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Method for evaluating and selecting backfill material survey areas for mineral resources planning: A case study in Ba Ria - Vung Tau province

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Abstract: *This research focuses on developing a method to select priority survey areas to be included in the exploration, exploitation, and utilization plans for minerals used as common building materials in Ba Ria - Vung Tau province, in accordance with the Planning Law 21/2017/QH14. The main objective is to ensure efficient and sustainable exploitation, environmental protection, and compliance with the Mineral Resources Law. The research methodology uses weighted multi-criteria evaluation integrated with GIS to create a priority zoning map for surveying backfill materials - the type of common building material occupying the largest area in the province. Two sets of criteria are applied: (1) 10 exclusion criteria to identify areas where mineral activities are not permitted, and (2) 8 impact assessment criteria based on mineral quality, economic efficiency, social and environmental impacts. The research results identify 30,434 ha (16.09% of the study area) as potential areas for backfill material survey, while the remaining 83.91% is excluded. The priority zoning map is divided into 4 levels from low to high, synthesized from various database sources. This study provides a support tool for planners and managers in the initial selection of areas for exploration and exploitation of common building materials in Ba Ria - Vung Tau. However, the criteria need to be adjusted appropriately when applied in practice, based on the latest database and mineral exploitation status.*

Keywords: *Mineral resouces planning; backfill material; Multi-criteria evaluation; Sustainable mining.*

1. Introduction

The optimal selection of locations for mineral resource exploitation, particularly construction materials, is a complex decision-making process requiring consideration of multiple, often conflicting criteria. These criteria may include geological factors, environmental impacts, economic feasibility, and social issues. To address this complexity, researchers and industry experts are increasingly turning to integrated methods combining Multi-Criteria Analysis (MCA), Analytic Hierarchy Process (AHP), and Geographic Information Systems (GIS). MCA provides a tool for evaluating options based on multiple criteria, allowing decision-makers to balance different factors in their assessment. AHP, developed by Saaty (1980) [14], offers a structured approach to organizing and analyzing complex decisions, breaking them down into a hierarchy of more comprehensible detailed issues. GIS tools, with their capability to manage, analyze, and visualize spatial data, add crucial geographic information to the decision-making process. The integration of these three methods - MCA, AHP, and GIS - creates a powerful toolkit for identifying and selecting priority mineral resource extraction areas. This integrated approach allows decision-makers to:

- Systematically evaluate multiple criteria related to resource extraction.
- Incorporate expert assessments and stakeholder priorities.
- Consider spatial relationships and geographic constraints.
- Visualize results through thematic maps that facilitate decision-making.

Recent studies have demonstrated the effectiveness of this integrated approach in various contexts related to resource management and land use planning. For example, Alkaradaghi et al. (2018) used remote sensing and GIS to assess land use and land cover changes in rapidly urbanizing areas, emphasizing the importance of geospatial analysis in understanding development patterns [7]. Abdullah et al. (2018) used a modified DRASTIC model based on AHP to assess groundwater vulnerability, demonstrating these methods' adaptability to different environmental contexts [3]. In site selection, Alkaradaghi et al. (2019) applied MCDA and GIS methods to select landfill sites in Sulaimaniyah Province, Iraq. Their study incorporated a range of natural and artificial factors, demonstrating this method's capability in handling complex, multifaceted decision problems [2]. Similarly, Thapa and Murayama (2008) integrated AHP and GIS techniques to evaluate land for peri-urban agriculture, illustrating the method's flexibility across different fields [6]. Carević et al. (2020) emphasized the importance of geological criteria in landfill site selection, integrating detailed geological data with geographical modeling. This approach highlights the potential application of similar methods for mineral resource extraction, where geological factors are paramount [5]. Yesilnacar et al. (2012) further demonstrated the advantages of GIS-integrated MCDA over traditional expert-based methods for site selection, emphasizing the ability to reproduce cognition and adapt to changing parameters [1]. Although these studies primarily focused on urban planning, waste management, and agricultural applications, their principles and methodologies are highly relevant to selecting priority areas for mineral resource extraction, particularly construction materials. The integration of MCA, AHP, and GIS provides a robust framework for balancing the diverse factors involved in this decision-making process, including geological suitability, environmental impact, economic feasibility, and social considerations.

In Vietnam, the MCA evaluation method combined with GIS technology has been widely researched and applied in resource and environmental management. Notable studies include creating landslide risk maps in Quang Tri and Thua Thien Hue [17], which used the AHP method to determine weights for influencing factors, thereby creating risk zoning maps. The integration of MCA and GIS has also been implemented in industrial zone planning, where planning location evaluation is based on multiple criteria such as distance to residential areas and water sources [18]. AHP and Fuzzy theory have helped improve accuracy in analysis and decision-making. Additionally, research on selecting locations for municipal solid waste landfills has shown the effectiveness of GIS and MCA. By evaluating various criteria, the research proposed suitable locations for landfill placement. This demonstrates that multi-criteria analysis and GIS have proven effective in supporting decision-making in resource and environmental management both in Vietnam and globally.

This study implements a novel integrated methodology in Ba Ria - Vung Tau province (Fig. 1) to optimize the selection of construction material extraction sites. The proposed framework combines Multi-Criteria Analysis (MCA), Analytic Hierarchy Process (AHP), and Geographic Information Systems (GIS) to systematically evaluate potential mining locations. The methodology incorporates two sets of criteria: 10 exclusion criteria that identify restricted areas where mining activities are prohibited, and 8 impact assessment criteria that evaluate sites based on mineral quality, economic viability, social impaction, and environmental considerations.

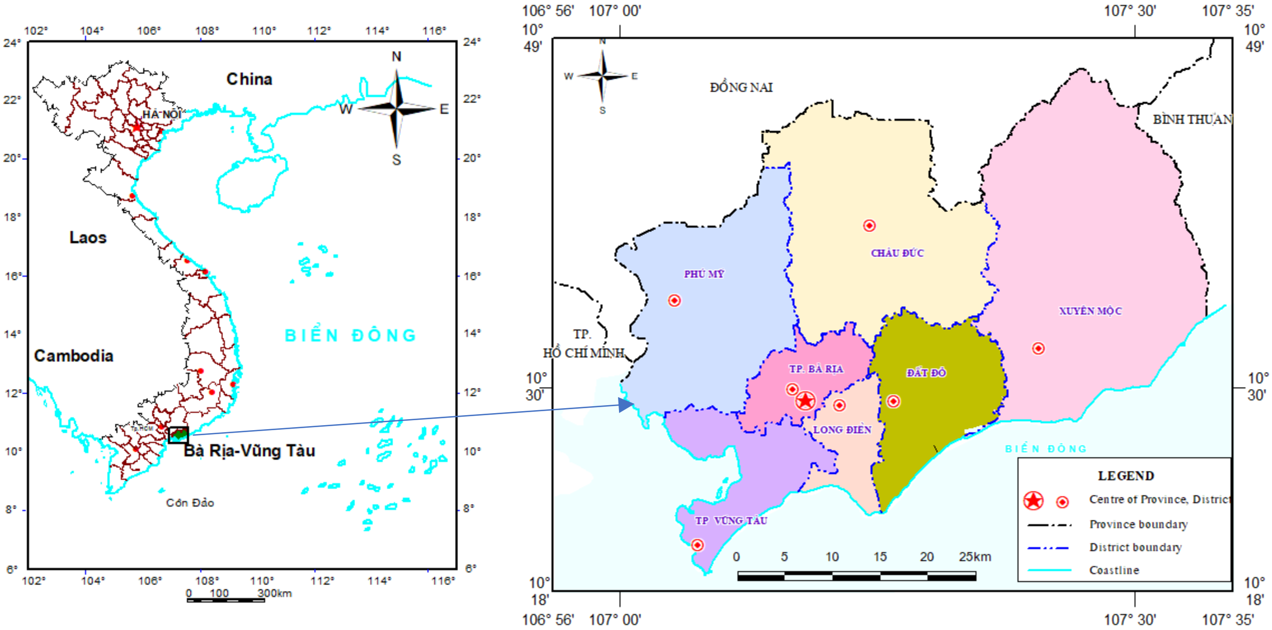

Fig. 1. Location map of the study area

2. Methodology Based on the above analysis, this study employs the MCA-AHP-GIS methodology system with a sequence of steps as shown in the following flowchart:

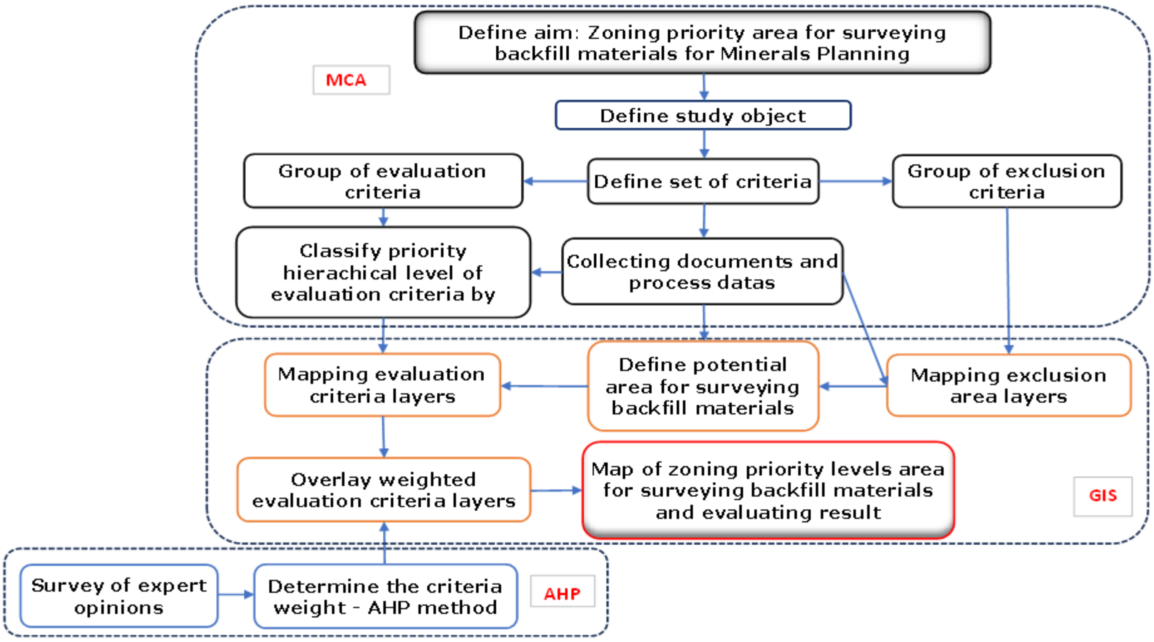

Fig. 2. Diagram of study method model

The MCA method is used to establish objectives for selecting priority areas according to the following requirements: not located within prohibited and temporarily prohibited mining zones; meeting mineral quality requirements; achieving high economic efficiency; and minimizing social impact while protecting the environment. Based on these objectives, exclusion criteria and evaluation criteria are determined. The exclusion criteria are used to establish zones where mineral activities are not permitted, while the evaluation criteria are factors that influence the selection of backfill material survey areas for mineral resouces planning.

The evaluation criteria are divided into group of level 1 include 4 criteria: geological, economic, environmental, and social. Within each evaluation criterion group level 1, they are further classified into group of level 2 which include 8 criteria: Geo; Ec1; Ec2; En1; En2; En3; En4; Soc (Fig.3). Tab1. describes viewpoints to evaluate level 1 and level 2.

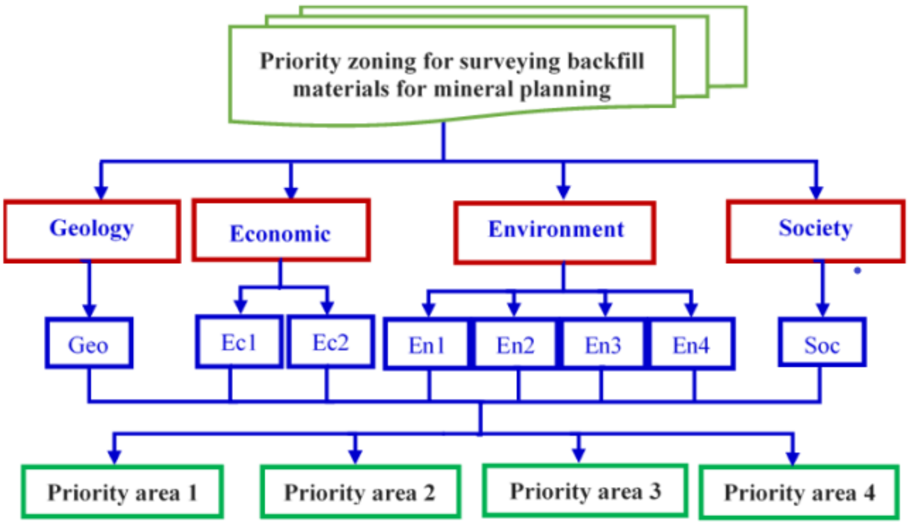

Fig. 3. Hierarchical structure diagram of criteria for zoning priority backfill material survey area

Tab. 1. Viewpoints to evaluate criteria for selecting backfill materials surveying area

Level 1 evaluation criteria group	Evaluation viewpoints	Level 2 evaluation criteria
Geology (1)	Criteria for evaluating quality characteristics and mineral prospects are based on existing levels of mineral geological research.	Geological characteristics and mineral prospects.
Economic (2)	Criteria for evaluating the level of convenience and economic efficiency when conducting mineral exploration, exploitation and consumption.	Distance to existing transportation roads
		Distance to existing mineral resouces planning area that have mine or mine cluster licensed for exploitation
Environment (3)	Criteria for evaluating the impact of mineral exploitation activities on the environment and landscape.	Distance to national highway, provincial road
		Distance to historical, cultural, scenery, religious and belief sites
		Distance to surface water protection corridor
		Distance to nature reserve area
Sociaty (4)	Criteria for evaluating the impact of mineral exploitation activities on social life.	Distance to residential area

The AHP method to analyse and calculate parameter weights, there are 4 steps [4,15]:

Step 1: Building the AHP Diagram, starting from the objective of zoning priority areas for backfill material surveys to be included in the mineral resouces planning proposal, identifying criteria that influence survey zone selection and establishing a hierarchy of criteria including level-1 and level-2 criteria, serving as the basis for pairwise comparison of criteria (Fig. 2).

Step 2: Establishing the Pairwise Comparison Matrix, criteria of the same level are compared and scored for their importance in selecting backfill material survey zones for mineral resouces planning proposals in pairs. This step requires surveying opinions from experienced experts in the field of mineral resources and environment.

Step 3: Calculating Criteria Weights, after establishing the pairwise comparison matrix

Step 4: Consistency Check, when evaluating criteria, the importance level of criteria depends on experts' subjective opinions, collected through survey forms (questionnaire - written responses), making it difficult to ensure objectivity.

The GIS method is used to construct a survey priority zoning map for backfill materials through the following steps: data collection, analysis, and processing of input data, followed by creating thematic map layers based on exclusion criteria and influencing criteria. Then, weighted overlay of the thematic maps is performed to produce a results map showing priority zones for surveying backfill materials, visually aiding decision-makers in mineral resouces planning (Fig. 4).

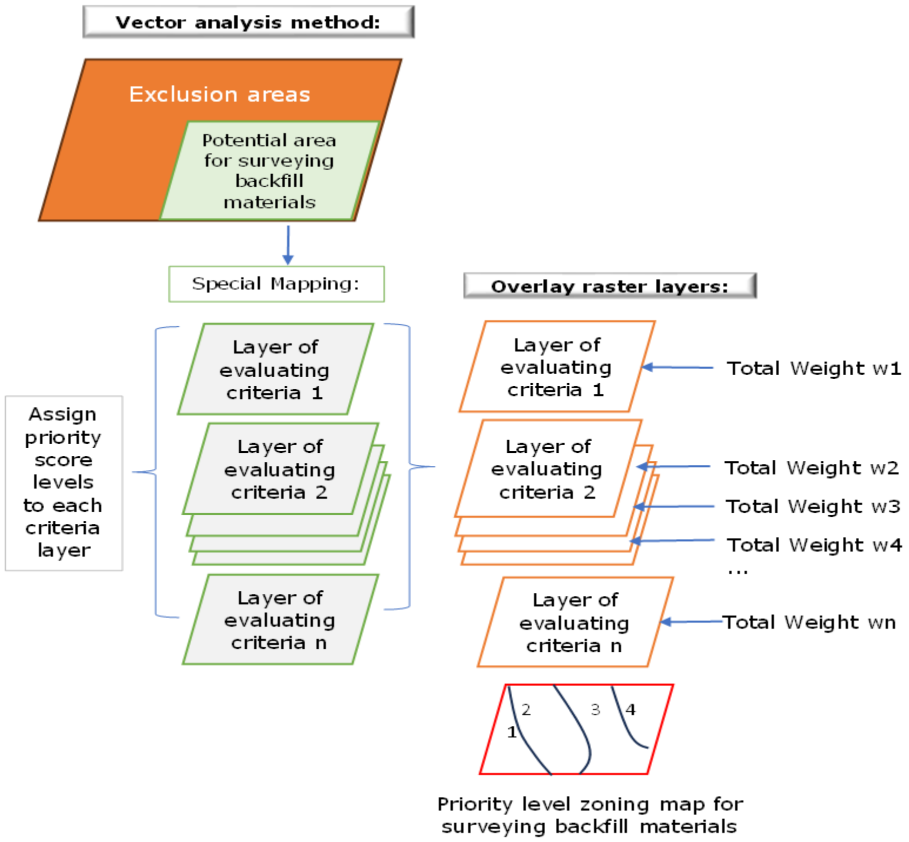

Fig. 4. Process of spatial analysis in GIS

There are 4 steps to carry out the GIS method**:**

Step 1: Construct the Exclusion Area Map, based on exclusion criteria, identify the exclusion layers, which include prohibited areas, temporarily prohibited mining areas, residential areas, urban zones, industrial areas, and surface water corridors that need protection. The exclusion layers are created in vector format, with data information representing the area of each zone. These layers are combined using the "Append Rows to Table" command, sequentially from E1 to E9, and all areas are combined to create the exclusion area E1_9 (Fig. 5).

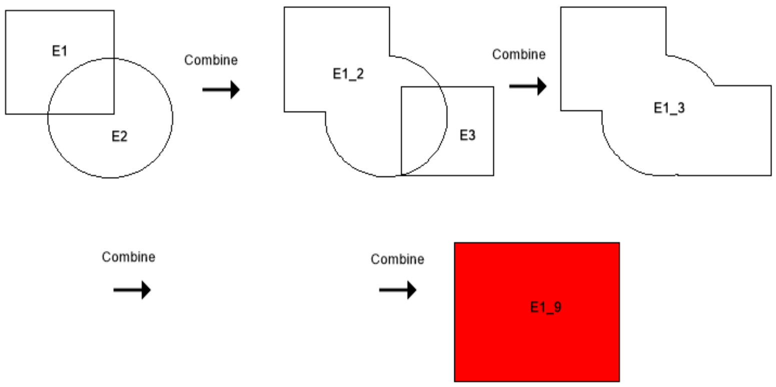

Fig. 5. The model illustrates the steps of combining exclusion layers to create the 9 criteria exclusion area

Step 2: Construct the potential survey map for backfill materials, this involves overlaying vector layers from the following maps:

- **Layer Tiemnang_SDD (A)**: Represents areas of land that can be converted for mining activities, taken from the land use planning map.
- **Layer Tiemnang_Diachat (B)**: Represents the distribution of geological strata suitable for backfill materials, all filtered and edited in vector format.
- **Layer E1_9**: The exclusion area E1_9 shows the zones where mining activities are not permitted, resulting from the overlay of the 9 exclusion criteria in Step 1. The outcome determines the potential survey area for backfill materials, referred to as "Tiemnang_VLSL."

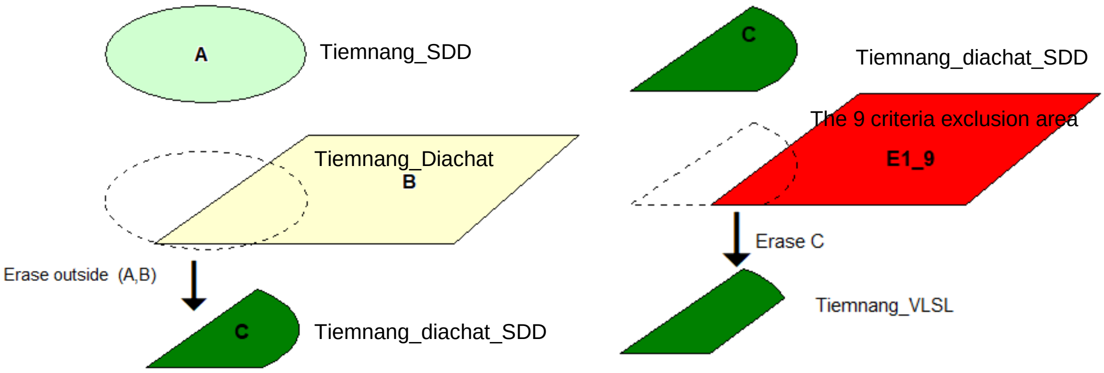

Fig. 6. The model illustrates the steps to create the potential area for surveying backfill materials 'Tiemnang_VLSL'The remaining area of the study region after subtracting the area of zone C is precisely the exclusion area E10, which is the area with no geological potential for backfill materials and/or cannot be converted for mining purposes. The comprehensive exclusion area E1_10 is the result of overlaying the exclusion area E1_9 with exclusion area E10.

Step 3: Construct Evaluation Criteria Layers and Assign Priority Scores, the evaluation criteria layers are developed based on the potential survey map for backfill materials (Tiemnang_VLSL) established in Step 2. Using the collected data layers to assess the criteria (8 criteria), buffer zones are created from the object boundaries at specified distances, and corresponding scores are assigned to reflect different priority levels for selecting backfill materials surveying areas. These criteria layers will then be overlaid with the 'Tiemnang_VLSL' area to create Evaluation Criteria Layers that only include areas within the potential backfill material survey region, which have been ranked according to the assessment scale.

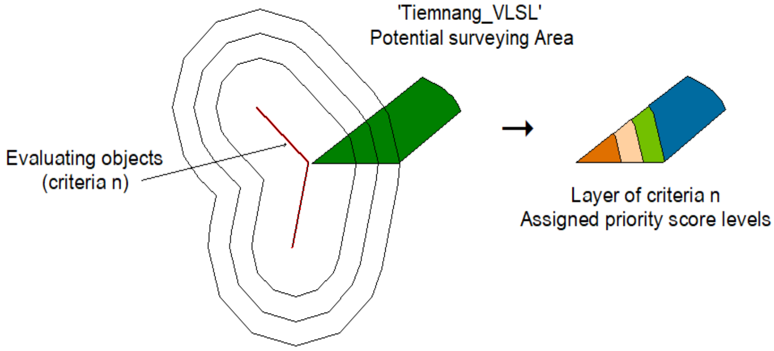

Fig. 7. The model illustrates the steps to create Evaluation Criteria Layers

The vector Evaluation Criteria Layers, which have assigned priority levels within the potential survey area for backfill materials, are converted to raster format preparing for overlaying weighted in ArcGIS.

Step 4: Establish the survey priority zoning map for mineral resouces planning: Overlaying weighted Evaluation Criteria Layers and calculate the Priority Index (PI) for each location, and the study proposes 4 priority levels (Low; Medium; High; Highest).

$$PI = \sum_{i=1}^{n} (Wij * xi)$$

Which:

PI: Priority Index;

W_{ij}: Overall weight of criteria i;

x_i: Priority hierarchical score of criteria i.

3. Results and dicussions

To implement the steps for selecting and zoning priority area for surveying backfill material for minerals planning in Ba Ria – Vung Tau Province, the first step is to study the regulations in the Planning Law [10] and the Mineral Resources Law [16], identifying exclusion zones that encompass areas designated for national defense and security; historical and cultural relics; religious and spiritual sites; land of

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information and communication; road corridor land; special-use forests, and protective forests. Additionally, areas designated for concentrated residential communities, existing urban areas, industrial zones, water source protection corridors, and other land areas that do not have the potential for conversion to mining activities are included, resulting in maps of exclusion zones.

Based on data collected from environmental impact assessment reports of backfill material mining projects in Ba Ria - Vung Tau Province, we assess the impact levels of mining activities at various distances. Following the regulations of the Planning Law and the Mineral Resources Law, we identify 10 exclusion criteria to study, labeled E1 to E10, which are specifically described in Table 3. The buffer zone is defined as the corridor protecting the area from the protected zone to the mining operational zone, where mining activities for fill materials are also not permitted.

- Exclusion zones with regular human activity (E1 to E6): Reference the distance values and environmental impact levels of the fill material mining site combined with on-site surveys of the mining areas.
- Exclusion zones without regular human activity (E6, E7, E8).
- Exclusion zone E9: The corridor as stipulated by the exclusion zone during mining.
- Exclusion zone E10: Areas excluded based on potential of geological and land-use conversion.

We used GIS tools to overlay the exclusion layers creating exclusion zone maps from E1 to E9, and the results are presented in Figure 8.

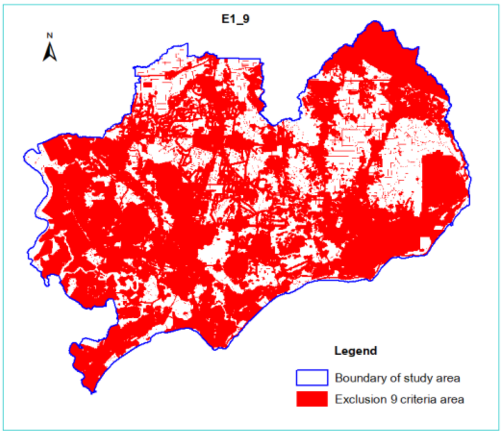

Fig. 8. Exclusion zone map of the 9 criteria E1-E9

After determining the excluded areas based on the 9 criteria (E1 to E9), we proceeded to Step 2, which involved creating a potential survey map for backfill material (VLSL) for Ba Ria - Vung Tau Province. To achieve this, we developed thematic map layers, including: (1) a land use potential map for mining activities, based on the guidance of the Land Law No. 45/2013/QH13; (2) a geological potential map for VLSL extraction. By overlaying these two map layers, we obtain the map of 'Tiemnang_Diachat_SDD' area (Fig. 10). We then overlaid this with the exclusion zone map E1_9 to identify the potential area for surveying backfill material (Tiemnang_VLSL), which was then incorporated into zoning the backfill material survey priority area for Ba Ria - Vung Tau Province (Fig. 10).

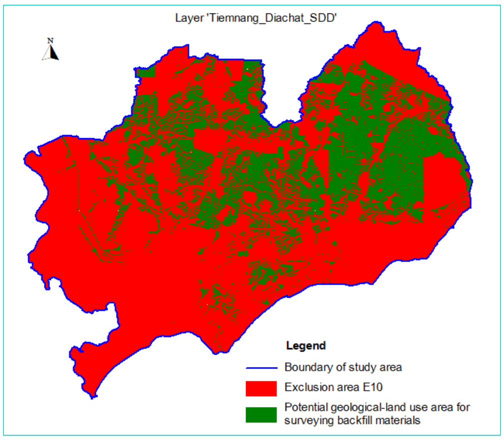

Fig. 9. Map of potential geological-land use area for surveying backfill materials

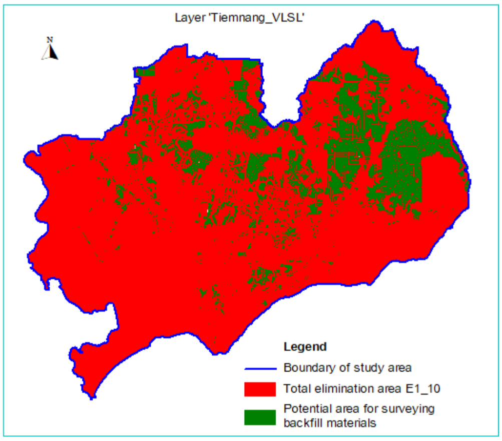

Fig. 10. Map of potential area for surveying backfill materials

The results summarized in Tab. 2 show that the entire study area has 28.42% of the land area with potential for conversion to mining activities and suitable geological conditions for fill material (Figure 10). After overlaying with the remaining exclusion areas, 16.09% of the land area remains with potential for surveying fill material, which corresponds to 30,434 ha (Fig. 11). The total excluded area E1_10 is 83.91%, equivalent to 158,741 ha.

Tab. 2. Summary table of potential survey area and exclusion area

Type of areas	Area (ha)	Percentage (%)
Total study areas	**189,175**	**100%**
Total exclusion areas	158,741	83.91%
Potential geological-land use area for surveying backfill materials	53,766	28.42%
Potential area for surveying backfill materials	30,434	16.09%

Based on the groups of criteria for evaluating the impact on the selection of survey areas for backfill material, as identified in Fig. 3, and on the analysis of collected data and field surveys of mining sites, 8 impact criteria of level 2 were selected for evaluation. These criteria were prioritized into 4 levels, with priority scores ranging from 1 to 4, corresponding to the following levels: highest priority, high priority, medium priority, and low priority, as shown in Tab. 3.

Tab. 3. Classify priority levels of evaluation criteria

No.	Criteria Level 2	Symbol	Criterion Hierarchy Level	Assessment Score	Reference Data Layer
	Technical (Geo)				
1	Geological characteristics and mineral prospecting	Geo	Forecasted Prospect B (*)	4	L1
			Forecasted Prospect C (*)	3	
			Forecasted Prospect D (*)	1	
	Economic (Ec)				
2	Distance to existing transportation roads (except national highways, provincial roads, and main traffic routes)	Ec1	10-150 m	4	L13
			150-300 m	3	
			300-500 m	2	
			>500m	1	
3	Distance to existing mineral resouces planning area	Ec2	0-500 m	4	L2
			500-1,000 m	3	
			>1,000 m	2	
	Environmental (En)				
4	Distance to national highway, provincial road	En1	>1,000 m	4	L12
			1,000-500 m	3	
			500-300 m	2	
			300-100 m	1	
5	Distance to historical, cultural, scenere, religious sites.	En2	>1,000 m	4	L8A, L8B, L9A, L9B
			1,000-500 m	3	
			500-300 m	2	
			300-100 m	1	
6	Distance to surface water protection corridor	En3	>150 m	4	L14
			100-150 m	3	
			0-100 m	2	
7	Distance to nature reserve area	En4	>150 m	4	L11

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No.	Criteria Level 2	Symbol	Criterion Hierarchy Level	Assessment Score	Reference Data Layer
			100-150 m	3	
			10-100 m	2	
	Social (Soc)				
8	Distance to residential area	Soc	>1,000 m	4	L4
			1,000-500 m	3	
			500-300 m	2	
			300-100 m	1	

(*)*Forecasted prospects are results of forecasting mineral prospects of Ba Ria - Vung Tau province in "Report of editing the mineral geological map of Ba Ria - Vung Tau province at scale 1/50.000"*

The evaluation criteria map layers are constructed from the vector map 'Tiemnang_VLSL,' creating intersections with the reference layers that have been assigned evaluation levels score according to Tab 3. The data layers then are converted to raster format in ArcGIS to prepare for weighted overlay analysis.

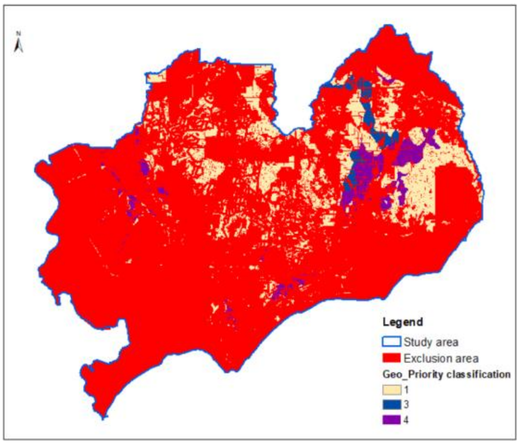

Fig. 11. Geo. Evaluation Criteria Layer

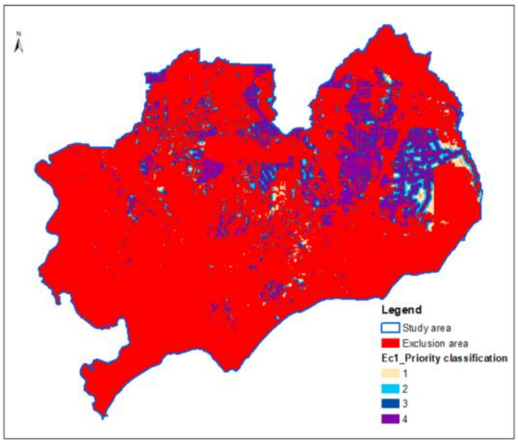

Fig. 12. Ec1 Evaluation Criteria Layer

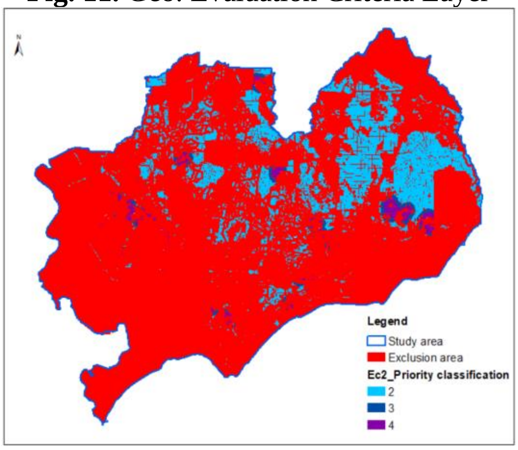

Fig. 13. Ec2 Evaluation Criteria Layer

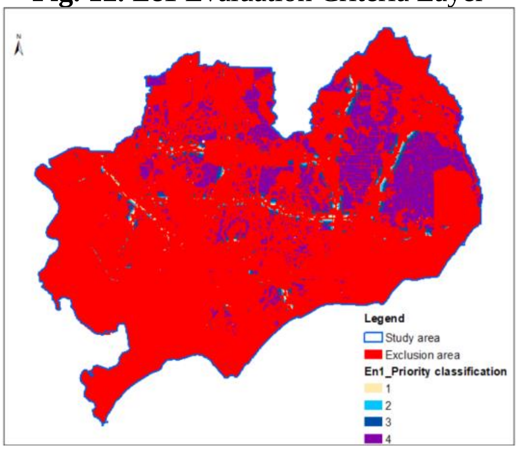

Fig. 14. En1 Evaluation Criteria Layer

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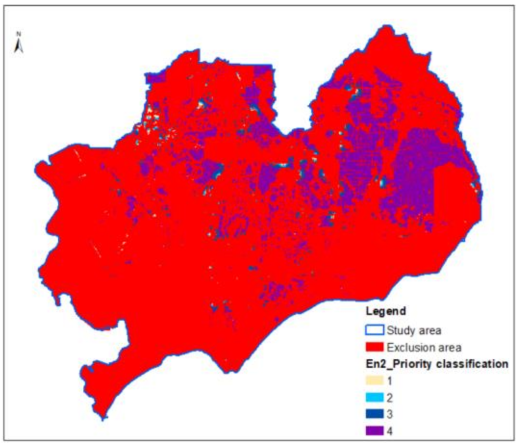

Fig. 15. En2 Evaluation Criteria Layer

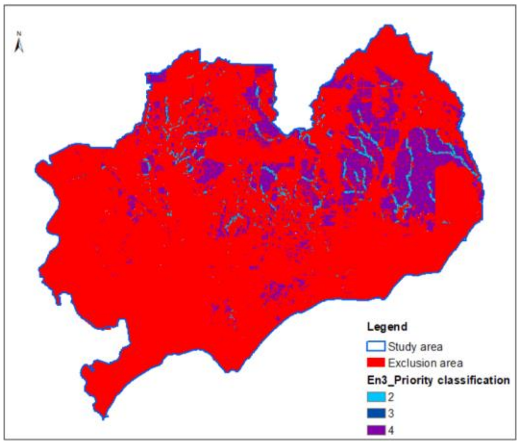

Fig. 16. En3 Evaluation Criteria Layer

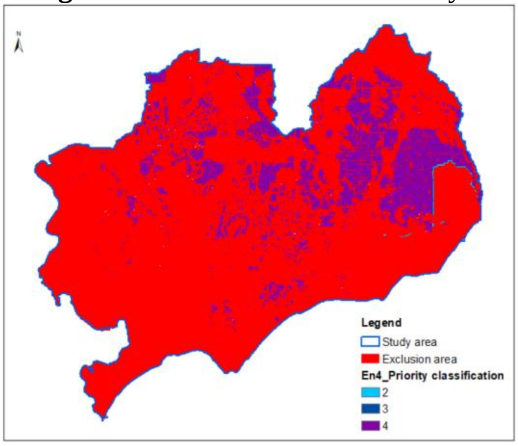

Fig.17. En4 Evaluation Criteria Layer

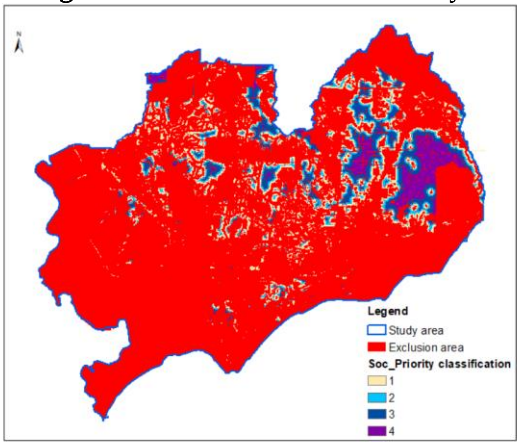

Fig. 18. Soc Evaluation Criteria Layer

The results produced 8 maps of evaluation criteria layers, with the maping layers are denoted as: Geo, Ec1, Ec2, En1, En2, En3, En4, Soc (Fig. 11 to Fig.18).

The study used the AHP method to survey opinions from 6 experts in different fields. The results of pair comparison matrix analysis of 6 experts all had a consistency ratio < 10%, meeting the requirements to participate in weight calculation. From the results of the matrix comparing pairs of each expert, make a matrix comparing pairs of groups using the product average method, described in Tab. 4.

After receiving survey results from experts, we calculate weights of evaluation criteria group level 1 in Tab. 5. The standard number w_{ij} is described in the table are shown in Tab. 7.

Tab. 4. Summary of the pairwise comparison matrix of the expert group

Level 1 evaluation criteria group	Geo. Geology	Ec. Economic	En. Environment	Soc. Society
Geo. Geology	1,000	1,135	1,809	2,083
Ec. Economic	0,881	1,000	2,172	3,267
En. Environment	0,553	0,460	1,000	1,570
Soc. Society	0,480	0,306	0,637	1,000
Total	**2,914**	**2,902**	**5,617**	**7,920**

Tab. 5. Result of normalization matrix - Group AHP method

Evaluation criteria group Level 1	Geo. Geology	Ec. Economic	En. Environment	Soc. Society	Total row value	Weight Wi
Geo. Geology	0.343	0.391	0.322	0.263	1.319	**0.330**
Ec. Economic	0.302	0.345	0.387	0.412	1.446	**0.361**
En. Environment	0.190	0.159	0.178	0.198	0.725	**0.181**
Soc. Society	0.165	0.105	0.113	0.126	0.510	**0.127**
Total	**1**	**1**	**1**	**1**	**4**	1

For the groups have two criteria level 2 or more (Tab. 3), we used the inverse order weighting method to calculate the weight for criteria level 2. The results ranked the order of importance of level 2 criteria and calculated the weight, described in Tab. 6. 4

Tab. 6. Table for calculating the weight of level 2 criteria

No.	Criteria level 2	Rank (rj)	Preliminary Score (t)	Normalized Weight (Wj)
Environmental Criteria (Env)				
1	En1- Distance to national highway, provincial road	1	4	0.40
2	En2- Distance to historical, cultural, scenery, religious sites	2	3	0.30
3	En3- Distance to surface water protection corridor	3	2	0.20
4	En4- Distance to nature reserve area	4	1	0.10
Total		10	1.0	
Economic Criteria (Eco)				
1	Ec1- Distance to existing transportation roads	1	2	0.67
2	Ec2- Distance to existing mineral resouces planning area	2	1	0.33
Total		3	1.0	

Tab. 7. The result of evaluation criteria overall weights

Criteria level 1	Weight of criteria	Criteria level 2	Weight of criteria	Overall Weight
Geo. Geological	0.330	Geo1- Geological characteristics and mineral prospects	1.00	0.330
Ec. Economic	0.361	Ec1- Distance to existing transportation roads	0.67	0.241
		Ec2- Distance to existing mineral resouces planning area	0.33	0.120
En. Environment	0.181	En1- Distance to national highway, provincial road	0.40	0.072
		En2- Distance to historical, cultural, scenery, religious and belief sites	0.30	0.054
		En3- Distance to surface water protection corridor	0.20	0.036
		En4- Distance to nature reserve area	0.10	0.018
Soc. Society	0.127	Soc- Distance to concentrated residential area	1.00	0.127

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The results of calculating the overall weight of the group of criteria level 1 and the weights of criteria level 2 is shown in Tab. 7. From the 8 criteria layers that were constructed and assigned overall weights according to the results in Tab. 7, a weighted overlay was performed using the Raster Calculator tool in ArcGIS 10.8. The result is a map illustrating the priority zoning for surveying backfill material to be included in the mineral resouces planning scheme, categorized into 4 priority levels from lowest to highest, as shown in Fig. 19.

The zoning map indicates a potential area for surveying fill material (VLSL) amounting to 30,434 hectares, which accounts for 16.09% of the study area, as detailed in Tab. 8.

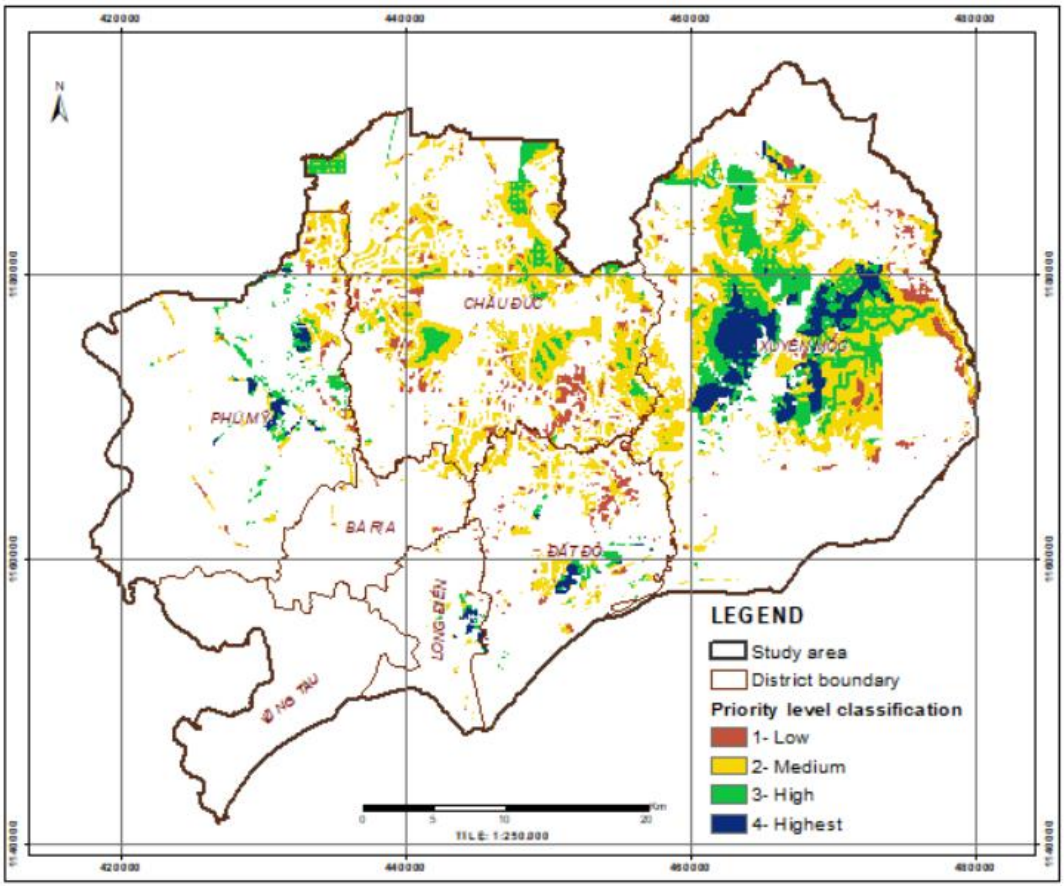

Fig. 19. Map of zoning priority area for surveying backfill materials of mainland of Ba Ria - Vung Tau Province

Tab. 8. The result of zoning priority areas

Priority level	Description of priority level classification	Area (ha)	Percent (%)	Colour coded
1	Low Priority	2,729	9.0%	
2	Medium Priority	16,184	53.2%	
3	High Priority	7,987	26.2%	
4	Highest Priority	3,534	11.6%	
Total Potential Area Assessed		**30,434**	**100%**	

The statistical analysis of the priority areas by district administrative unit shows that: the priority survey area is not distributed in Vung Tau City and which is very limited in Ba Ria City. The area with the highest priority for surveying is Xuyen Moc district, accounting for 57.43% of the total assessed area. This is followed by Chau Duc district, which represents 29.77% of the total assessed area. All districts have a medium priority level, which is the most prevalent (Tab.9).

Tab. 9. Distribution of priority area according to district administrative unit

District Administrative Unit	Low Priority	Medium Priority	High Priority	Highest Priority	Total	Percentage (%)
Ba Ria	23.1	102.8	0.0	0.0	125.9	0.41%
Phu My	202.2	865.1	563.2	328.3	1,958.6	6.44%
Chau Duc	1,115.0	6,364.2	1,579.9	0.0	9,059.1	29.77%
Vung Tau	0.0	0.0	0.0	0.0	0.0	0.00%
Long Dien	10.2	81.5	60.0	69.9	221.6	0.73%
Xuyen Moc	1,065.8	7.849.1	5,562.9	2,999.6	17,477.4	57.43%
Dat Do	312.9	921.6	220.8	136.5	1,592	5.23%
Total	**2,729.1**	**16,184.3**	**7,986.8**	**3,534.2**	**30,434.4**	**100%**

(Unit of area: ha)

The evaluation of the distribution of priority survey areas compared to the distribution of some important assessment criteria shows that high-priority areas are located within the forecasted mineral potential areas of level B (the highest level for construction materials), close to existing mineral resouces planning sites, and not too close to major roads and residential areas. This aligns with the weighted assessment results of the criteria regarding mineral geology, economic effectiveness, and social impact, which are ranked from high to low in terms of priority for survey area selection. Some planned areas do not meet these criteria and are often located near residential areas and major transport routes.

Thus, with 8 assessment criteria for selecting survey areas and 10 exclusion criteria, a priority survey area map has been created based on a multi-criteria analysis integrated with GIS software. The priority survey area map reflects the distribution of survey priority levels, in accordance with the weighted assessment results of the influencing criteria. The areas with the highest priority levels are those that meet the most important evaluation criteria.

4. Conclusion

The study results for selecting backfill material survey areas for common construction material minerals planning, pilot for Ba Ria - Vung Tau Province utilized a multi-criteria weighted assessment system combining and GIS to create a survey priority area map as a basis for planning, consisting of two sets of criteria: exclusion criteria and evaluation criteria. The research is based on the regulations of the Mineral Resources Law, Planning Law, and guidelines from the Ministry of Natural Resources and Environment regarding prohibited mining activities. Additionally, other land areas in land use planning that cannot be converted to mining activities are also included in the exclusion zones. The study identified 10 exclusion areas with a total overlapping area of 158,741 ha, accounting for 83.91% of the study area. The remaining area, which constitutes 16.09% of the study area, was identified as a potential area for construction material surveys. This area is assessed based on the evaluation criteria and categorized into four priority levels from low to high.

The evaluation criteria influencing survey area selection included 8 criteria across 4 groups based on the goal of meeting requirements for mineral quality, high economic efficiency, minimal social impact, and environmental protection. The criteria were prioritized based on geological mineral data, minimum safety distances from mining activities to protected areas, and practical surveys of mining sites. The assessment criteria were weighted using the AHP method for the group criteria and the inverse rank weighting method for the secondary criteria. The overall weight is calculated as the product of the group weight and the secondary criteria weight, which will be assigned to the prioritized map layers for each criterion for overlaying in ArcGIS. The overlay results of the criteria in GIS have constructed a survey priority area map with four levels of priority from low to high. Among these, the medium priority area accounts for the highest proportion at 53.2%, followed by the high priority area at 26.2%, while the low and highest priority levels account for 9.0% and 11.6%, respectively. The district with the most survey areas selected is Xuyen Moc, with 57.43%, which also has the largest proportions of high and highest priorities. These areas correspond well with the criteria established during the priority assessment.

The survey priority zoning map for backfill material is a comprehensive result synthesizing various data sources, which can assist planners and managers in the initial stages of developing exploration, extraction, and utilization plans for common construction materials across Ba Ria – Vung Tau Province. With newly updated databases and current conditions regarding mineral extraction over time, the criteria may need adjustments for practical application.

This study has proposed a methodological system that are reliable, comprehensive, detailed, ensure economic - social - environmental safety to select surveying areas of backfill material as a basis for the mineral resources planning. This methodological system has integrated multi-criteria assessment method and GIS which the current mineral resources planning works have not applied for comprehensive and effective assessment.

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