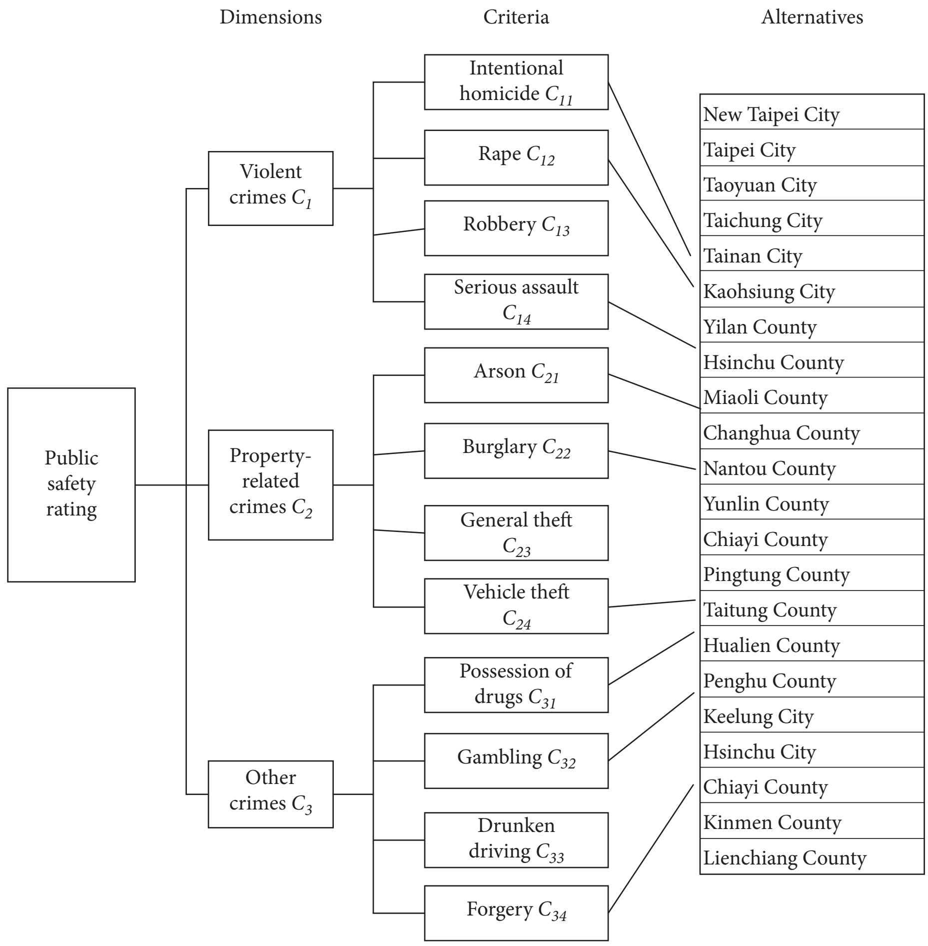

Figure 2: Public safety rating-based hierarchical structure for cities and counties in Taiwan.

Table 1: Weights of public safety-related dimensions and criteria.

Goal	First-level dimensions	Second-level criteria	$\overline{w_q}$
Rate the public safety of cities and counties in Taiwan	Violent crimes (C_1)0.74	Intentional homicide (C_{11})	0.37
		Rape (C_{12})	0.26
		Robbery (C_{13})	0.08
		Serious assault (C_{14})	0.04
	Property-related crimes (C_2)0.16	Arson (C_{21})	0.10
		Burglary (C_{22})	0.02
		General theft (C_{23})	0.03
		Vehicle theft (C_{24})	0.01
	Other crimes (C_3)0.10	Possession of drugs (C_{31})	0.04
		Gambling (C_{32})	0.02
		Drunken driving (C_{33})	0.02
		Forgery (C_{34})	0.01

reasonable, and governments should be more committed to preventing these crimes.

Regarding the relative closeness coefficients (CO_p^+) to the positive-ideal solutions in the cities and counties, Lienchiang County and Taitung County had a CO_p^+ of 1.0000 and 0.9704, respectively, ranking first and second in public safety rating among cities and counties in Taiwan. The two counties also had the fewest crimes (based on the aforementioned criteria). By contrast, Taipei City and New Taipei City, which had a CO_p^+ of 0.1178 and 0.2876, ranked last and second last in public safety. Compared with other cities and counties, Taipei City and New Taipei City had higher numbers of violent crimes (i.e., intentional homicide, rape, robbery, and serious assault), which, coupled with the fact that this crime dimension had a higher weight than other crime dimensions, contributed to these cities' low CO_p^+ values and reflected their actual public safety situations. These results confirmed that the rating model

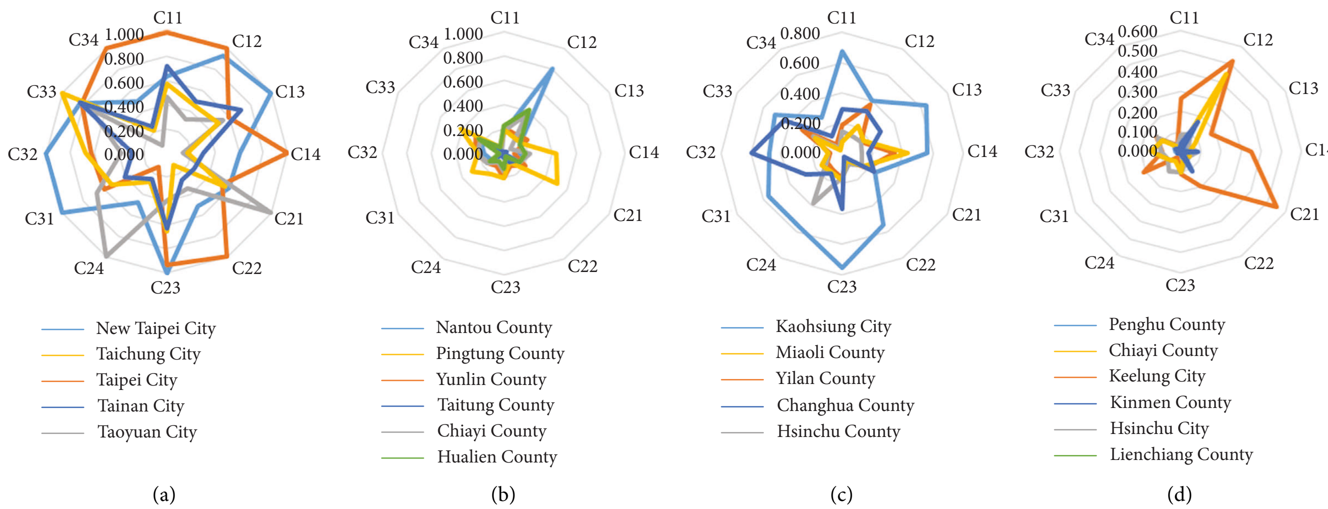

Figure 3: Normalized public safety data for each city and county.

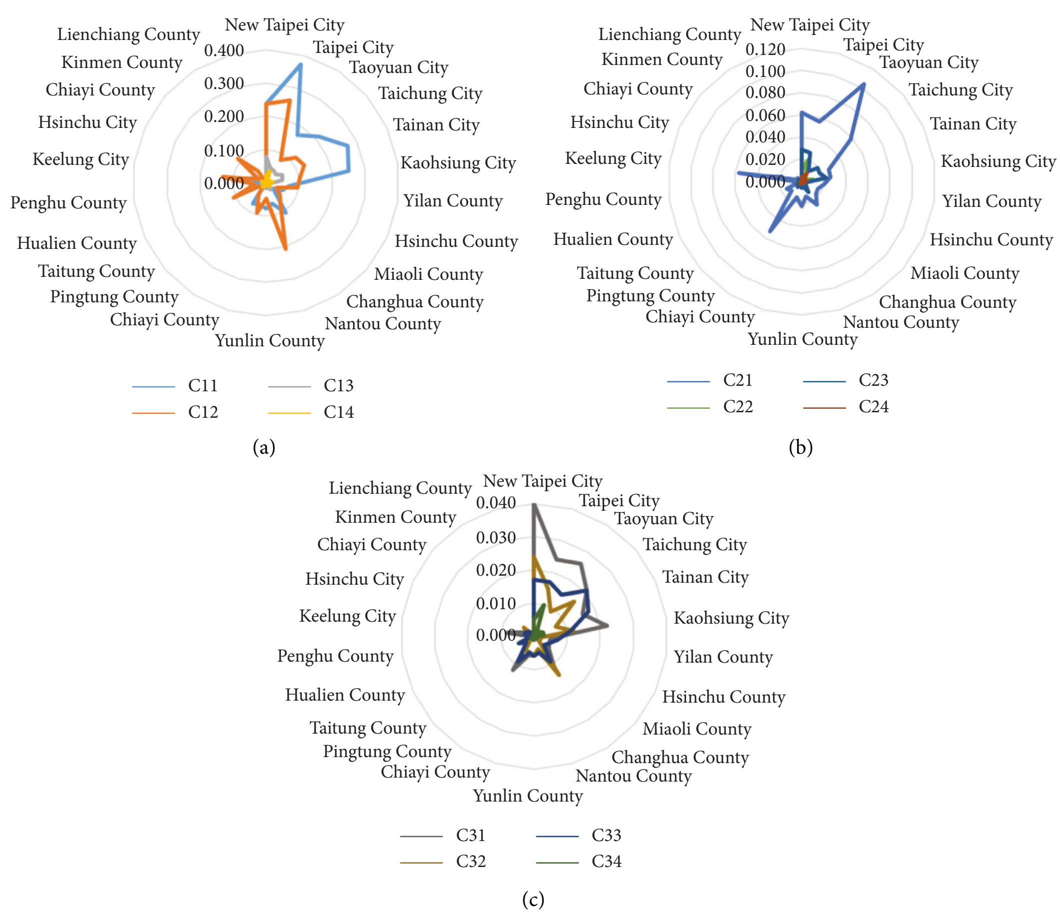

Figure 4: Normalized data after weights had been assigned.

developed in this study is applicable. For the cities and counties with a low public safety ranking, such as Taipei City, New Taipei City, Tainan City, Kaohsiung City, and Taichung City, the central government and local governments must focus on decreasing the number of violent crimes to effectively elevate the public safety ratings of the cities and counties.

Data visualization is regarded by those in many disciplines to have an identical meaning to visual communication. It involves establishing and researching visual data.

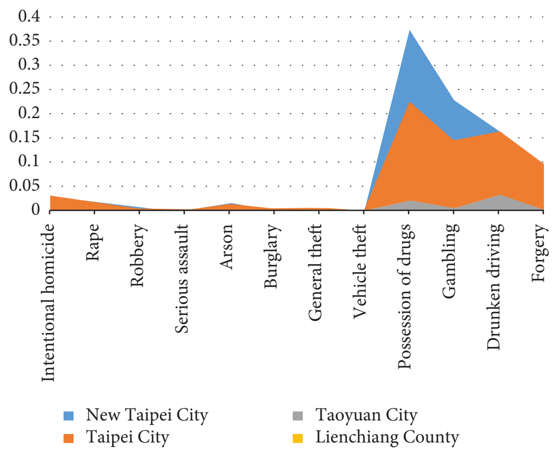

Figure 5: Crime data-related radar charts of cities and counties.

Table 2: Overall public safety-related rankings of cities and counties in Taiwan.

Cities and counties	S_p^+	S_p^-	C_O^+	Ranking
New Taipei City	0.357	0.144	0.2876	21
Taipei City	0.462	0.062	0.1178	22
Taoyuan City	0.225	0.271	0.5462	17
Taichung City	0.256	0.225	0.4671	18
Tainan City	0.305	0.191	0.3849	20
Kaohsiung City	0.281	0.215	0.4335	19
Yilan County	0.122	0.364	0.7494	12
Hsinchu County	0.067	0.409	0.8585	7
Miaoli County	0.067	0.418	0.8621	6
Changhua County	0.144	0.334	0.6990	14
Nantou County	0.219	0.337	0.6060	16
Yunlin County	0.096	0.381	0.7988	8
Chiayi County	0.119	0.369	0.7566	11
Pingtung County	0.103	0.381	0.7874	9
Taitung County	0.014	0.467	0.9704	2
Hualien County	0.139	0.348	0.7149	13
Penghu County	0.038	0.446	0.9224	3
Keelung City	0.176	0.317	0.6430	15
Hsinchu City	0.041	0.436	0.9133	4
Chiayi County	0.115	0.415	0.7827	10
Kinmen County	0.047	0.441	0.9042	5
Lienchiang County	≤0.001	0.477	1.0000	1

Data visualization is mainly conducted using graphical means to clearly and effectively convey and communicate information. This study used a crime-related radar chart (Figure 5) obtained after relevant data were normalized to examine crime types in cities and counties in Taiwan. One feature of radar charts is that they can be used to compare the different characteristics of a single individual or multiple individuals, making it a suitable method for comparing the various aspects of different plans and selecting the most suitable plan. Radar charts, which are easy-to-use visualization tools, are widely used in the fields of engineering, management, and education. Crime types with higher values on radar charts occupy larger areas in charts because they account for higher rankings of crimes in cities and counties. Conversely, crime types with lower values account for lower rankings in cities and counties. Figure 5 shows the crime types in each city and county. According to the radar chart, which was developed after the relevant weighted data were normalized, the two highest-ranking cities and counties (i.e., Lienchiang County and Taitung County) had fewer crimes of all types, whereas the two lowest-ranking cities and counties (i.e., Taipei City and New Taipei City) had more crimes of all types. The two lowest-ranking cities and counties had a particularly high frequency of crimes involving drug possession, gambling, and drunk driving. Drug possession, gambling, and drunk driving in New Taipei City occupied larger areas of the chart than did such crimes in Taipei City, whereas intentional homicide, rape, robbery, serious assault, arson, burglary, and general theft in New Taipei City occupied smaller areas of the chart than did such crimes in Taipei City. Thus, overall crime type assessments showed that Taipei City trailed behind New Taipei City in terms of public safety ranking.

5. Sensitivity Analyses

Sensitivity analyses examine how independent variables influence dependent variables under specific conditions. Sensitivity analyses reveal how various uncertainty variables in mathematical models contribute to overall model uncertainties, and such analyses are used depending on the specific ranges of one or more input variables. The researchers performed sensitivity analyses using the proposed model to examine whether changes in public safety indicator weights significantly changed the public safety rankings of the different cities and counties in Taiwan. The weights of the three dimensions (i.e., violent crimes (C_1), property-related crimes (C_2), and other crimes (C_3))were increased from 0.1 to 0.9 in 0.1 increments to calculate the public safety rankings of the cities and counties under each weight. The weights of the remaining two dimensions were adjusted according to the original ratios, and all dimensions had nine ranking results (i.e., Run 1-Run 9).

According to Figure 6, as the weight of violent crimes (C_1) increases, Taipei City, Tainan City, and Kaohsiung City drop in safety ranking. For example, Taipei City, Tainan City, and Kaohsiung City dropped from 20th place to 22nd place, from 15th place to 20th place, and from 16th place to 19th place, respectively. By contrast, Taitung County, Pingtung County, and Keelung City rose in ranking from 6th place to 2nd place, from 17th place to 8th place, and from 18th place to 15th place, respectively. These results showed that the weight of violent crimes (C_1) exhibited considerable effects on the rankings of the aforementioned cities and counties. Among violent crimes, intentional homicide and rape had the highest weights. Thus, when formulating and implementing public safety-related policies in Taipei City, Tainan City, and Kaohsiung City, relevant units should pay particular attention to strengthening laws against intentional homicide and rape and preventing and controlling these crimes.

According to Figure 7, when the weight of property-related crimes (C_2) increases, Taoyuan City, Yunlin County, and Pingtung County drop in ranking, from 17th place to 22nd

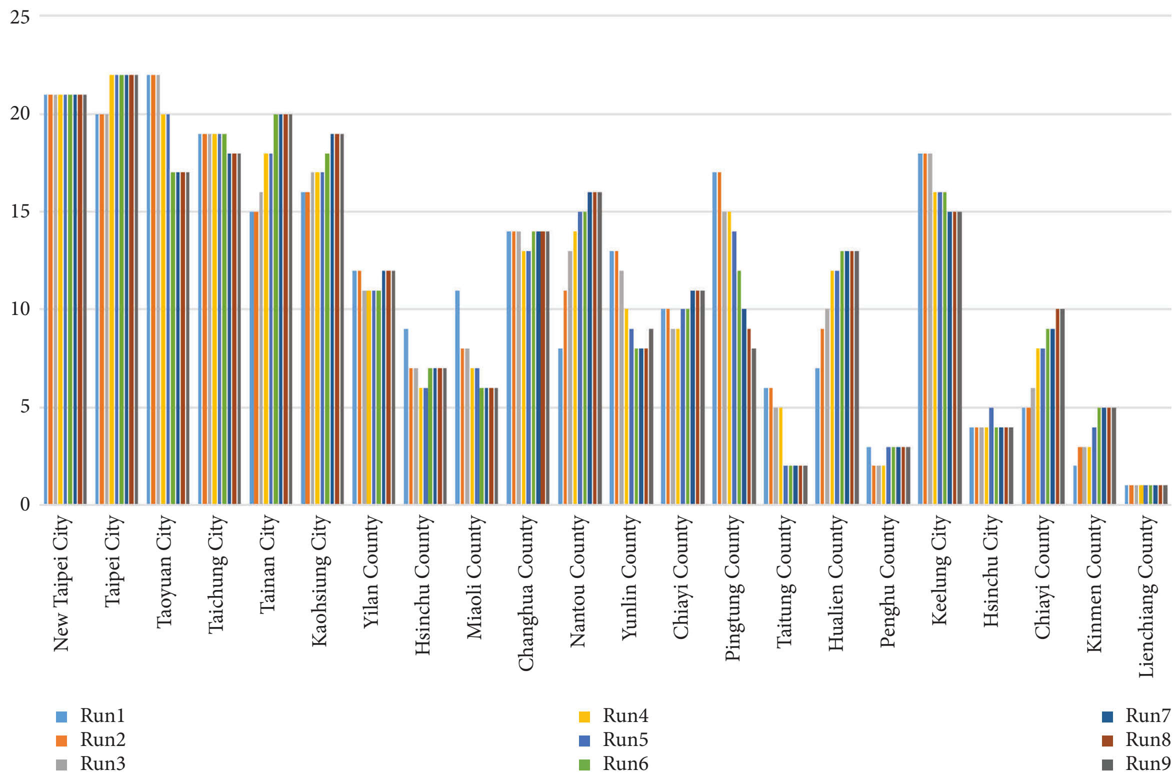

Figure 6: Sensitivity analysis: violent crimes (C_1).

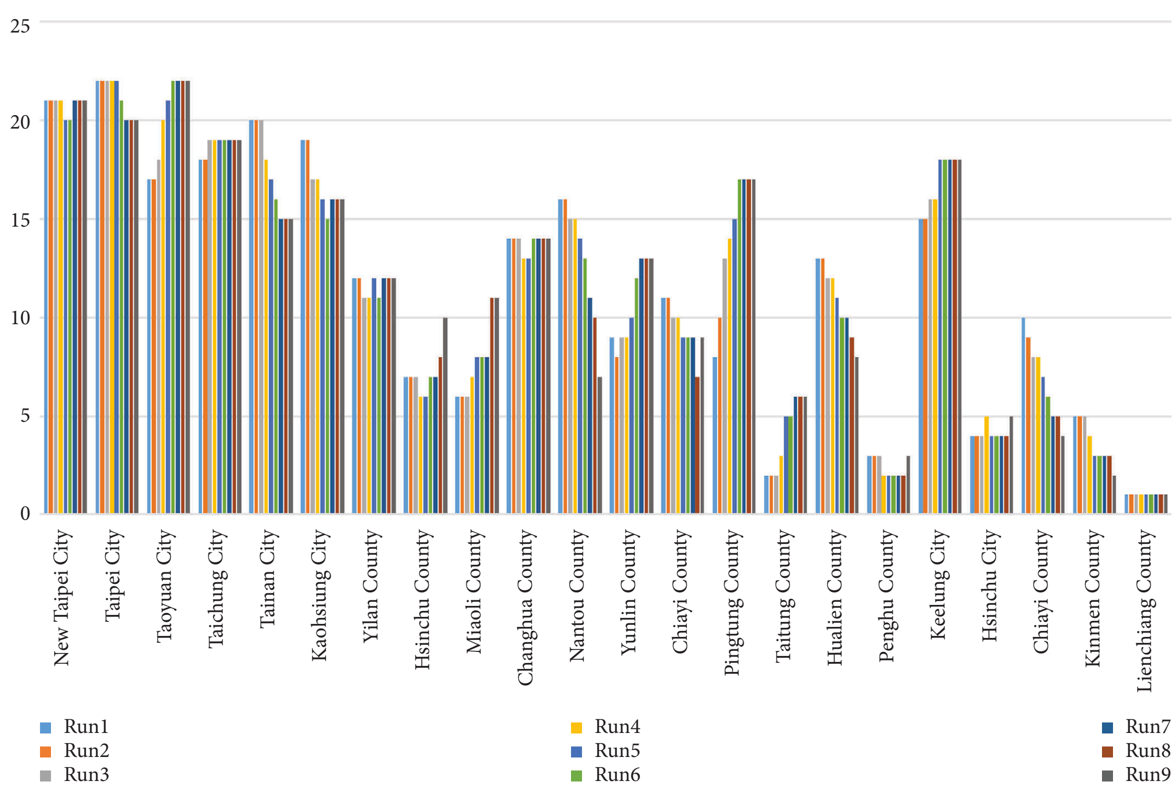

Figure 7: Sensitivity analysis: property-related crimes (C_2).

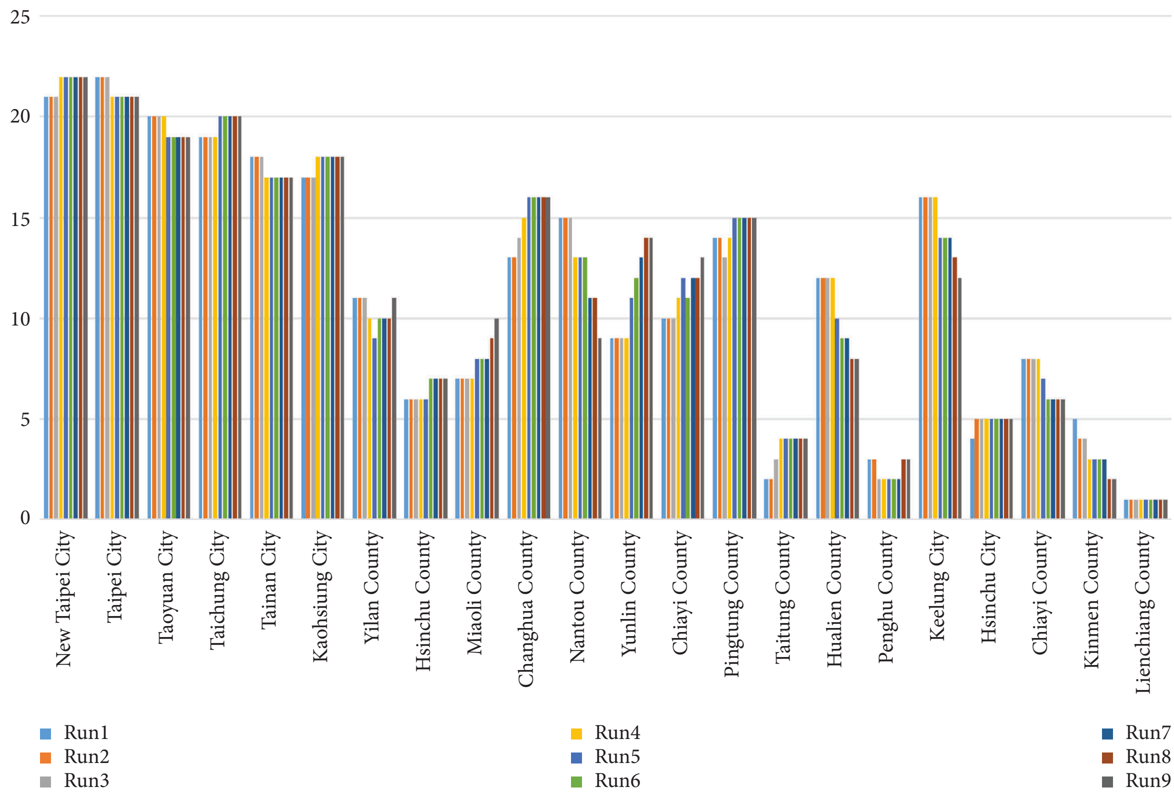

Figure 8: Sensitivity analysis: other crimes (C_3).

place, from 9th place to 13th place, and from 8th place to 17th place, respectively. By contrast, Kinmen County, Chiayi City, and Nantou County rose in ranking from 5th place to 2nd place, from 10th place to 4th place, and from 16th place to 7th place, respectively. Regarding the other cities and counties, changes in the weight of property-related crimes (C_2) did not exhibit considerable effects on the changes in their public safety rankings. Among property-related crimes, arson had the highest weight. Therefore, relevant units should focus on formulating arson-related prevention mechanisms.

According to Figure 8, when the weight of other crimes (C_3) increases, Miaoli County, Changhua County, and Yunlin County drop in ranking. For example, Miaoli County, Changhua County, and Yunlin County dropped from 7th place to 9th place, from 13th place to 16th place, and from 9th place to 14th place, respectively. By contrast, Nantou County, Hualien County, and Keelung City rose in ranking from 15th place to 9th place, from 12th place to 8th place, and from 16th place to 12th place, respectively. These results showed that the weights of other crimes (C_3) exhibited considerable effects on the rankings of these cities and counties. Among other crimes, possession of drugs had the highest weight. Thus, preventing the possession of drugs should be a public safety-related issue that Miaoli County, Changhua County, and Yunlin County units give special attention to. Concerning other cities and counties, changes in the weights of other crimes (C_3) exhibited minimal effects on their public safety rankings. Lienchiang County was the only administrative region that did not see changes in public safety (i.e., consistently in no. 1) regardless of the weights assigned to violent crimes (C_1), property-related crimes (C_2), and other crimes (C_3). This was because all crime types occurred less frequently in Lienchiang County.

6. Conclusions

Enhancing public safety and protecting the personal safety, property, and rights and interests of the public are goals that facilitate the sustainable development of societies. Accordingly, this study introduced an objective, systematic MCDM assessment model (which combined the AHP and TOPSIS techniques) for evaluating the public safety performance of cities and counties in Taiwan. The researchers compiled data following a literature review and interviews with current police officers to derive 3 dimensions (i.e., violent crimes, property-related crimes, and other crimes) and 12 criteria, and they used the AHP to calculate the weights of the dimensions and criteria. Subsequently, the researchers employed TOPSIS to calculate the relative closeness coefficients between alternatives and positive-ideal solutions and used these coefficients to rank the public safety performance of the aforementioned cities and counties. The results revealed that among the three dimensions, violent crimes had the highest weight; among the 12 criteria, intentional homicide and rape had the highest weights. Cities and counties with lower public safety rankings had more violent crimes. These crimes pose more serious threats to people's safety, and the public safety rating structure developed in this study mirrors public perception. The assessment model proposed in this study was used to identify the key factors (i.e., crime types) that influenced public safety ratings in cities and counties in Taiwan, and objective public safety rankings were produced. The results suggest that governments and police units should focus on preventing the aforementioned crimes to promote social harmony. At present, the assessment model primarily uses the number of crimes as the basis for crime data analyses and does not include factors such as government policies, environmental factors, economic factors, and human culture. Although these factors exhibit considerable effects on public safety, no systematic data on these factors are currently available, and such data are difficult to collect. In the future, we will attempt to gradually expand the model developed in this study and incorporate these factors into the model. Additionally, because many MCDM techniques are available, we will plan to integrate such techniques into our model to explore the applicability of each technique [58].

Data Availability

The data used to support the findings of this study can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] R. Chauhan, T. Singh, A. Tiwari, A. Patnaik, and N. S. Thakur, "Hybrid entropy-TOPSIS approach for energy performance prioritization in a rectangular channel employing impinging air jets," *Energy*, vol. 134, pp. 360–368, 2017.

[2] W. Sałabun and A. Piegat, "Comparative analysis of MCDM methods for the assessment of mortality in patients with acute coronary syndrome," *Artificial Intelligence Review*, vol. 48, no. 4, pp. 557–571, 2016.

[3] S. Hashemkhani Zolfani, M. Pourhossein, M. Yazdani, and E. Kazimieras Zavadskas, "Evaluating construction projects of hotels based on environmental sustainability with MCDM framework," *Alexandria Engineering Journal*, vol. 57, no. 1, pp. 357–365, 2018.

[4] J. Fay, *Contemporary Security Management*, Butterworth-Heinemann, 3rd Ed edition, 2010.

[5] J. A. Winterdyk, *Crime Prevention: International Perspectives, Issues, and Trends*, Routledge, Boca Raton, Florida, U.S, 2017.

[6] M. E. Hamill, M. C. Hernandez, K. R. Bailey, M. D. Zielinski, M. A. Matos, and H. J. Schiller, "State level firearm concealed-carry legislation and rates of homicide and other violent crime," *Journal of the American College of Surgeons*, vol. 228, no. 1, pp. 1–8, 2019.

[7] K. E. McCollister, M. T. French, and H. Fang, "The cost of crime to society: New crime-specific estimates for policy and program evaluation," *Drug and Alcohol Dependence*, vol. 108, no. 1-2, pp. 98–109, 2010.

[8] R. Pandey and G. O. Mohler, "Evaluation of crime topic models: topic coherence vs spatial crime concentration," in *Proceedings of the IEEE International Conference on Intelligence and Security Informatics (ISI)*, Miami, FL, USA, November 2018.

[9] T. Epperlein and B. C. Nienstedt, "Reexamining the use of seriousness weights in an index of crime," *Journal of Criminal Justice*, vol. 17, no. 5, pp. 343–360, 1989.

[10] Y. K. Kwan, W. C. Ip, and P. Kwan, "A crime index with Thurstone's scaling of crime severity," *Journal of Criminal Justice*, vol. 28, no. 3, pp. 237–244, 2000.

[11] M. M. Silva, A. P. H. de Gusmão, T. R. N. Clemente, K. T. M. Santiago, and A. P. C. S. Costa, "A multicriteria nominal classification method to define public safety policies in Brazilian states," in *Proceedings of the IEEE International Conference on Systems, Man and Cybernetics*, October 2018.

[12] C. Kahraman, S. C. Onar, and B. Öztayşi, "Fuzzy multicriteria decision-making: a literature review," *International Journal of Computational Intelligence Systems*, vol. 8, no. 4, pp. 637–666, 2015.

[13] M. Baumann, M. Weil, J. F. Peters, N. Chibeles-Martins, and A. B. Moniz, "A review of multi-criteria decision making approaches for evaluating energy storage systems for grid applications," *Renewable and Sustainable Energy Reviews*, vol. 107, pp. 516–534, 2019.

[14] H. S. Ruiz, A. Sunarso, K. Ibrahim-Bathis, S. A. Murti, and I. Budiarto, "GIS-AHP multi criteria decision analysis for the optimal location of solar energy plants at Indonesia," *Energy Reports*, vol. 6, pp. 3249–3263, 2020.

[15] P. C. Deshpande, C. Skaar, H. Brattebø, and A. M. Fet, "Multi-criteria decision analysis (MCDA) method for assessing the sustainability of end-of-life alternatives for waste plastics: a case study of Norway," *Science of the Total Environment*, vol. 719, Article ID 137353, 2020.

[16] V. Kozlov and W. Sałabun, "Challenges in reliable solar panel selection using MCDA methods," *Procedia Computer Science*, vol. 192, pp. 4913–4923, 2021.

[17] C. Vlachokostas, A. V. Michailidou, and C. Achillas, "Multi-criteria decision analysis towards promoting waste-to-energy management strategies: a critical review," *Renewable and Sustainable Energy Reviews*, vol. 138, Article ID 110563, 2021.

[18] K. Figueiredo, R. Pierott, A. W. A. Hammad, and A. Haddad, "Sustainable material choice for construction projects: a life cycle sustainability assessment framework based on BIM and Fuzzy-AHP," *Building and Environment*, vol. 196, Article ID 107805, 2021.

[19] M. Sahabuddin and I. Khan, "Multi-criteria decision analysis methods for energy sector's sustainability assessment: robustness analysis through criteria weight change," *Sustainable Energy Technologies and Assessments*, vol. 47, Article ID 101380, 2021.

[20] J. A. Sward, R. S. Nilson, V. V. Katkar et al., "Integrating social considerations in multicriteria decision analysis for utility-scale solar photovoltaic siting," *Applied Energy*, vol. 288, Article ID 116543, 2021.

[21] P. H. Dos Santos, S. M. Neves, D. O. Sant'Anna, C. H. d. Oliveira, and H. D. Carvalho, "The analytic hierarchy process supporting decision making for sustainable development: an overview of applications," *Journal of Cleaner Production*, vol. 212, pp. 119–138, 2019.

[22] M. Kordi and S. A. Brandt, "Effects of increasing fuzziness on analytic hierarchy process for spatial multicriteria decision analysis," *Computers, Environment and Urban Systems*, vol. 36, no. 1, pp. 43–53, 2012.

[23] C. L. Hwang and K. Yoon, "Methods for multiple attribute decision making," in *Multiple Attribute Decision Making. Lecture Notes in Economics and Mathematical Systems*, vol. 186, pp. 58–191, Springer, Berlin, Heidelberg, 1981.

[24] J. M. Hummel, J. F. P. Bridges, and M. J. Ijzerman, "Group decision making with the analytic hierarchy process in benefit-risk assessment: a tutorial," *The Patient: Patient-Centered Outcomes Research*, vol. 7, no. 2, pp. 129–140, 2014.

[25] T. L. Saaty, "Decision making with the analytic hierarchy process," *International Journal of Services Sciences*, vol. 1, no. 1, pp. 83–98, 2008, https://www.rafikulislam.com/uploads/resourses/197245512559a37aadea6d.pdf.

[26] S. Wijitkosum and T. Sriburi, "Fuzzy AHP integrated with GIS analyses for drought risk assessment: a case study from Upper Phetchaburi River Basin, Thailand," *Water*, vol. 11, no. 5, p. 939, 2019.

[27] J. P Shim, "Bibliographical research on the analytic hierarchy process (AHP)," *Socio-Economic Planning Sciences*, vol. 23, no. 3, pp. 161–167, 1989.

[28] F. Zahedi, "The analytical hierarchy process: a survey of the method and its applications," *Interfaces*, vol. 16, no. 4, pp. 96–108, 1986.

[29] T. L. Saaty, *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*, RWS Publications, Pittsburgh, 2000.

[30] D. Ho, G. Newell, and A. Walker, "The importance of property-specific attributes in assessing CBD office building quality," *Journal of Property Investment & Finance*, vol. 23, no. 5, pp. 424–444, 2005.

[31] A. Ishizaka and S. Siraj, "Are multi-criteria decision-making tools useful? An experimental comparative study of three methods," *European Journal of Operational Research*, vol. 264, no. 2, pp. 462–471, 2018.

[32] E. Broniewicz and K. Ogrodnik, "Multi-criteria analysis of transport infrastructure projects," *Transportation Research Part D: Transport and Environment*, vol. 83, Article ID 102351, 2020.

[33] N. Lazar and K. Chithra, "A comprehensive literature review on development of building sustainability assessment systems," *Journal of Building Engineering*, vol. 32, Article ID 101450, 2020.

[34] K. D. Balt, *A Methodology for Implementing the Analytical Hierarchy Process to Decision-Making in Mining*, University of the Witwatersrand, Johannesburg, South Africa, 2015, https://core.ac.uk/download/pdf/188775811.pdf.

[35] H. Subramanyan, P. H. Sawant, and V. Bhatt, "Construction project risk assessment: development of model based on investigation of opinion of construction project experts from India," *Journal of Construction Engineering and Management*, vol. 138, no. 3, pp. 409–421, 2012.

[36] H. H. Ali and S. F. Al Nsairat, "Developing a green building assessment tool for developing countries–Case of Jordan," *Building and Environment*, vol. 44, no. 5, pp. 1053–1064, 2009.

[37] J. H. Lai and F. W. Yik, "Perception of importance and performance of the indoor environmental quality of high-rise residential buildings," *Building and Environment*, vol. 44, no. 2, pp. 352–360, 2009.

[38] H. Alwaer and D. J. Clements-Croome, "Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings," *Building and Environment*, vol. 45, no. 4, pp. 799–807, 2010.

[39] S. S. Wakchaure and K. N. Jha, "Determination of bridge health index using analytical hierarchy process," *Construction Management & Economics*, vol. 30, no. 2, pp. 133–149, 2012.

[40] N. H. Tran, S. H. Yang, C. Y. Tsai, N. C. Yang, and C. M. Chang, "Developing transportation livability-related indicators for green urban road rating system in Taiwan," *Sustainability*, vol. 13, no. 24, Article ID 14016, 2021.

[41] S. Lee, W. Kim, Y. M. Kim, and K. J. Oh, "Using AHP to determine intangible priority factors for technology transfer adoption," *Expert Systems with Applications*, vol. 39, no. 7, pp. 6388–6395, 2012.

[42] R. Dorado, A. Gómez-Moreno, E. Torres-Jiménez, and E. López-Alba, "An AHP application to select software for engineering education," *Computer Applications in Engineering Education*, vol. 22, no. 2, pp. 200–208, 2014.

[43] C. R. Chard and L. R. Potwarka, "Exploring the relative importance of factors that influence student-athletes' school-choice decisions: a case study of one Canadian university," *Journal of Intercollegiate Sport*, vol. 10, no. 1, pp. 22–43, 2017.

[44] C. C. Frangos, K. C. Fragkos, I. Sotiropoulos, I. Manolopoulos, and E. Gkika, "Student preferences of teachers and course importance using the analytic hierarchy process model," in *Proceedings of the World Congress on Engineering, II*, London, UK, July 2014, http://www.iaeng.org/publication/WCE2014/WCE2014_pp852-856.pdf.

[45] M. Z. Asmawi, N. Ngaimin, N. Z. Mahamod, N. M. Noor, and H. Omar, "Assessing the forestry environmental condition using GIS-AHP approach in the forest research institute Malaysia (FRIM) campus, Malaysia," *Advanced Science Letters*, vol. 23, no. 7, pp. 6372–6376, 2017.

[46] A. Shafaghat, O. J. Ying, A. Keyvanfar et al., "A treatment wetland park assessment model for evaluating urban ecosystem stability using analytical hierarchy process (AHP)," *Journal of Environmental Treatment Techniques*, vol. 7, no. 1, pp. 81–91, 2019.

[47] S. Escolar, F. J. Villanueva, M. J. Santofimia, D. Villa, X. d. Toro, and J. C. López, "A Multiple-Attribute Decision Making-based approach for smart city rankings design," *Technological Forecasting and Social Change*, vol. 142, pp. 42–55, 2019.

[48] P. Sharma and S. Singhal, "Implementation of fuzzy TOPSIS methodology in selection of procedural approach for facility layout planning," *International Journal of Advanced Manufacturing Technology*, vol. 88, no. 5-8, pp. 1485–1493, 2017.

[49] I. I. Falqi, M. Ahmed, and J. Mallick, "Siliceous concrete materials management for sustainability using Fuzzy-TOPSIS Approach," *Applied Sciences*, vol. 9, no. 17, p. 3457, 2019.

[50] D. Zhao, C. Li, Q. Wang, and J. Yuan, "Comprehensive evaluation of national electric power development based on cloud model and entropy method and TOPSIS: a case study in 11 countries," *Journal of Cleaner Production*, vol. 277, Article ID 123190, 2020.

[51] A. Awasthi, S. S. Chauhan, and S. K. Goyal, "A multi-criteria decision making approach for location planning for urban distribution centers under uncertainty," *Mathematical and Computer Modelling*, vol. 53, no. 1-2, pp. 98–109, 2011.

[52] R. Kampf, P. Průša, and C. Savage, "Systematic location of the public logistic centres in Czech Republic," *Transport*, vol. 26, no. 4, pp. 425–432, 2012.

[53] Y. Li, X. Liu, and Y. Chen, "Selection of logistics center location using Axiomatic fuzzy set and TOPSIS methodology in logistics management," *Expert Systems with Applications*, vol. 38, no. 6, pp. 7901–7908, 2011.

[54] J. Freeman and T. Chen, "Green supplier selection using an AHP-Entropy-TOPSIS framework," *Supply Chain Management: International Journal*, vol. 20, no. 3, pp. 327–340, 2015.

[55] M. H. Mammadova and Z. G. Jabrayilova, "Decision-making support in human resource management based on multi-objective optimization," *TWMS Journal of Pure and Applied Mathematics*, vol. 9, no. 1, pp. 52–72, 2018, http://www.twmsj.az/Files/Contents%20V.9,%20N.1,%202018/pp52-72.pdf.

[56] X. Yu, S. Guo, J. Guo, and X. Huang, "Rank B2C e-commerce websites in e-alliance based on AHP and fuzzy TOPSIS," *Expert Systems with Applications*, vol. 38, no. 4, pp. 3550–3557, 2011.

[57] S. Mahmoodzadeh, J. Shahrabi, M. Zaeri, and M. S. Zaeri, "Project selection by using fuzzy AHP and TOPSIS technique," *World Academy of Science, Engineering and Technology*, vol. 30, no. 1, pp. 333–338, 2007.

[58] M. F. Abd Khabir, M. M. Kasim, and M. Zulkifli, "Construction of vehicle theft index by using TOPSIS method with entropy based criteria weights," *International Journal of Supply Chain Management*, vol. 6, no. 4, pp. 294–298, 2017, https://ojs.excelingtech.co.uk/index.php/IJSCM/article/view/1961/990.