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Article

Investigating Lateritic Soil Properties and Impacts from Quarrying Activity on Communities in Southern Thailand: A Case Study

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Abstract. This paper details the impact arising from the lateritic soil quarrying activity in many communities within the Songkhla province in Southern Thailand. The affected communities of Ban Khuan Chong, Ban Huay Oan and Ban Thung Don were selected as target areas for the study based on the suitability of their active quarry sizes and locations which are conspicuous on the aerial photographs of Google Maps, and where permission to collect data was forthcoming from the quarry operators. Assessments were made to determine the extent of impact on the communities in terms of the environment, people's health, and effects on transport infrastructure. Findings from the study are disseminated through a website featuring a database of quarry sites in the province, engineering properties of the soils therefrom, and details of impacts from various types of soil excavation. The website is designed to help promote responsible quarrying and optimize the use of lateritic soil for road building.

Keywords: Lateritic soil, soil quarry business, impacts from soil quarrying.

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1. Introduction

Lateritic soil is a suitable natural aggregate for such uses as landfill, or as the main ingredient in the base or subbase layers of road pavement. Lateritic soil has always been employed as an option along with crushed rock which has greater load bearing strength. But due to shortages of crushed rock in many regions of Thailand and the environmental impact from rock quarrying, lateritic soil has been increasingly employed as an alternative material. The strength profile of lateritic soil can be adequately upgraded upon stabilization of its matrix using a small volume of cement to aid bonding of the soil particles. Tests of stabilized soil samples have shown that the unconfined compressive strength and elasticity of such mixture are improved significantly as its cement content is increased. Such a characteristic makes lateritic soil a viable substitute for crushed rock [1, 2].

In Thailand, the largest volume of lateritic soil deposit is found in the northeast region which accounts for some 42% of the country-wide volume while only 12.23% is found in the southern region. The top five provinces in the South having large deposits are Songkhla (SKA), Chumphon (CPN), Surat Thani (SNI), Trang (TRG) and Nakhon Si Thammarat (NRT) [3]. The deposits in SKA, SNI and NRT are among the more significant in terms of their investment value assessed for the construction industry in 2012 and 2013. It should be noted that the Gross Provincial Products (GPP) of these three provinces were over two times higher than those of TRG and CPN. During the years of assessment, the trend of investment in the construction sector relative to GPP indicated that SKA had the largest sector growth of 0.97%. The rate was well above that for the entire South (0.1%). During the same period, the construction sectors of SNI and NRT showed negative growths of -0.39% and -0.13% respectively [4]. (See Table 1)

For the period assessed, the construction industry in the South was entering a revival phase. Table 1 indicated that the combined contributions by the construction sectors of SKA, SNI and NRT to the 2013 GPP amounted to 22,078 million baht, or 75.9% of the total contribution to the Southern economy. As a result of this growth surge, demand for construction materials went up, thus spawning large increases in the volume of lateritic soils that were employed for landfill and road pavement. While demand for the material had risen, construction companies in the South were finding it more difficult to properly manage their supplies of lateritic soil. This was due to adverse factors, such as: the dwindling volumes of the local deposits, poor land-use plans, inadequate information on soil quarry locations as well as lack of precise specification of soil properties from the quarries. Excavation of laterite in the South has largely been operated by local entrepreneurs on permits from the Provincial Industry Office, Ministry of Industry [5]. With demand taxing the supply capacity of the licensed pits, some entrepreneurs have resorted to illegal practices by which laterite is mined for sale without a permit. Such undesirable enterprises have thrived due to the shortages of government inspectors and monitoring budgets. The largely under-supervised quarrying, combined with the illegal practices, have given rise to environmental issues including inappropriate land-use, health impacts on people in the communities, damage to transport infrastructure and impacts on other spheres of human activity.

Table 1. GPP values, Investment in construction sector, and Investment in construction sector relative to GPP of five Southern provinces, for 2012 and 2013 [4].

Province	GPP (Million baht)		Construction sector (Million baht)		Construction sector/GPP (%)		Diff. (%)
	2012	2013	2012	2013	2012	2013	
Songkhla	215,485	220,712	10,664	13,063	4.95	5.92	0.97
Surat Thani	169,550	161,949	5,936	5,034	3.50	3.11	-0.39
Nakhon Si Thammarat	144,020	139,625	4,286	3,981	2.98	2.85	-0.13
Trang	72,773	68,146	1,893	1,755	2.60	2.58	-0.02
Chumphon	64,439	63,724	1,759	2,011	2.73	3.16	0.43
Southern Region	737,190	738,562	28,278	29,086	3.84	3.94	0.10

To aid the optimization of lateritic soil use and to look into the impact of its quarrying activity, the Study Team began this project in December 2014. This paper describes the outcome of the Team's examination of properties of the soils from the quarries surveyed and the stated preferences of the communities affected by impacts from them. The Team has established a website to disseminate the information from the study to people whose jobs concern materials planning as well as to interested stakeholders and government agencies. Soil quarry locations are indicated on GIS maps supplemented by survey data to assist planners when sourcing materials and for mitigating likely impacts on the communities. Scope of the website may be extended in the future to include soil deposits in other provinces [6].

2. Methodology

2.1. Criteria for Selecting Study Areas

Songkhla (SKA) was selected due to its highest volumes of lateritic soils as well as its having the highest construction sector growth relative to GPP in the interval from 2015 to 2016. Three lateritic soil quarries in the province were chosen for the investigation of soil properties plus appraisal of the impacts the quarrying activity has on surrounding communities. These quarries are chosen for the following reasons:

1. The quarry size is large enough to be seen on the aerial photographs of Google Maps.
2. Permission to conduct surveys on the premises was forthcoming from the owner/operator.

2.2. Survey Data and Analysis of Lateritic Soil Properties

Data pertaining to each site were obtained including soil samples, daily productivity, characteristics of location and communities. The soil samples were subjected to laboratory analysis to determine properties such as color, moisture content, dry density, Atterberg Limits, compaction test, CBR, sieve analysis as well as classification by the Unified and AASHTO systems.

2.3. Evaluation of Impact Severity on Surrounding Communities

The impacts from lateritic soil quarrying were evaluated by way of a questionnaire survey involving respondents who were living in the communities. The questionnaire employed consisted of three sections: respondent's personal information, data relating to impacts from quarry activity, and factors affecting the respondents' preference level for severity of impact. The respondent sample size was determined by Cochran's formula, shown as Eq. (1) [7] below.

$$n = \frac{p(1-p)Z^2}{e^2} \tag{1}$$

where	n	=	Sample size
	p	=	The estimated proportion of an attribute that is present in the population
	e	=	The acceptable sampling error
	Z	=	Confidence level at 95%

For this study, the impact from soil quarrying is categorized into four areas, each with its associated sub-types, as follows:

1. **Land-use**: impact on the land adjacent to the excavation pits and on surrounding agricultural land.
2. **Environment and Health-related**: impact from the spread of soil dust from the pits, from the soil hauling trucks; noise, vibration and exhaust emission from the trucks; contamination of public water sources and effects on people's health.
3. **Transportation**: damage to road pavement and increased likelihood of road accidents.
4. **Other** forms of impact.

The impact severity levels were determined by the Likert scale [8] based on five response alternatives cited by the interviewers, as follows: no effect = 1; minor effect = 2; neutral = 3; moderate effect = 4 and major effect = 5. The severity of impact was found to vary with the distance the respondent's home is away from a soil pit. The severity contours were rendered, using ArcView software, at a 10km radius on a multi-

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layered data map and contour lines on the map are color-graded according to severities of impact as shown in Fig. 1.

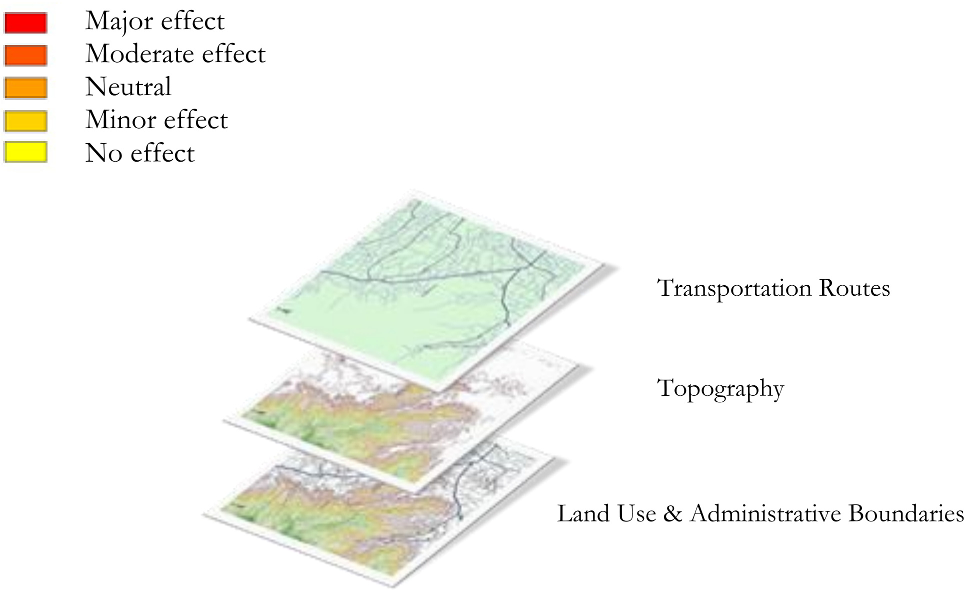

Fig. 1. Multi-layered data map rendered by ArcView.

In using ArcView to determine the impact severity levels on GIS map, the four steps listed below were followed for each quarry.

1. Determine the coordinates of a soil quarry.
2. Determine the contour lines around the pit at intervals of 1 km./line, consisting 10 lines for a total distance of 10 km.
3. The average level of impact is evaluated and rendered according to severity on the contour lines for each distance from the soil pit to the respondent's home.
4. The impact severity levels are shown on the GIS map by type: i.e. Land-use impact on the terrain layer, Environment and Health-related impacts on the administrative boundaries layer and Transport impact on the transportation layer.

2.4. Simulation Models and Website Development

Logit models were employed to analyze the factors of impact based on the Random Utility Theory given that they are generally preferred for producing forecasts in cases where there are two or more categorical variables. A Binary model is used in cases where the number of choice variables is limited to only two while a Multinomial model where it is more than two. The logit model is represented by Eq. (2). [9, 10]

$$P_{iq} = \frac{e^{V_{iq}}}{\sum_{j=1}^{k} e^{V_{jq}}} \tag{2}$$

where	P_{iq}	=	Probability of the ith alternative for the qth individual
	V_{iq}	=	Representative utility = Uiq - εiq = $\Sigma\beta jkXikq$
	U_{iq}	=	The utility of the ith alternative for the qth individual
	β_i	=	Utility parameter of independent variables
	ε_{iq}	=	A random component
	X_{ikq}	=	Set of vectors of measured attributes of the decision makers

Output from the simulation models were compiled and published on a website specifically developed to provide information that will help to promote better use of lateritic soil within the industry. Users may obtain from the website information such as locations (with coordinates) of the soil quarries, soil properties, characteristics of the affected communities and the nature of impact upon them from the quarrying activity.

3. Results and Discussion

3.1. Specifics of the Study Areas

The three communities of Ban Khuan Chong, Ban Huay Oan and Ban Thung Don in SKA, which served as the target areas of this study, are shown in Fig. 2 below.

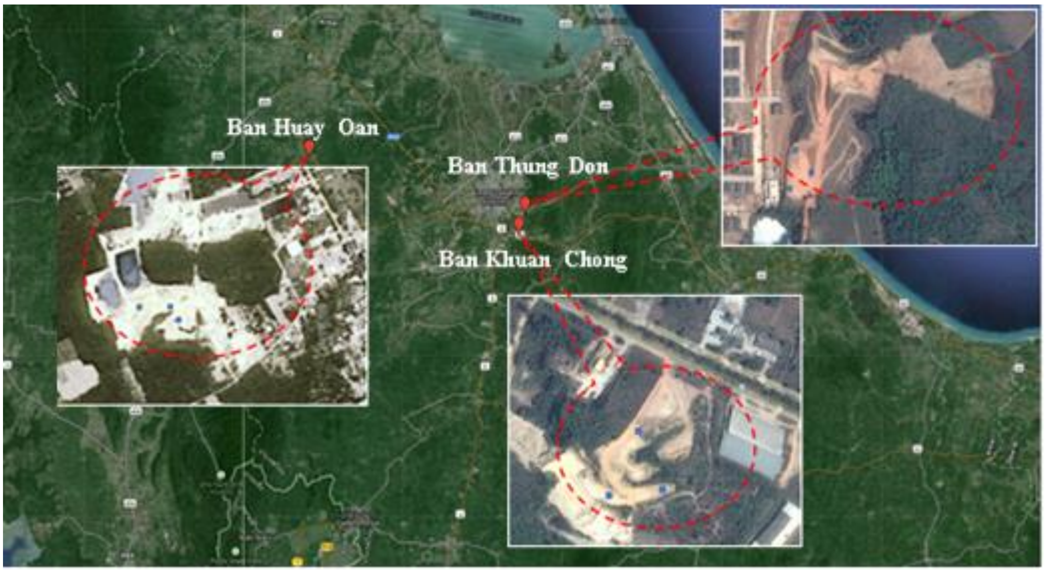

Fig. 2. Locations of the lateritic soil quarries within the three SKA communities under study [11].

Table 2 below shows the characteristics of the lateritic soil pits and their surrounding communities.

Table 2. Characteristics of the lateritic soil pits and communities.

General Information	Ban Khuan Chong	Ban Huay Oan	Ban Thung Don
Location	Sta.1+200 RT.3.3 km. Highway No. 2085	Sta.30+000 LT. 700 m. Highway No.4	Sta.2+300 RT. 300 m. Highway No.43
Coordinates of community location	N6.967638, E100.498879	N7.050219 E100.267219	N6.987855 E100.505381
Productivity/day	80-100 of 10-wheeled trucks	100 of six-wheeled trucks	50-80 of six-wheeled trucks
Operator contact number	081-0942199	089-1978036	085-8920669
Community characteristics	• Demographics mainly business operators and wage employees. • Distance of 2 km from soil pits to local roads. • Homes located along the two roads and close to the soil pits.	• Mainly farmers. • Distance of 300 m from soil pits to local roads. • Five operating soil pits in community.	• Farmers, business operators and wage employees. • Distance of 800 m from soil pits to local roads. • Many soil pits and factories in community.

3.2. Properties of Soil Samples Surveyed

Results of laboratory analysis of the soil samples from the three communities are shown in Table 3.

Table 3. Engineering properties of lateritic soil samples from communities under study.

Descriptions	Ban Khuan Chong	Ban Huay Oan	Ban Thung Don
Coordinates of lateritic soil quarry	And6.967941, E100.499094	And7.050381, E100.2666610	And6.987572, E100.505238
Soil color	Dark Brown	Light Brown	Dark Brown
Moisture content (%)	7.72	5.26	4.66
Atterberg limits			
Liquid limit (%)	23.80	35.05	43.20
Plastic limit (%)	15.47	23.76	24.52
Plastic index (PI) (%)	8.33	11.29	18.68
Compaction test (Modified Proctor)			
OMC* (%)	7.00	12.50	13.00
Maximum dry density (Tonne/m^3)	2.150	1.780	2.040
California Bearing Ratio (CBR)			
95% modified proctor	110.0	45.0	110.0
Sieve Analysis (Sieve no. & % Passing)			
3/8	93.46	93.97	82.30
4	85.96	90.37	72.66
10	73.29	82.08	67.36
20	59.72	74.95	62.09
40	46.67	69.77	58.84
100	26.05	63.55	51.79
200	23.44	62.90	49.00
Pan	00.00	00.00	00.00
Soil Classification			
AASHTO	A-2-4	A-6	A-7-6
Unified	SC	CL	GC

*Remark: *OMC is Optimum Moisture Content*

Table 3 shows the test-derived properties of the soil samples from Ban Khuan Chong: color is dark brown, moisture content 7.72%, PI 8.33%, maximum dry density 2.150 tonne/m^3, CBR 110% of 95% modified proctor with OMC 7%. They are classified as A-2-4 of the AASHTO system and SC of the Unified system. The samples from Ban Huay Oan are light brown, having a moisture content 5.26%, PI 11.29%, maximum dry density 1.780 tonne/m^3, CBR 45 % of 95% modified proctor with OMC 12.5%; and a classification of A-6 in the AASHTO system and CL in the Unified system. Samples from Ban Thung Don are dark brown, with moisture content 4.66%, PI 18.68%, max. dry density 2.040 tonne/m^3, CBR 110% of 95% modified proctor with OMC 13%; and fit in the A-7-6 AASHTO and GC Unified classifications.

Table 4 lists the ratings and suitable uses of aggregates on the AASHTO and Unified systems. Based on these ratings, it can be seen that the soil from Ban Khuan Chong, which exhibits a mixture of well-graded sand with small clay (SC), a CBR of 110% and an Excellent rating (A-2-4), is suitable for bearing loads as the base layer of road structures. The sample from Ban Huay Oan is a range of inorganic or gravel or sandy clays (CL) with lower load capacity (CBR, 45%) and a Fair rating (A-6). It may be used as aggregate for a subbase layer. The soil of Ban Thung Don is a mixture of gravel-sand-clay (GC) which has good load capacity (CBR 110%) and a Fair rating (A-7-6), all of which would make it a good candidate for use as a road base layer.

Table 4. Unified and AASHTO classifications of road aggregates [12].

% CBR	Rating	Uses	Unified System	AASHTO System
0 – 3	Very Poor	Subgrade	OH, CH, MH, OL	A-5, A-6, A-7
3 – 7	Poor to Fair	Subgrade	OH, CH, MH, OL	A-4 ,A-5, A-6, A-7
7 – 20	Fair	Subbase	OL, CL, ML, SC, SM, SP	A-2 ,A-4, A-6, A-7
20 – 50	Good	Subbase, Base	GM, GC, SW, SM, SP,GP	A-1-b, A-2-5, A-3, A-2-6
>50	Excellent	Base	GW, GM	A-1-a, A-2-4, A-3

3.3. Evaluation of Impact Severity Levels Affecting the Communities

The required number of respondents was calculated using Eq. (1) with $p = 0.5$ (if unknown proportion of population) and $e = 0.10$. The calculation gave the number of respondents at 96 per community. This was rounded up to 100 respondents per community. Responses from respondents of Ban Khuan Chong averaged to an overall 'no effect' choice. For Ban Huay Oan and Ban Thung Don, some of the respondents cited the 'minor effect' caused by air-borne dust from the soil pits and the hauling trucks, noise and vibration impact from these vehicles, road pavement damage and traffic accidents. Yet some others cited 'no effect' from similar disturbances. The outcome of impact investigation in the communities is shown in Table 5.

Table 5. The average levels of impacts in the study communities of SKA.

Impact	Ban Khuan Chong		Ban Huay Oan		Ban Thung Don	
	Score	Level of impact	Score	Level of impact	Score	Level of impact
Land Use						
Land adjoining the pits	1.08	No effect	1.14	No effect	1.33	No effect
Agricultural areas	1.00	No effect	1.17	No effect	1.20	No effect
Environment & Health Related						
Dust from soil pits	1.43	No effect	1.50	No effect	1.54	No effect
Dust from hauling trucks	1.65	No effect	2.27	Minor effect	2.17	Minor effect
Noise/Vibration from trucks	1.50	No effect	1.95	Minor effect	1.55	No effect
Truck exhaust emission	1.29	No effect	1.71	No effect	1.48	No effect
Public water sources	1.10	No effect	1.11	No effect	1.27	No effect
Public health	1.36	No effect	2.05	Minor effect	2.41	Minor effect
Transportation						
Roads pavement damage	1.55	No effect	2.07	Minor effect	2.21	Minor effect
Road traffic accidents	1.54	No effect	2.27	Minor effect	2.15	Minor effect
Other forms of impact						
other	1.00	No effect	1.00	No effect	1.00	No effect

The severity of impact is represented by contour lines for distances from 0 to 10 km from a soil pit to respondent's home. The contours indicate that quarrying operations have no effect upon land-use on the areas adjacent to the excavation pits or agricultural land within the three communities. Some types of impact, however, are felt by the residents. These are environmental and health problems including dust from the pits and the haulage of the excavated soil, noise, vibration and exhaust emission from hauling trucks. The effects range from 'neutral' to 'moderate' as shown by the contour lines. Similarly, 'neutral' to 'moderate' impacts are experienced by the respondents in regard to transportation activities. The extent of damage to road pavement at 10 km from the soil pits of Ban Thung Don is viewed as a major impact. (See Table 6).

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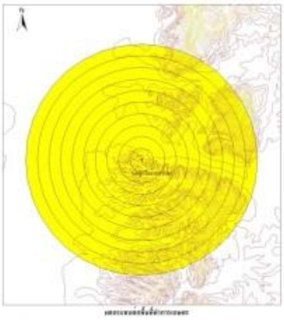
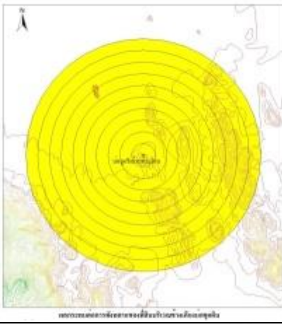
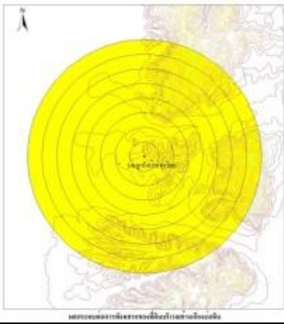
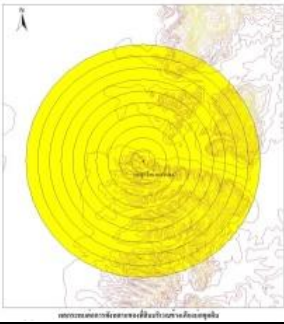
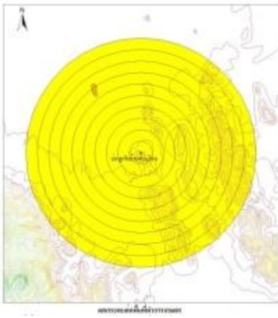
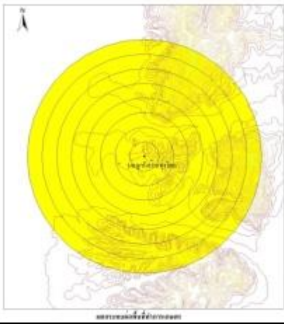
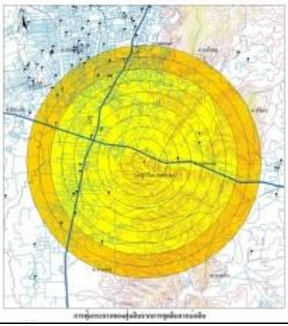
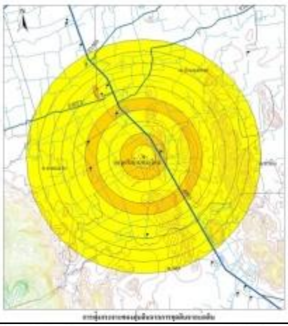
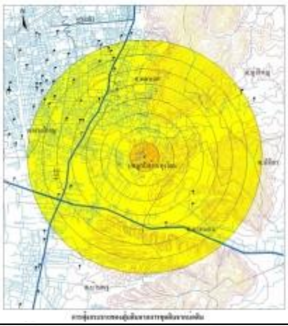
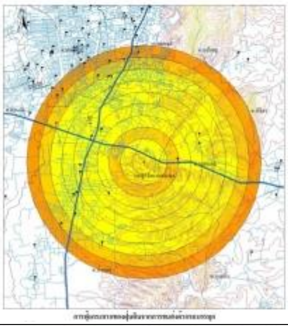
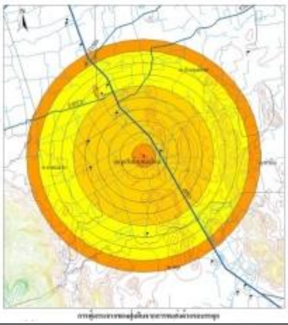
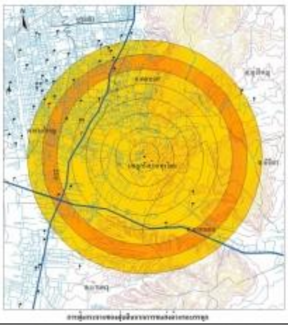
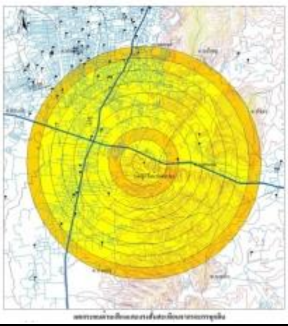
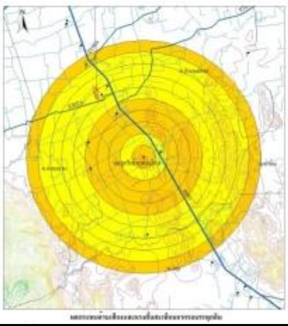
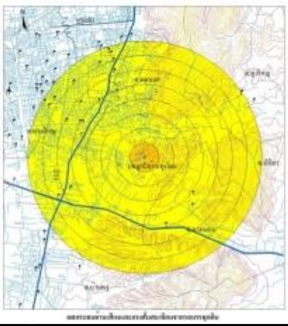
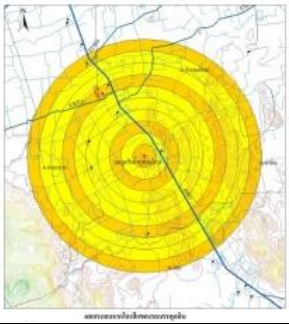
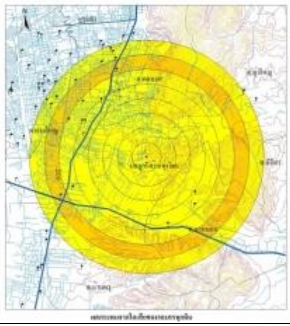
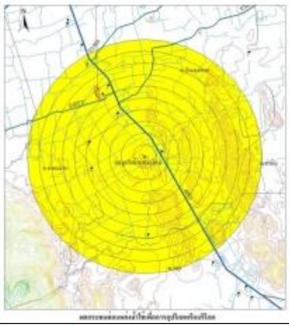
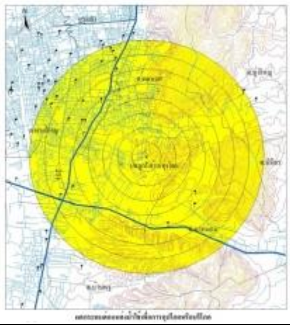
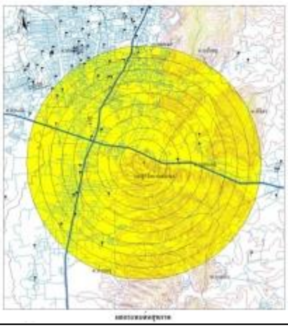
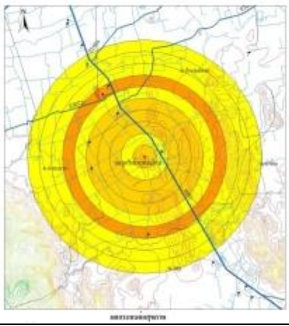
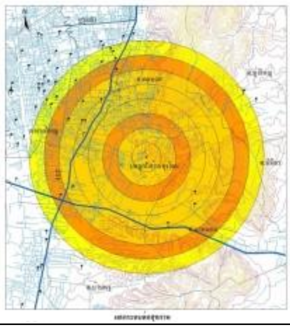
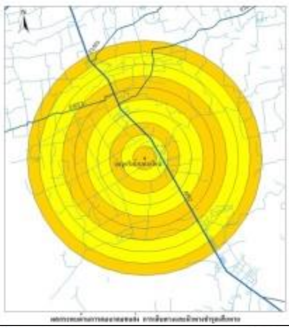
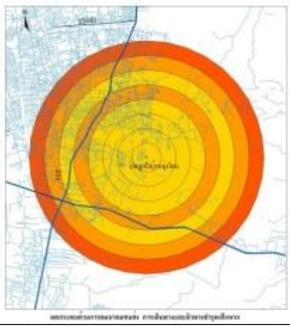
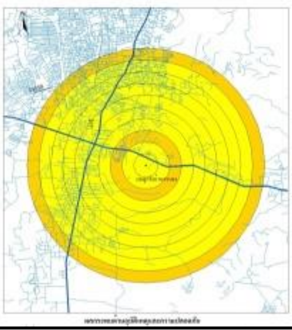
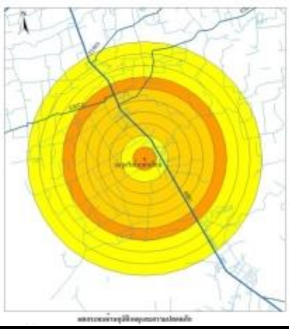
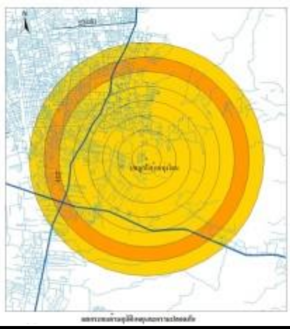
Table 6. ArcView generated contour lines of impact on the communities.

Type of Impact	Ban Khuan Chong	Ban Huay Oan	Ban Thung Don
Land Use			
1. Land around excavation pits			
2. Agricultural areas			
Environmental & Health Related			
1. Dust spreading from the pits			
2. Dust from soil trucks			
3. Noise/Vibration from soil trucks			

4. Exhaust emission from soil trucks			
5. Public water sources			
6. Public health			
Transportation			
1. Road pavement damage			
2. Road traffic accidents.			

As shown above, the effects on the Environment & Health Related and Transportation sectors are the most significant of soil quarrying impacts. Figure 3 below summarizes the averages of impact intensity felt by the respondents of the three communities. Environmental & Health impact was cited by about 65% of the respondents; Transportation impact was named by 26%; other impacts, 7% and Land Use impact, at a mere 2%.

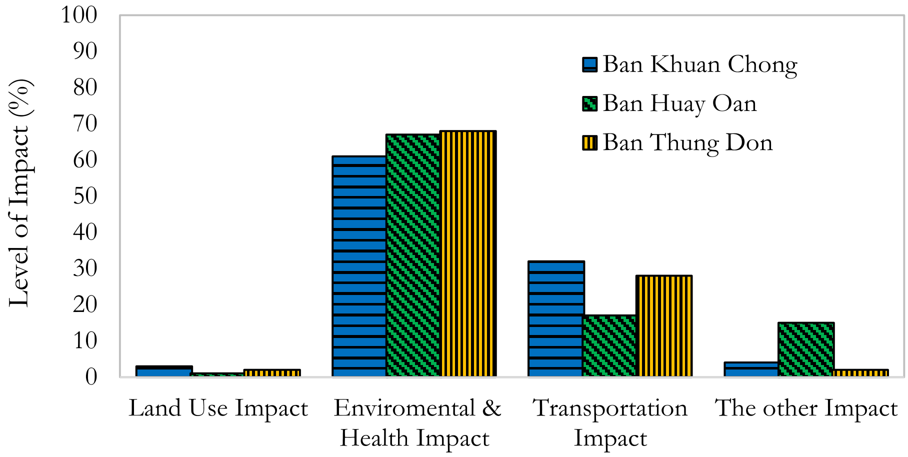


Fig. 3. Levels of impact felt by the three communities.

3.4. Model Results

Table 6 above shows that the outcome of impact investigations at the three communities are quite similar. This was due to the fact that the general characteristics of a quarry is more or less dictated by the regulational requirement of the Provincial Industry Office in regard to the siting of a soil pit. Given these conditions, the Team therefore chose to analyze the questionnaire data from the three communities as a combined lot. The Binary Logistics Regression model was employed to analyze such socio-economic and preferential factors that are likely to have an influence upon the level of impact felt by the respondents. The use of this regression model is appropriate given that the sample size at each community was smaller than 30 times the number of the independent variables considered in this research. There were eight attributes that accounted for the independent variables while the Environmental & Health and Transportation impacts made up the dependent variables.

Land-Use and Other impacts were disregarded at this step due to their being insignificant: out of 300 responses, only 27 cited these two types of impact. Dropping the said 27 thus left a sample size of 273.

The Binary Logistics Regression model is shown as Eq. (3) and details of dependent variables and independent variables are listed out in Table 7.

$$Y = \ln\left[\frac{P_{(Y=1)}}{P_{(Y=0)}}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots + \beta_i X_i \quad (3)$$

where Y = Independent Variables
βo = Utility parameter of Y intercept
βi = Utility parameter of independent variables

Table 7. Details of dependent variables and independent variables of Binary Logistics Regression model.

Variable	Meaning	Conditions
X_3	Marital status	Divorced = 0, Single = 1, Married = 2, Widow = 3
X_5	Occupation	Other = 0, Unemployed = 1, Government official = 2, Owner = 3, Employee = 4, Student = 5, Agriculturist = 6
X_9	Car ownership	In ranges
X_{18}	Timeframe of residency in the community; before or after soil pit operation?	After pit operation = 0, Before pit operation = 1
X_{26}	Dust impact from soil pit	No effect = 0, Effect =1
X_{40}	Impact on water sources	No effect = 0, Effect =1
X_{46}	Pavement damages	No effect = 0, Effect =1
X_{47}	Road traffic accidents	No effect = 0, Effect =1
$Y = \ln\left[\frac{P_{Y=1}}{P_{Y=0}}\right]$	Which impact from soil excavation in your community has the most effect?	Environmental & Health impact; Y = 0, Transportation impact: Y = 1

For an independent variable to be eligible as model input, it must be tested first to ensure its model fit, i.e. having a low degree of multicollinearity between that variable and its counterpart. To pass this test, the variable pair's Correlation Coefficient as determined from its Pearson's Chi-square ratio must not exceed 0.8. Where model fit is lacking, the problematic variable pair is to be inputted one by one for separate calculations whose outputs are then compared for reliability by looking at the values of their loglikelihood and adjusted R^2 [13].

The outcome of model analysis of the factors influencing level of impact from lateritic soil quarrying in Songkhla are shown in Table 8.

Table 8. Parameter estimation results of Binary Logistics Regression model.

Variable	β	S.E.	Wald	df.	Sig.	Exp(β)	95% C.I. for Exp(β)	
							Lower	Upper
β_0	.068	2.486	.001	1	.978	1.071	-	-
$X_3(2)$	-2.501	1.085	5.316	1	.021**	.082	.010	.687
$X_5(4)$	-1.132	.684	2.737	1	.098*	.322	.084	1.232
X_9	.630	.364	2.995	1	.084*	1.879	.920	3.836
X_{18}	2.287	.604	14.351	1	.000**	9.848	3.016	32.161
X_{26}	-1.023	.588	3.029	1	.082*	.359	.114	1.138
X_{40}	-1.807	.782	5.336	1	.021**	.164	.035	.761
X_{46}	.909	.298	9.314	1	.002**	2.482	1.384	4.449
X_{47}	1.251	.721	3.006	1	.083*	3.492	.850	14.357
Number of observations	*273*							
LL(0)	*281.028*							
LL(β)	*195.196*							
Cox&Snell R^2	*.303*							
Nagelkerke R^2	*.437*							
Hosmer & Lemeshow	$\chi^2 = 5.183$, *df.* = 8, *p-value* = .738							
Percentage correct	*82.9*							

*Remarks: *Confidence level at 90%, **Confidence level at 95%*

Table 8 shows the values of parameters that would have an influence on the level of impact. The results thus obtained indicated that this model is fit since the *p-value* of the *Hosmer & Lemeshow* test was higher than 0.05 (accepted null hypothesis) and its loglikelihood of constant (*LL(0)*) was higher than the loglikelihood of utility parameter of independent variables (*LL(β)*).

The analysis yields values of *Cox & Snell* R^2 and *Nagelkerke* R^2 at 30.3% and 43.7% respectively. The *Nagelkerke* R^2 indicates a moderately strong relationship between the observed and expected values. Also, the accuracy percentage of the Binary Logistics Regression is 82.9%. The range of independent variables with possible influence on the level of impact, at 95% confidence interval, include: $X_3(2)$: status (married), $X_{18}(1)$: respondents living in community before soil pit operation, X_{40}: impact to water sources and X_{46}: pavement damages. However, estimation at 90% confidence level produces the following parameters: $X_5(4)$: occupation (employee), X_9: Car ownership per household, X_{26}: Dust dispersion impact and X_{47}: Road traffic accidents. Utility function model is shown below.

$$\begin{aligned} Y = .068 - 2.501X_3(2)** - 1.132X_5(4)* + .630X_9* + 2.287X_{18}** - 1.023X_{26}* \\ - 1.807X_{40}** + .909X_{46}** + 1.251X_{47}* \end{aligned} \quad (4)$$

As shown in Equation (4), respondents cited transportation impact more than they did for environmental and health impact because constant variable (β_0) shows a positive sign. Respondents who were married or working as wage employees gave more concern to the impact on the environment and health caused by dust dispersion and water contamination by soil excavation activity. As can be expected, people who cited the effects on transport were those from car-owning households, who are also concerned about pavement damages and road traffic accidents along the soil haulage routes.

Values obtained from the simulation pointed to an interplay of the two major impacts felt by them: Transportation impact and Health & Environmental impact.

- Married persons (93%) and wage employees (76%) were concerned with health & environmental impacts;
- Car owners were more concerned with transportation impact — nearly twice (1.879) the level of concern over that of health & environmental impacts;
- Residents after pit operation were even more concerned with transportation impact — nearly ten times more.
- 74% of people affected by dust from the pits or water contamination voiced their concern on health & environmental impacts;
- For each level increase in severity of water resource impact, the respondents would exhibit more concern for health & environment rather than transport, on a ratio of 6.09;
- For each level increase in severity of transport impact (e.g. road damage), the respondents would exhibit more concern for transport impact rather than health & environment, on a ratio of 2.482;
- More people were concerned with road accidents and safety of transportation impact — 3.492 times more than concern for health & environmental impacts.

3.5. Website Development

A website was developed at *http://techno.nstru.ac.th/piti/project* to help people in the construction industry to optimize lateritic soil utilization and to provide information for the interested public. This facility features 4 sections including: 1) navigation, 2) sites and coordinates of soil pits on Google Maps, 3) lateritic soil properties and 4) impact contour lines by type, as shown in Fig. 4.

Figure 4 shows the navigation pane of the 4-sections as described below:

- Section 1 shows the navigation pane from where the users can select provinces, soil pits in a province and type of impacts.
- Section 2 shows the selected lateritic soil pit on Google Maps.
- Section 3 shows general information and properties of soil in the selected pit.
- Section 4 shows impact level contour lines of the site chosen in Section 1.

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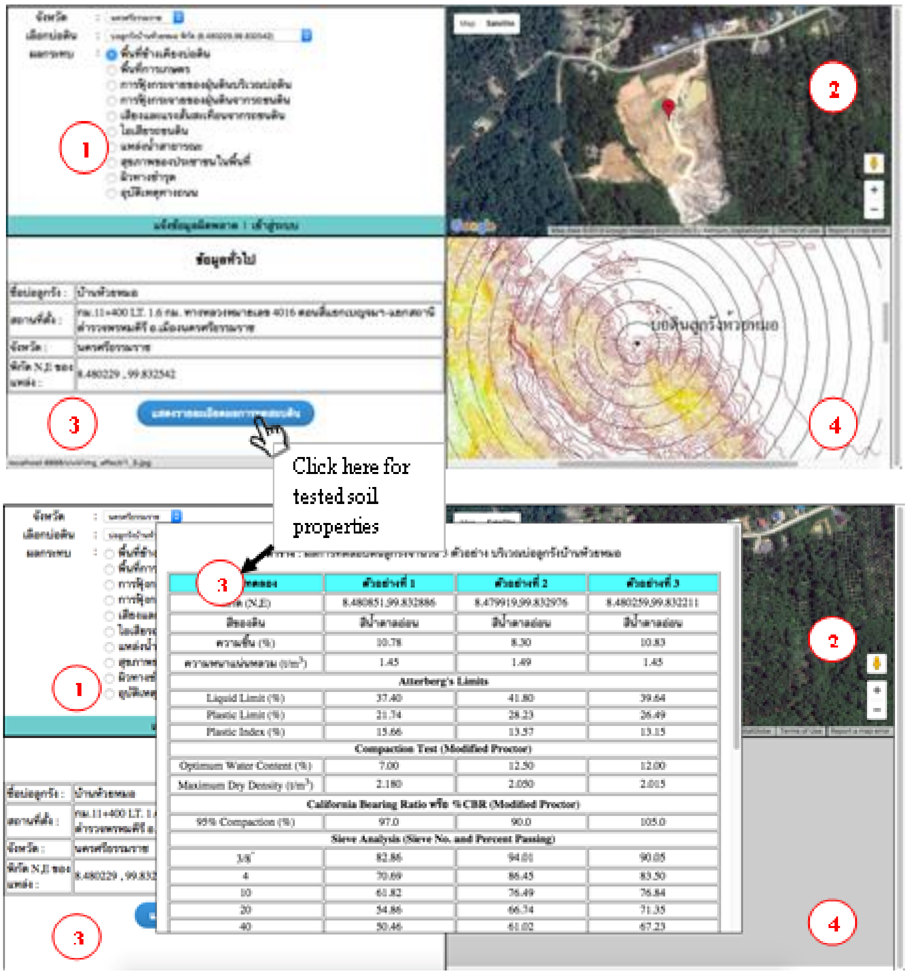

Fig. 4. A page of the website http://techno.nstru.ac.th/piti/project.

4. Conclusion and Recommendations

Lateritic soil quarrying activity in the target areas of SKA was investigated for its impact on nearby communities and for appraising the properties of the quarried soil for its suitability as a construction material. Two major types of impact were identified: Environmental & Health impact and Transportation impact, which are manifested by dust dispersion and contamination of water sources with soil debris, damage to road pavement and increased likelihood of traffic accidents along the soil transportation routes.

A website has been established at http://techno.nstru.ac.th/piti/project, to offer information on soil quarry sites, soil properties and the types of existing impacts from quarry operations. The followings are preliminary recommendations to soil quarry businesses and their stakeholders for mitigating some of the prevailing impact from soil excavation:

1. Perennial trees and cover crop should be planted around a soil pit to shield dust.
2. Clarifiers and settling ponds should be installed to treat quarry effluent before releasing the water into canal or natural waterway.
3. Local authorities should take more serious action on soil laden truck driven without proper rear dumper covering to prevent spillage, and on overloaded hauling vehicles using public roads.

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