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Applying AHP to Evaluate the Decision Priority of Typhoon Disaster Preparedness and Emergency Response

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Abstract

Disaster response involves facing the pressure of making decisions that are multidimensional, uncertain, and highly variable under states of emergency. The present study primarily employed the analytic hierarchy process to explore the selection and prioritization of major decision-making factors while preparing for imminent disasters and during the emergency response stage of when a typhoon strikes. A literature review was conducted, and important factors for typhoon response measures were identified. An expert interview was performed to stipulate the decision-making and action indicators for the response stage. Subsequently, the modified Delphi method was applied for indicator screening of the expert questionnaire. Ultimately, three indexes, 20 indicators, and 86 items were identified and used in the weight analysis questionnaire for the next stage of the study. Indexes, indicators, and items were employed as the three layers to establish an AHP analysis model. The collected questionnaires underwent consistency testing, the absolute weight of the factors of the various hierarchies were identified, and the ranking of the various response items was confirmed. The analysis results indicated that “action of

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emergency response" yielded the highest value (0.497) in Layer 1, whereas "securing disaster prevention and relief resources and telecommunications" ranked the highest in Layer 2 (0.14703). Thus, these two factors should be prioritized for disaster response for Layers 1 and 2.

Keywords: Imminent disaster, Decision-making indicators, Emergency response, Analytic hierarchy process.

摘　要

災害應變需面對緊急狀態下多面向、不確定性及高變異性的決策及處置壓力。本研究主要應用 AHP 於颱風災害時，臨災整備及緊急應變階段重要決策因子的選定及應變處置的優先序。研究藉由文獻回顧並確認颱風應變處置重要事項，專家學者訪談擬定應變階段決策與作為指標後，再透過修正式德爾菲法專家問卷進行指標篩選，最後採計 3 構面、20 項指標、86 評估項目，提供做為下一階段的權重分析問卷；續依構面、指標項、評估項目三階層建立 AHP 分析模式，針對回收之問卷進行一致性檢驗並求出各階層因子之絕對權重，確認各應變項目的優先序。研究分析結果顯示，颱風臨災整備及應變決策因子在第一層級之風災災害緊急應變權重值最高 (0.497)，第二階層絕對權重值則以防救災資、通訊之確保 (0.14703) 為最高，可做為應變的首要項目。

關鍵詞：臨災、決策指標、緊急應變、階層分析法

1. Introduction

Disasters are, by nature, highly uncertain and variable. Different disaster scenarios occur with the passage of time, and each scenario is accompanied by an urgent need for responses (Kaufhold et al., 2019). The state of a disaster under high tension is often dependent on the decisions made at pivotal points. Thus, identifying the optimal solution and making decisions within a finite amount of time to respond to high uncertainties and instabilities has become a mindset requirement for decision-makers during the disaster response stage (Janssen et al., 2010; Park & Avery, 2019). Researchers have indicated that when decisions involve negative effects and are made under time pressure, decision-makers will mitigate loss through risk evasion (Kocher et al., 2013; Ordóñez et al., 1997). Therefore, erroneous decisions made under disaster management that lack integration, rapid response, and quick decision-making may lead to extreme or potentially disastrous results (Lee et al., 2011). Burnett (1998) explored crisis management and used the four variables of threat level, response options, time pressure, and degree of control to divide all crises into 16 items. Subsequently, the 16 crisis items were classified into five types based on a crisis level ranging from zero to four. In Burnett's (1998) classification, type four is the most troubling crisis for decision-makers, because this type of crisis is characterized by a high threat level, high time pressure, and low degree of control. Although type two and type three crises are not as urgent as type four crisis, they remain difficult to handle, whereas type one and type zero crises can be processed after more urgent problems have been settled.

Using the timeline of typhoons as an example, when there is an absence of typhoons in Taiwan, disaster reduction efforts are primarily centered on training, drills, and regulatory amendments, all of which have low time pressure and a high degree of control. When a sea warning is issued, disaster management is subject to high time pressure but remains highly controllable. At this point, inspections of various facilities, equipment, and supplies are carried out, and residents of high-risk zones or the comparatively underprivileged are preemptively evacuated. Strong winds and torrential rain occur from when the typhoon makes landfall to when the typhoon's radius clears Taiwan, which is also when the public is the most aware of the effect of the disaster. As a result, hotlines are flooded with calls and are often overwhelmed.

Common disasters include collapsed roads, flooded underpasses, fallen trees, damaged houses, and threats to life. While the Central Emergency Operation Center (CEOC) remains operational, emergency rescue personnel are confounded by the hostile environment created by strong winds and rain. Thus, personnel, vehicles, and disaster relief equipment are often grounded. This type of scenario can be described as having high time pressure, a low degree of control, and a high threat level, making it the most stressful stage for the commander of the CEOC. Depending on the severity of the typhoon, the post-disaster clean-up and restoration, after Taiwan is cleared of the typhoon's radius, can be carried out either under high or low time pressure, but with a low degree of control.

As disaster management is divided into long-term, daily operations and the highly stressful emergency response stage during the strike of a disaster, disasters are characterized by high uncertainty and high variability. Different disaster scenarios occur as a disaster progresses, and each scenario is subject to a different level of time pressure for initiating responses. Decision-makers are faced with changes in stress levels during different disaster scenarios and for different types of disasters. For example, typhoons are divided into four phases based on the sequence of typhoon events. Phase I refers to the stage in between the typhoon's formation and when its path remains unknown. This stage is centered on information analysis and identification. As information remains inconclusive, and the typhoon may not pose a threat during this phase, response personnel and decision-makers have ample time to make decisions and may even produce no responses or decisions. Thus, this phase is subject to low decision-making stress. If the typhoon is confirmed to not affect Taiwan, response personnel and decision-makers are immediately relieved of stress. Phase II refers to the period from when the path of the typhoon has been identified to when the typhoon makes landfall. As the typhoon's path has been confirmed, this phase enables more accurate interpretations of disaster information. During this phase, corresponding response preparations are carried out, and response personnel and decision-makers experience an increase in stress levels. Phase III is when the typhoon has made landfall and poses a threat. The responses and decisions made during this phase directly affect the typhoon's aftermath and it is consequently the stage in which all personnel face the highest level of stress. Phase IV refers to the aftermath of the typhoon.

Decision-makers take corresponding actions in different stages of the disaster, and also face pressures of different intensity as the disaster progresses. The correlation between the effects of different phases of typhoons listed above and the stress performance of response personnel and decision-makers is presented in Fig. 1. The figure is divided into two halves, with the top half indicating the typhoon's path and scope via a pressure tube with a tapered section, and the bottom half illustrating the stress performance of response personnel and decision-makers in case of disaster occurrence, with and without disaster decision support (DDS). A smaller surface area of the pressure tube's section indicates a higher flowing pressure. Thus, a typhoon can be pictured as entering a pressure tube with a tapered section. The typhoon strikes the moment it reaches the smallest surface area of the pressure tube's section. Therefore, compared to the bottom half of Fig. 1, response personnel face the greatest level of stress at this point, especially in the absence of DDS assistance. If the typhoon makes landfall but does not cause severe damage, an immediate and rapid decrease in pressure occurs along with the typhoon's departure. However, if the typhoon results in severe damage, stress continues to increase until restoration efforts are complete (Wang, 2020).

As a disaster prevention and response duty, emergency units are required to act frequently as decision-makers and responders to make decisions and take correct and effective actions under time pressure. The purpose of this research is to focus on decision-making items that decision-makers and responders need to confirm during the disaster, so that they can fully understand "what decision-making and actions are needed to be executed sequentially during disaster response stage." This study uses the Delphi method to establish decision factors and then uses a hierarchical structure to design a hierarchical analysis questionnaire. After performing pairwise comparison of decision factors, the rank depending on the weight of each level factor is determined. The research results can enable decision-makers and responders to make a complete and orderly response within limited time using complex data, and strive to provide more safety buffer time to reduce the pressure on decision-makers and responders.

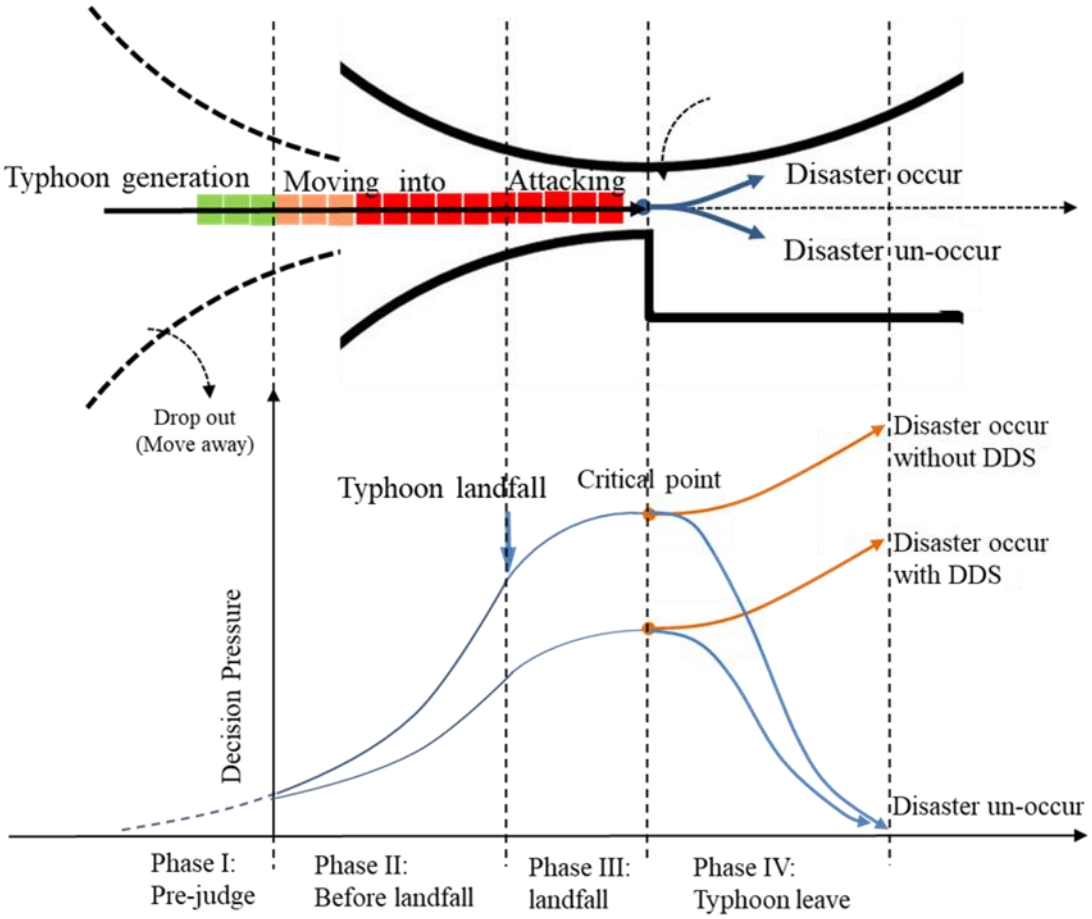

Fig.1. Decision pressure performance during the different disaster phases
Source: Modified from Wang (2020)

2. Delphi technique and analytic hierarchy process

2.1 Delphi Technique

The Delphi technique was first developed by RAND, a well-known think tank in the United States, the Delphi technique was first used for national defense purposes. Since 1960, it has been applied to various issues related to science and technology, industry trends, government agencies, and academic institutions, as well as for experts' opinion integration and decision-making. In order to improve the effectiveness of the traditional Delphi technique which emphasizes the mandatory requirements of iteration and anonymity of Delphi panels, Murry and Hammons (1995) proposed the modified Delphi method (MDM). MDM leads to structured questionnaire development based on literature review and expert interviews instead of an open

questionnaire. The implementation procedure of MDM is shown in Fig. 2.

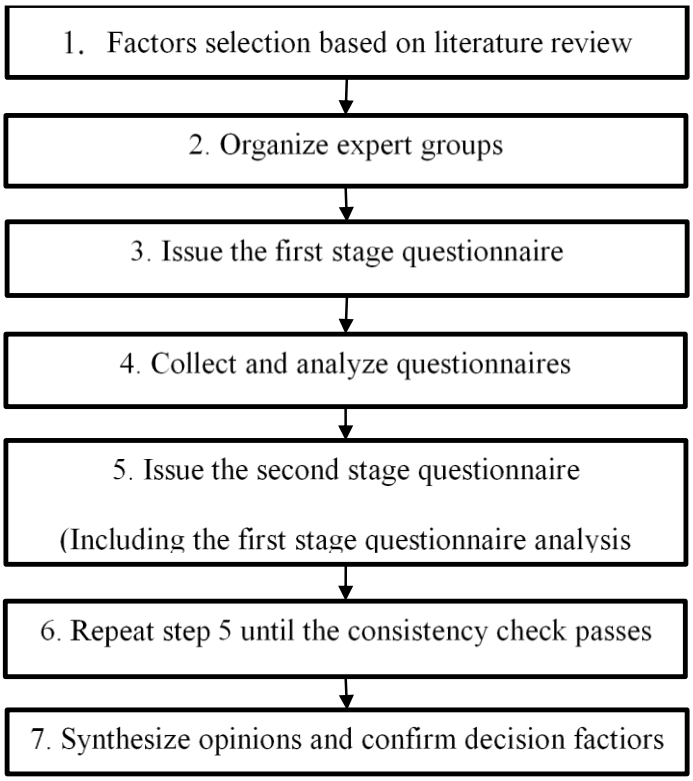

Fig.2 Implementation procedure of MDM

2.2 Analytic hierarchy process (AHP)

The analytic hierarchy process (AHP) is a multi-criteria decision-making method proposed by Thomas L. Saaty in 1971 (Saaty, 1980). AHP was primarily applied to decision-making problems with uncertainties and multiple assessment criteria. Subsequently, various correction methods were built based on the AHP and in combination with other decision-making models (Cegan et al., 2017; Dweiri et al., 2016; Emrouznejad & Marra, 2017; Huang et al., 2012; Khan et al., 2016; Moghaddam, 2015; Nefeslioglu et al., 2013).

The AHP is both a qualitative and quantitative research method that employs expert knowledge for conducting analysis. This method does not require a large-scale database and is easy to operate and follow (Nefeslioglu et al., 2013). After systematically breaking down questions and linking and layering relevant factors, a pairwise comparison is conducted to identify the relative importance ratio between

different elements, and a rank of options is compiled as reference for selecting the best solution (Saaty, 1990). The AHP can be used to analyze complex and disputed questions. By systemizing complex questions and using quantitative judgment to contextualize and integrate information, the AHP can be widely applied in various fields (Barker & Zabinsky, 2011; Dweiri et al., 2016; Ghosh & Kar, 2018; Huang et al., 2012; Huizhea et al., 2011; Khaksari, 2017; Khan et al., 2016; Okokpujie et al., 2020; Wang, Hao, et al., 2019; Wang, Xie, et al., 2019; Yang et al., 2013; Yayla et al., 2015). The AHP offers sufficient information to decision-makers, who can then use the results of the AHP as basis for determining the best solution, thereby decreasing the risks involved in decision-making.

The AHP transforms complex questions into several concise layers, which clearly and comprehensively explain the structure and functions of the system. The number of layers is determined based on the complexity of the problem.

Inter-layer factors undergo pairwise comparisons through the use of a nominal scale. After data are compiled and a positive reciprocal matrix is established, the eigenvectors of the inter-layer factors are used to represent the priority ranking of factors in the same layer, that is, the relative weight of the various factors.

After calculating the eigenvectors of the various factors, the eigenvalue is maximized to assess the matrix's level of consistency. Finally, the levels of consistency of the matrixes of the various layers are used to calculate the consistency index (C.I.) and consistency ratio (C.R.) of the overall decision layer. If the result fulfills the standards, the yielded priority ranking can be used as reference for decision-making. Conversely, portions of the interviewees' responses that did not comply with transferability were reassessed.

By implementing the process mentioned above, the relative weight between the various factors of the various layers is determined. The absolute weights of the factors in the lowest layer are calculated using the weighted method, that is, by multiplying the relative weights of the factors of the various levels (Zahedi, 1986).

3. Response decision-making factor

Emergency decision-making (EDM) is the most critical stage of disaster response. In particular, the actions taken for disasters with a broad impact must fulfill complex and multidimensional demands (Wang, 2020; Zhao et al., 2018). Many studies have

conducted comprehensive reviews of unexpected accidents, or EDM carried out in actual disasters (Bernroider & Stix, 2007; Fan, 2007; Federal Emergency Management Agency, 2003; He & Gong, 2013; Lin, 2018; Lindell et al., 2005; Peng et al., 2011; Sun et al., 2018); however, few have elaborated on typhoons or other natural disasters that have a greater effect on public safety.

Disaster management encompasses mitigation, preparedness, response, and recovery (Zhou et al., 2018), with response being the main stage where disaster management is executed. Although Taiwan has accumulated abundant experience in typhoon emergency response over a long period of time, the following four dimensions of problems continue to exist with regard to which responses and actions should be prioritized (Tseng & Wang, 2011):

(1) The organization system dimension: Insufficient integrated management capacity for disaster prevention and relief systems, and chaotic commands induced by a lack of coordination render decision-makers unable to effectively integrate and instruct affiliated departments of the specific level of government involved. Ambiguous authority over the supervision and collaboration of different levels of government hinder both vertical and lateral collaboration within the organization system.

(2) The operating procedure dimension: This dimension involves a lack of understanding of local governments' administrative operating procedures; an incomprehensive mechanism for communicating requests for inter-level support; and an ambiguous definition, division of labor, and integration of workflows. All of these insufficiencies have resulted in unsolved problems related to the corresponding command mechanism of the operating procedure, as well as planning, supervision, accountability, and integration.

(3) The resource supply and demand dimension: Resource integration is a common problem. Rapid and effective interorganizational resource reallocation is imperative when a department has insufficient disaster prevention and relief resources. The current methods and regulations for reallocating such resources, and the lack of information immediacy and transparency have created obstacles in the sharing of disaster prevention and relief resources.

(4) The information system dimension: This dimension is centered on segmented development models. During the disaster relief process, various parties have urgent

demands for information on the state of preparedness, coordination mechanisms, the effect of the disaster, the progress of other departments, and the compliance basis for decision-making. The immediacy, integration, accuracy, and comprehensiveness of this information are major focus areas. However, the information systems of the central government and those of local government departments are often independent of each other because of a difference in levels of government, demands, and funding sources. As a result, cross-communication between different disaster prevention information systems is difficult, leading to a lack of integration of resources and information between different organizations, operating procedures, and departments, which then creates errors in the informedness of decision-makers.

In recent years, both the disaster command departments of the public sector and various studies have proposed important and prioritized decision-making items in response to the problems mentioned in the previous paragraph. For example, the major focus of the preparation stage is to collect information on the effect of the disaster; ensure the usability of communications equipment and apply disaster analysis results; provide emergency rescue and emergency medical care; prepare emergency supplies; reallocate and supply emergency shelter, food, potable water, and necessities; ensure emergency repair of facilities; provide affected persons with information about the state of the disaster; prevent secondary disasters; accept international aid; and handle the bodies of victims; as well as remaining updated about various preparation measures and disaster outcomes and making judgments accordingly, evacuating and consoling disaster victims, and requesting the armed forces for support (National Fire Agency, 2019). The organization and planning of the CEOC, the preparation of disaster prevention and relief equipment, and drills (National Fire Agency, 2019) are also major focus domains. Immediate actions that should be taken during a typhoon or at the time of a disaster include ensuring emergency relief at the site of the disaster, establishing an on-site command center, initiating traffic control, maintaining community security, requesting the armed forces for support, mass evacuation of disaster victims, handling mass casualty incidents, confirming the list of injuries and deaths, offering emergency shelter and relief, combining public and civic resources, ensuring smooth logistics and food for disaster relief personnel, investigating and reporting on the state of the disaster, and media work (National Fire Agency, 2019; Su et al., 2010; Sun et al., 2018).

The objective of the present study is to elucidate the important decision-making factors that must be delivered and confirmed by the commanders of different levels of the CEOC during a typhoon. Thus, disaster prevention and response personnel and commanders of different levels are able to reference relevant studies in preliminarily determining major decision-making factors during the disaster mitigation phase, which precedes the occurrence of the typhoon. The present study referred to practical work items and relevant literature and employed the Delphi method during the first open questionnaire survey to identify decision-making factors. Subsequently, a layered structure was used to design an analytic hierarchy questionnaire. After performing a pairwise comparison of the importance of different decision-making factors, the weight and rank of factors in the various layers were determined.

4. Results

4. 1 Results of the Delphi method questionnaire

The present study employed MDM and conducted a literature review to retrospectively and preliminarily identify 95 important decision-making factors (Chen, 2011; Fire Department of the Ministry of the Interior, 2017; Fire Department of the Ministry of the Interior Web, 2020; Taitung County Government, 2016). An open question was added at the end of each paragraph, allowing respondents to add items not mentioned in the preliminary questionnaire based on their knowledge, research, and practical experience. After the questionnaires were recovered and analyzed, the overall and individual results were used as feedback for the second questionnaire, and the method mentioned above was repeated. After the answers reached a certain level of consistency, a five-point Likert scale was employed for assessments, where 5 = "extremely important," 4 = "important," 3 = "normal," 2 = "unimportant," and 1= "extremely unimportant." Decision-making factors with a higher score indicated a higher level of agreement. The retention and deletion of decision-making factors was based on the standards proposed by Hobbelen et al. (2008), where the median of 5 is considered as "highly agree," 3.5-4.5 is seen as "agree," and less than 3.5 implies "disagree." Decision-making factors with an average score lower than 3.5 were considered less important and were subsequently deleted. Based on suggestions proposed by Chang et al. (2002), a coefficient of variation (CV) less than 0.3 indicates a high level of consistency among expert opinions. A CV ranging between 0.3 and 0.5 indicates that the decision-making factor remains in an acceptable range. To ensure

discretion, the present study contended that a CV exceeding 0.3 indicates poor consistency among expert opinions, in which case a new questionnaire was produced and distributed. This method enabled the present study to yield a high level of consistency across expert opinions, upon whose affirmation, important decision-making factors were identified. After identifying the important decision-making factors, the first MDM questionnaire was distributed. Statistics on the retrieval of this questionnaire are presented in Table 1.

Table 1. Statistics on the first retrieval of the first MDM questionnaire

Questionnaire object	Attribute	Year of working experience
A	Experts and scholars	6~10
B	Experts and scholars	6~10
C	Experts and scholars	Above 21
D	Experts and scholars	Above 21
E	Government agencies	Above 21
F	Government agencies	11~15
G	Government agencies	11~15

After the first MDM questionnaire was recovered, the average and CV were determined based on the data provided by experts and scholars and were used for statistical analysis. Three factors were deleted, including "enhancing patrol to prevent opportunistic theft and illicit activities," "having personnel of water management facilities stand by," "having various telecommunications providers center all efforts on repairing damaged telecommunication lines and equipment." Finally, the 95 decision-making factors were reduced to 86, and a three layer hierarchy defined by class as indexes (Layer 1, 3 factors), indicators (Layer 2, 20 factors), and items (Layer 3, 86 factors) was then employed as content for the AHP weighted questionnaire.

4.2 Results of the index weight analysis

The objective of the present study was to determine the ranking of "important decision-making factors during the pre-disaster preparation stage and emergency response stage of typhoon disasters," the results of which can be used as reference by the commander for emergency response decision-making, prioritizing actions, and

conducting typhoon-related situational deductions. The present study employed the AHP and used three layers (three indexes, 20 indicators, and 86 items) of the pairwise comparison matrix to determine the index eigenvector. The C.I. and C.R. of the three layers were calculated, and all were $0.00 \leqq 0.1$, confirming consistency among expert opinions in this section of the questionnaire.

(1) Results of weight analysis for Layers 1 and 2 (index, indicator)

The results of the weight analysis for Layer 1 (index) and Layer 2 (indicator) are presented in Table 2. Among the three indexes in the first layer following the ultimate objective layer, "Index B Action of emergency response" ranked most important (0.497), followed by "Index A Ensuring the collection, report, and communication of disaster information" (0.326) and "Index C Organization operation" (0.177). The score for "Index B Action of emergency response" was nearly equal to the sum of the two other indexes. In other words, the experts contend that action of emergency response should be the top consideration for the commander.

Of the 20 indicators in Layer 2, the five with the highest absolute weights were, in order from high to low, "A.2 Securing disaster prevention and relief resources and telecommunications (0.451)," "A.1 The collection and report of disaster information (0.415)," "C.1 Establishing the CEOC (0.338)," "C.2 Report on major disasters and response measures (0.286)," and "B.1 Forecasting typhoons and issuing and disseminating alerts (0.231)." The meaning revealed by the results of the weight analysis for Layer 2 is further elucidated in the following sections.

Table 2. Analysis of the weight ranking of Layer 1 (index) and Layer 2 (indicator)

Assessment Index (Layer 1)	Weight	Ranking	Assessment Indicator (Layer 2)	Weight	Ranking
A. Ensuring the collection, report, and communication of disaster information	0.326	2	A.1 The collection and report of disaster information	.415	2
			A.2 Securing disaster prevention and relief resources and telecommunications	.451	1
			A.3 The execution of the disaster report system	.134	8
B. **Action of emergency response**	0.497	1	B.1 Forecasting typhoons and issuing and disseminating alerts	.231	5
			B.2 Community emergency Response	.207	6
			B.3 Disaster prevention Measures	.163	7
			B.4 Guiding civilians in disaster prevention and seeking shelter	.095	10
			B.5 Emergency transportation	.048	16
			B.6 Emergency shelter	.064	14
			B.7 Search and rescue and emergency medical care	.081	12
			B.8 The reallocation and supply of food and necessities	.042	17
			B.9 The emergency repair of facilities	.039	18
			B.10 Preventing secondary disasters	.032	20
C. **Organization operation**	0.177	3	C.1 Establishing the CEOC	.338	3
			C.2 Report on major disasters and response measures	.286	4
			C.3 Dispatching personnel to the command (coordination) center	.131	9
			C.4 Support from the armed Forces	.083	11
			C.5 Cross-county/city Support	.038	19
			C.6 All-out defense mobilization	.049	15
			C.7 Press releases	.076	13

(2) Weight analysis of Layer 3 (item)

After exploring the importance ranking of indexes (Layer 1) and indicators (Layer 2), the layering and weight relations of items (Layer 3), as detailed questions and decision-making factors, are presented in Table 3. The absolute weight refers to the outcome of the analysis of 86 items. When ranked based on absolute weight, the top five items were "A.2.1 Ensuring telecommunications functions (0.12512)," "B.2.2 Practice community disaster prevention and execute response work (0.08323)," "A.1.1 Diverse collection and compilation of the state of the disaster (0.05790)," "A.1.3 Using information to analyze disasters (0.04532)," and "A.3.1 Utilizing rosters to facilitate effective disaster information reporting (0.02590)."

Table 3. Analysis of the weight ranking of Layer 3 (item)

Assessment Indicator	Assessment Item	Absolute Weight	Absolute Rank
A.1 The collection and report of disaster information	A.1.1 Diverse collection and compilation of the state of the disaster	.05790	3
	A.1.2 Collecting images using aircraft	.02083	7
	A.1.3 Using information to analyze disasters	.04532	4
	A.1.4 Report current losses to the supervising agency	.01123	14
A.2 Ensuring disaster prevention and relief telecommunications	A.2.1 Ensuring telecommunications functions	.12512	1
	A.2.2 Control communications and distribute communications resources	.02191	6
A.3 The execution of the disaster report system	A.3.1 Utilizing rosters to facilitate effective disaster information reporting	.02590	5
	A.3.2 Inform residents to evacuate and provide information	.01778	9
B.1 Forecasting typhoons and issuing and disseminating alerts	No assessment item	---	---
B.2 Community emergency response	B.2.1 Provide support after receiving community requests	.01965	8
	B.2.2 Practice community disaster prevention and execute response work	.08323	2
B.3 Disaster prevention measures	B.3.1 Enhance preparations for variousagencies	.01361	12
	B.3.2 Enhance transportation and supplies	.00608	26

Assessment Indicator	Assessment Item	Absolute Weight	Absolute Rank
	to prevent isolation		
	B.3.3 Ban hiking	.00437	38
	B.3.4 Ensure proper drainage and sewage systems in cities	.00478	33
	B.3.5 Evacuate persons in alert zones	.00640	23
	B.3.6 Promoting disaster prevention via the media	.00729	20
	B.3.7 Evacuate persons in potential disaster zones	.00705	21
	B.3.8 Ensuing architecture safety	.00340	45
	B.3.9 Promote the reallocation of ships to safe areas	.00340	45
	B.3.10 Distribute machinery and equipment to various areas	.00243	58
	B.3.11 Establish temporary shelters	.00462	35
	B.3.12 Prepare supplies for shelters	.00381	41
	B.3.13 Prepare medical material	.00373	43
	B.3.14 Strengthen the elimination of obstructions in ditches and sluices	.00421	39
	B.3.15 Identify specific regions to implement disaster prevention measures	.00583	28
B.4 Guiding civilians in disaster prevention and seeking shelter	B.4.1 Issue various disaster alerts and warnings	.01728	10
	B.4.2 Provide evacuation information	.01275	13
	B.4.3 Provide interregional shelters	.00335	47
	B.4.4 The early evacuation of the underprivileged	.00812	17
	B.4.5 Assist those with special needs in seeking shelter	.00567	30
B.5 Emergency transportation	B.5.1 Prioritize the transportation of households in danger zones	.00377	42
	B.5.2 Implement localized or regional transportation control measures	.00219	61
	B.5.3 The emergency repair of damaged traffic facilities	.00229	60
	B.5.4 Remain up to date about transportation tools and emergency transportation routes	.00167	72
	B.5.5 Utilize CCTV to collect information on damage to traffic conditions	.00134	74
	B.5.6 Traffic control	.00169	70
	B.5.7 Guiding tow trucks and police	.00067	81

Assessment Indicator	Assessment Item	Absolute Weight	Absolute Rank
	Cars		
	B.5.8 Removing road obstacles	.00138	73
	B.5.9 Emergency road repair and the planning of alternative routes	.00174	69
	B.5.10 Reporting road status	.00169	70
	B.5.11 Port repair	.00045	85
	B.5.12 Establish signs to mark waterway anomalies	.00050	84
	B.5.13 Plan helicopter airfields	.00095	79
	B.5.14 Remain up to date about railway damage	.00107	77
	B.5.15 Request coast guard support	.00055	83
	B.5.16 Request support from the armed Forces	.00081	80
	B.5.17 Request CEOC support	.00060	82
	B.5.18 Coordinate fuel supplies	.00043	86
B.6 Emergency shelter	B.6.1 Provide shelter information	.00620	25
	B.6.2 Establish temporary shelters	.00490	31
	B.6.3 Planning and maintaining shelters	.00455	36
	B.6.4 Seek help from volunteers	.00258	55
	B.6.5 Remain up to date about the physiological and psychological status of those seeking shelter	.00254	56
	B.6.6 Maintain a quality living environment and order within shelters	.00299	50
	B.6.7 Prevent secondary disasters from Occurring	.00254	56
	B.6.8 Request resources from the CEOC	.00130	75
	B.6.9 Offer cross-county/city sheltering for affected civilians	.00105	78
	B.6.10 Provide interregional shelters	.00121	76
	B.6.11Assist those with special needs in seeking shelter	.00197	64
B.7 Search and rescue and emergency medical care	B.7.1 Disaster rescue	.00797	18
	B.7.2 Initiate emergency medicine	.00608	26
	B.7.3 Initiate the mass casualty Mechanism	.00656	22
	B.7.4 Remain up to date about the disaster damage at the responsible hospitals	.00346	44
	B.7.5 Remain up to date about the status of emergency medical personnel	.00314	49
	B.7.6 Integrate and coordinate medical	.00386	40

Assessment Indicator	Assessment Item	Absolute Weight	Absolute Rank
	operations in affected areas		
	B.7.7 Ensure the establishment of emergency aid stations and sufficient supplies at the medical station	.00290	52
	B.7.8 Have responsible hospitals in nearby counties/cities provide support	.00193	66
	B.7.9 Request support from the armed Forces	.00209	63
	B.7.10 The requisition of civilian Resources	.00217	62
B.8 The reallocation and supply of food and necessities	B.8.11 Reallocate and supply food, potable water, medication and medical material, and necessities	.01371	11
	B.8.12 Provide relief supplies to Civilians	.00451	37
	B.8.13 The requisition of civil supplies	.00265	54
B.9 The emergency repair of facilities	B.9.1 The emergency repair work of sewage facilities	.00273	53
	B.9.2 The emergency repair of subsistence pipelines	.00583	28
	B.9.3 The emergency repair of Embankments	.00787	19
	B.9.4 Recruit relevant professionals and technicians to assist with emergency repair work	.00297	51
B.10 Preventing secondary disasters	B.10.1 Facility repairs and building Inspections	.00194	65
	B.10.2 Immediately implement drainage measures during torrential rain and floods	.00835	16
	B.10.3 Demolish dangerous structures	.00237	59
	B.10.4 Remove dangerous fallen Objects	.00324	48
C.1 Establishing the CEOC	No assessment indicator	---	---
C.2 Report on major disasters and response measures	No assessment indicator	---	---
C.3 Dispatching personnel to the command (coordination) center	No assessment indicator	---	---

Assessment Indicator	Assessment Item	Absolute Weight	Absolute Rank
C.4 Support from the armed forces	C.4.1 Regional commanders actively communicate with response centers of different levels and receive dispatches	.00473	34
	C.4.2 Pre-allocate troops	.00624	24
	C.4.3 Request support from the armed Forces	.00187	67
	C.4.4 Establish databases for the various support units	.00185	68
C.5 Cross-county/city support	No assessment indicator	---	---
C.6 All-out defense mobilization	No assessment indicator	---	---
C.7 Press releases	C.7.1 Hold press conferences	.00858	15
	C.7.2 Make corrections to media Information	.00487	32

5. Discussion and conclusions

Disasters occur frequently around the world as the climate changes. Among these disasters, typhoons and typhoon-associated disasters are particularly devastating. Taiwan is located in the Pacific Northwest, which is a region frequented by typhoons. The exacerbation of climate change has increased the frequency of typhoon rainfall, which is the main cause of disasters. An increasing number of disasters have made news headlines in recent times, increasing public skepticism toward the competency of experts and decision-makers. After a disaster, public concern raises the pressure of disaster decision-making.

It is the government's duty to avoid disaster losses of people. Typhoon forecasting and early warning technology has become more advanced in recent times with contribution by the Central Meteorological Bureau, and academic and research institutions. However, there is still a slight discrepancy between the forecast and the real event. Such slight differences result in decision-making difficulties. Especially during a disaster, clear, fast, and effective decision-making and response actions must be made, which is also the main source of pressure for decision-makers. Therefore, employing the MDM to identify the tasks for the various layers and then applying the AHP to divide all factors into three levels serves to solve this problem.

The objective of the present study was to summarize disaster response factors and

determine the ranking of “important decision-making factors during the pre-disaster preparation stage and emergency response stage of typhoon disasters,” the results of which can be used as a reference by the commander in determining the priority of decisions. A total of 95 decision-making factors were collected. Finally, 86 factors were confirmed using MDM and a three layer hierarchy defined by Layers 1, 2, and 3, namely index, indicator, and item, respectively was introduced. In the proposed structure, Layers 1 and 2 encompass the categorization of large-scale indicators, whereas Layer 3 includes items that the commander must highlight. The commander can reference the concept of leveled management and assign a deputy commander based on indicator weight.

(1) The results of AHP analysis show that among the three indexes in Layer 1 (Index) following the ultimate objective layer, “B Action of emergency response” ranked the most important, followed by “A Ensuring the collection, report, and communication of disaster information” and “C Organization operation.” The score for “B Action of emergency response” was nearly equal to the sum of the two other indexes. In other words, the experts contend that action of emergency response should be the top consideration for the commander.

(2) The analysis results revealed that "B.1 Forecasting typhoons and issuing and disseminating alerts" had the highest weight. This result reflected the importance of decision-makers' grip on correct information and the dissemination of information before the strike of a typhoon. The weights of "B.2 Community emergency response" and "B.1 Forecasting typhoons and issuing and disseminating alerts" were nearly identical, highlighting that both are important indicators. "B.3 Disaster prevention measures" and "B.4 Guiding civilians in disaster prevention and seeking shelter" are both indicators that require civilian collaboration during disaster emergencies and involve the repeated inspection of prevention measures before the strike of a disaster. The execution involved in "B.7 Search and rescue and emergency medical care," "B.6 Emergency shelter," "B.5 Emergency transportation," "B.8 The reallocation and supply of food and necessities," "B.9 The emergency repair of facilities," and "B.10 Preventing secondary disasters" can mostly be completed during the disaster preparation stage. Among these indicators, only a few relate to preparedness and emergency response during the strike of a disaster, or are less important when compared to

saving lives and protecting property. Thus, these indicators can be listed as major points of focus for the deputy commander or should be further explored by various departments during scenario deductions or when sufficient time is on hand. Although these indicators have a lower weight, they were nonetheless screened using the MDM, which highlights their significance.

(3) A total of 39 of the 86 items in Layer 3 had an absolute weight greater than 0.004. Should the commander be unable to supervise or execute detailed items during decision-making due to the number of items requiring supervision, the four indicators mentioned in the previous paragraph can be handed over to the deputy commander for progress supervision. Doing so will enable the complete execution of key decision-making factors. These indicators can also be included in drills during scenario deductions.

The results also show that the quality of decision-making depends on practical experience. In Taiwan, decision-maker and responders' disaster response capability is mainly established through disaster scenario deduction and drills, in addition to regular education and training. This research uses Taitung County's contingency practice, but the government commanders at all levels can follow the results of this research to repeatedly practice, familiarize themselves with the process, and add to their experience to achieve and strengthen their capability to respond to disasters.

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