Identification of Most Suitable Locations for Rock Quarrying to Supply Aggregate Requirements of the Colombo Port City Development Project

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Abstract: 'Colombo Port City Development Project' aims at reclaiming a minimum of 269 hectares of waterfront sheltered by Colombo South Harbour Breakwater for mixed development activities. It has been estimated that a total requirement of 26.6 million m^3 of dredged sand and 3.45 million m^3 of quarry materials for the reclamation and construction of coastal structures. The main objective of the present study is to assess and characterize the capability of identified quarry sites to provide different categories of rock for the project. The quarry site assessment of eleven quarries were carried out by incorporating factors such as rock quality parameters, mineable rock volume, type of rock, jointing or racturing in the rock mass, licence category, mining, hydrogeological and socio economic aspects. The data were gathered using numerous sources. Having combined geographic information systems (GIS) and Multi-Criteria Evaluation (MCE), the present study sought to locate the most suitable areas for rock quarrying to supply rock materials to Port City Project. The findings of the research indicate that four quarry sites are most capable of supplying all categories of rock and rest are more suitable for supplying rock products below 500 kg. Further findings of the research include suitable transportation routes and capacities for rock materials, potential adverse impacts on supplying materials and corresponding mitigatory measures to be adopted.

Keywords: ArcGIS, Multi-Criteria Evaluation, Satellite Imagery Analysis, Spatial Analysis

1. Introduction

'Colombo Port City Development Project' is one of the mega projects of the decade with the primary objective of developing Colombo as a dynamic naval, commercial and knowledge hub using Sri Lanka's strategic geographic location in the Indian Ocean. China Harbour Engineering Company Ltd., as the project company estimates a total requirement of 3.45 million m^3 of quarry materials varying from aggregates to armour rocks for the reclamation and construction of coastal structures to protect the land for the proposed Port City. However 0.12 million m^3 has been already used for erection of marine structures partly, prior to the temporary termination of the project in March 2015. Further 0.50 million m^3 of materials are stockpiled at the project site and can be used for the construction work once the project recommences. Therefore only 2.83 million m^3 of rock material is required to complete the marine structures of the Port City Project. The project company has identified 20 numbers of quarries with all of them being either IML/A or IML/B grade quarries with required approvals to

provide rock materials for marine structure construction. [1 and 2]

However, before recommencing the Port City Development Project in near future, it has become an urgent requirement to properly assess the capability of aforesaid quarries to provide the required construction material.

Given the above background, the main objective of this study is to evaluate and map suitable quarry sites for rock quarrying, based on developed indicators.

2. Methodology

2.1. Data collection and identification of key factors

The potentially suitable quarry sites for rock quarrying to obtain all different categories of required rock materials have certain features which are contingent upon several factors.

Considering the literature [3] and the local conditions of the studied areas and in order to build on the previous research, six parameters namely total mineable rock volume, Industrial Mining License (IML) category, state of weathering, state of fracturing, overburden thickness and distance to project site were identified as key criteria in the present study.

2.2. Development of spatial data layers

Table 1: Thematic layers with corresponding classes and weightages

Thematic Layers	Normalized weightage	Classes and weightages
Total mineable rock volume	0.1364	1 – 11 Depending on descending order of values
IML Category	0.2727	1 – IML/A (Suitable) 0 – IML/B (Not suitable)
State of weathering	0.2273	3 – Not weathered 2 – slightly weathered 1 – Moderately weathered 0 – Heavily weathered
State of fracturing	0.2273	3 – Not fractured 2 – slightly fractured 1 – Moderately fractured 0 – Heavily fractured
Overburden thickness	0.0909	1 – 11 Depending on ascending order of average and maximum overburden thickness
Distance to project site	0.0454	1-4 Depending on descending order of average distance
Total	1.0000	

The layers based on the importance of the layer and classes within layers based on their suitability were provided with weightages using ranking method as shown in above in Table 1 for MCE [4 and 5].

2.3. Development of an integrated layer

An integrated map layer for identifying most suitable quarry sites which can provide all rock categories were developed using the following feasibility index (FI) equation by integrating the classified thematic layers.

$$FI=(W_{rv}+W_{ot}+W_{dis})\times(W_{cat}\times W_{w}\times W_{f}) \quad .....(1)$$

Where, *FI*: Feasibility Index (0-least feasibility), *Wrv*:Weighted total mineable rock volume rank, *Wot*: Weighted overburden thickness rank, *Wdis*: Weighted distance from quarry site to project site rank, *Wcat*: Weighted IML category rank, *Ww*: Weighted state of weathering rank

and *Wf*: Weighted state of fracturing rank.

In the present study, based on the literature review and the local conditions of the area, three layers including IML category, weathering and fracturing states were taken into account to determine the exclusionary areas for supplying quarry materials over 1000kg.

2.4. Data analysis

Further analysis was carried out to determine the ability to meet the usual national requirements of aggregates and other rock materials, while supplying material to Port City Project, types of vehicles and daily rock capacities based on average daily requirement of rock materials, transportation routes for haulage of extracted material from quarry sites to Port City, potential adverse social and environmental impacts due to mining, loading/unloading and haulage of material at quarry sites, haulage routes and project site (including stockpiling sites) and appropriate mitigatory measures.

3. Results

Test results [6] for target quarry material are given in Table 2.

Table 2: Test results

Test	Quarry run	Quarry stone
Apparent relative density (BS 812:Part 2)	>2600 kg/m^3	>2650 kg/m^3
Water Absorption (BS 812: Part 2)	<5%	<2%
Soundness – $MgSO_4$ (BS 812: Part 121)	<18%	<12%
Los Angeles Abrasion (ASTM C- 535)	<35%	<18%

The total mineable rock volume of all studied quarries is 7,287,758 m^3 Therefore, the total requirement of balance rock materials (2.83 million m^3) is only 38.8% of the total mineable rock volume of 11 studied quarry sites.

Careful analysis of data shows that each and every quarry site studied is capable of providing rock materials to the Port City Project. However, integrated map layer obtained through MCE based on six factors shows four quarry sites are more suitable for supplying all categories of rock and others are more suitable for providing materials mostly below size 500 kg. The other factors which are not used for MCE show similar effect on all studied quarry sites. Two trips of 35 numbers of ten wheelers and two trips of 293 numbers of six wheelers per day will be transporting quarry materials from the selected quarry sites to the Port City Project Site via six land routes so that traffic jams would be minimum.

Table 3: Supply of different categories of rock

Description	Total (m^3)	Quarries in the order of feasibility
2000-5000 kg rock	168,000	4,8,1,6
1000-3000 kg rock	15,000	4,8,1,6
2000-3000 kg rock	154,000	4,8,1,6
200-500 kg rock	7,500	All quarry sites
300-500 kg rock	30,000	All quarry sites
700- 1400 kg rock	42,000	All quarry sites
1200-2500 kg rock	364,000	All quarry sites
Quarry run (1-500 kg)	1,260,000	All quarry sites
Inverted filter rock	161,000	All quarry sites
Rubble stone rock	132,000	All quarry sites
10-100 kg rock	100,000	All quarry sites
1-50 kg rock	80,000	All quarry sites
Gravel stone	180,000	All quarry sites
Total	3,413,000	

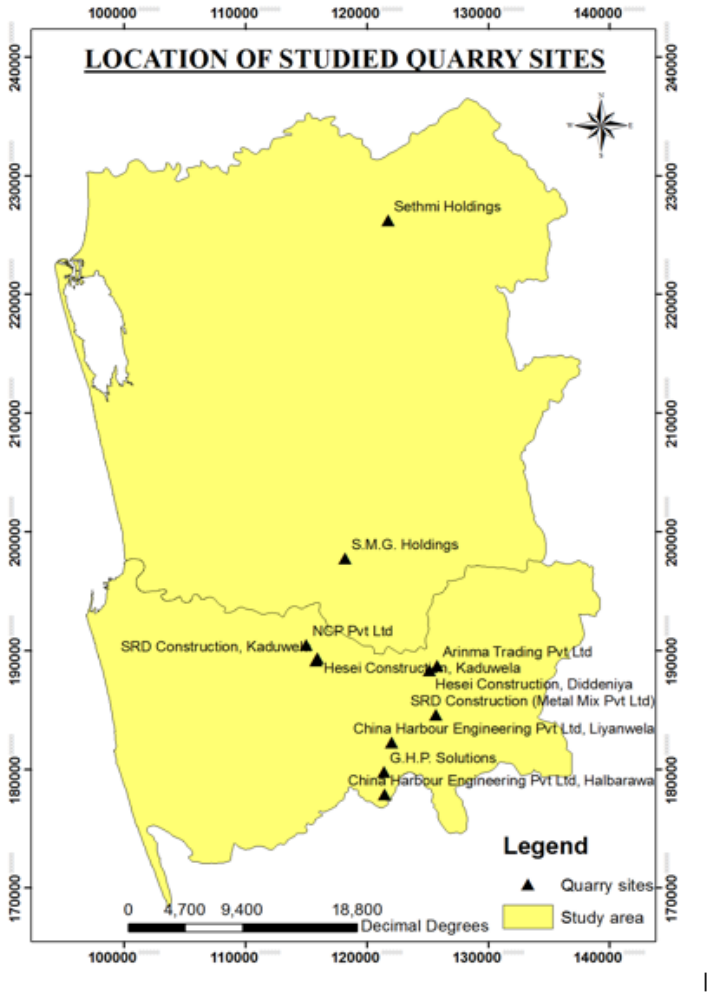

Figure 1: Studied quarry sites

4. Conclusions and Recommendations

The studied areas contain primarily gneissic and migmatic rock bearing garnet and biotite as major minerals. The materials had been tested for apparent relative density, water absorption, resistance to weathering, abrasion and the results of all samples are within the required limits for a project of this nature.

Table 4: Most suitable areas for rock quarrying to supply rock materials larger than 1000 kg

No	Name and address of the quarry	Ranking based on FI
4	SRD Construction – Nooranim Estate, Meepe, Padukka (Metal Mix Pvt.ltd)	1
8	NCP (Pvt) Ltd – Nawagamuwa, Ranala	2
1	Hesei construction – Ranala South, Kaduwela.	3
6	China harbour Engineering, Liyanwela,Padukka	4

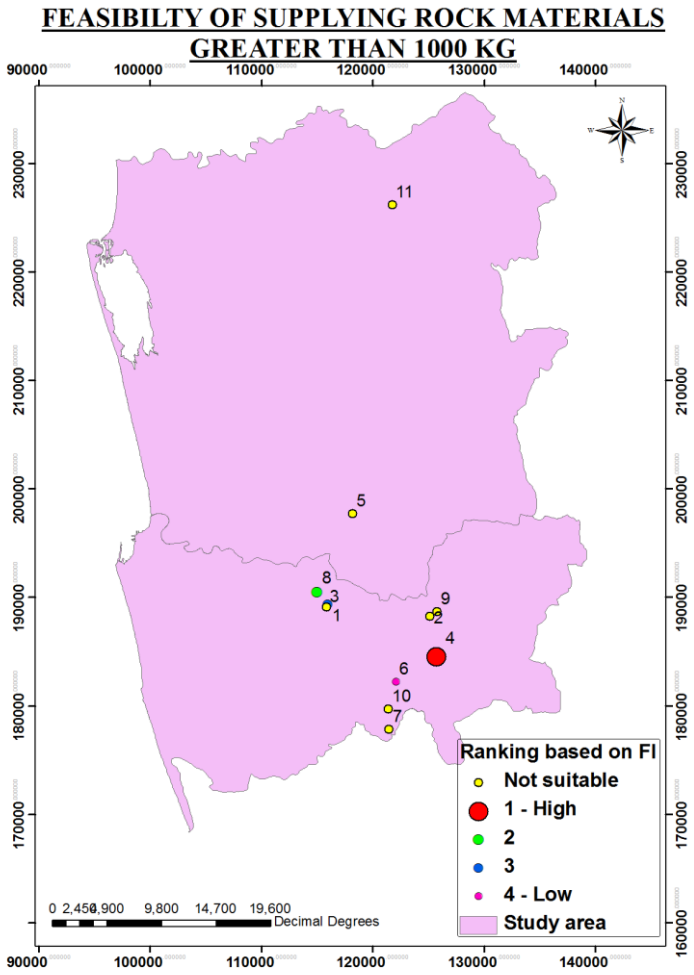

Figure 2: Most suitable areas to supply rock materials larger than 1000 kg

Studied quarry sites together are capable of providing all required rock materials for the Port City project where four quarry sites are more suitable for supplying all categories of rock (Figure 2 and Table 4) and others are more suitable for providing materials mostly sizes below 500 kg. Supply of materials for Port City Project will not cause significant impact on meeting aggregate demand for other running projects in the Western Province since such demand can be met by remaining IML/A and IML/B grade quarry sites in the area. Hence, there will not be any influence on the prices of quarry material will be resulted.

However, certain other potential socio-economic, ecological impacts are present due to quarrying, haulage and loading/unloading of materials during the course of supplying quarry materials to the Port City Project site which requires satisfactory mitigatory measures.

Based on the research outcome of this study, following recommendations can be made:

- The study had been limited to quarry sites identified by the

project proponent. Hence, it is recommended to search for other quarry sites which has the capability of supplying quarry materials at the optimum cost benefit balance for the following phases of the Port City Development Project and other projects of similar nature. MCE was carried out based on only six crucial factors, but it is recommended to consider other influential factors to obtain more accurate results along with expert judgement.

- The project requires significant amounts of boulders which is not a usual output of the identified quarries. Therefore, it is recommended to propose certain guidelines to obtain a larger proportion of boulders from the total rocks fragmented by blasting while controlling fly rocks, ground vibration and air blast over pressure within statutory requirements [7].
- Additionally, meeting the increasing demand for rock materials for projects of similar nature by establishing a mega quarry in an appropriate area would be an innovative approach.

Acknowledgements

The authors wish to extend their gratitude to all academic and non-academic staff of the Department of Earth Resources Engineering of University of Moratuwa for their assistance in every aspect of this study and Geological Survey and Mines Bureau (GSMB) and GSMB – Technical Services for providing necessary support for making this project a success.

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