Sea navigation, challenges and potentials in South East Asia: An assessment of suitable sites for shipping canal in South Thai Isthmus

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Abstract: This paper discusses situation of sea navigation in south East Asia focusing on the Strait of Malacca. The strait links the Indian and Pacific oceans, which is considered one of the busiest in several narrow channels around the world. The paper highlights the significance of the strait to global maritime trade, volume of traffic, and rising environmental and social consequences in the strait. A feasibility study of constructing a new shipping canal in the South Thai Kra Isthmus as an alternative option of Malacca route had been studied since 19th century. The paper explores suitable sites for a potential shipping canal in the Kra Isthmus using physiographic spatial data i.e., elevation, sea charts, geology, soils and river systems. Each spatial data was considered as a separate decision variable for site evaluation. Separate evaluation criterions were prepared for each variable based on shipping canal requirements. Overlaying the maps in ArcGIS environment, the variables were carefully evaluated, and five geographic sites for the canal were derived. The length of the shipping canal over sea and land was computed for each site. Site B located in south of Ranong and Chumphon provinces, was found shortest one, whereas site C in Surat Thani, Pangnna and Krabi provinces, was the longest. However, each site consisted of benefits and constrains.

Keywords: Transportation, Malacca Straits, Kra Isthmus, Shipping canal, Sea navigation

Introduction

The mobility of people and freight from one place to another and information communication are becoming basic needs of human beings. Contemporary economic processes have been accompanied by a significant growth in mobility and higher levels of accessibility. Now, societies have been increasingly dependent on their transport systems to support a wide variety of activities ranging from traveling, supplying energy needs to distributing products (Rodrigue 2005). Globalization processes, economic integration and expansion of international trade have extended considerably the need for international transportation. International transportation is concerned with the highest scale in the mobility of freight and passengers with intercontinental and inter-regional movements by air, land and ocean using modern means of transportation. World output grew in 2006 by 4% over 2005. Developed economies were able to grow at 3%, whereas developing countries recorded an average growth of 6.9%. World merchandise exports grew by 8% (UNCTAD 2007). Furthermore, world seaborne trade recorded 7.4 billion tones in 2006 for an annual growth rate of 3.9%.

The international shipping industry is responsible for the carriage of 90% of world trade. Shipping is the backbone of the global economy. Intercontinental trade, the bulk transport of raw materials, and the import/export of affordable food and manufactured goods are dependent on shipping (ShippingFact 2005). For instance, consider the oil movement; a large volume of oil consumption occurs mainly in the industrialized countries, while oil production takes place largely in the Middle East, former Soviet Union, West Africa, and South America. The overall volume of seaborne crude oil trade increased by 4.5% in 2005. Average freight indices for VLCC/ULCC, Suezmax and Aframax tonnage increased by 86%, 40% and 27% respectively (UNCTAD 2006). A significant volume of oil is traded internationally of which 66% of the world's oil trade (crude and refined oil) moves by VLCC's tanker carrying 2 million barrels of oil per voyage. Tankers have made global (intercontinental) transport of oil possible because of low cost, efficiency, and extreme flexibility as compared to other means of transportation (EIA 2004).

The world trading fleet was made up of 46,222 ships, with a combined tonnage of 598 million gross tones (ShippingFact 2005). Transportation by sea generally follows a fixed set of maritime routes (Figure 1). Along the way, it encounters several narrow channels, such as the Strait of Malacca linking the Indian Ocean and the Strait of Hormuz leading out of the Persian Gulf. Other important maritime passage-ways include the Bab el-Mandab passage from the Arabian Sea to the Red Sea; the Panama Canal connecting the Pacific and Atlantic Oceans; the Suez Canal connecting the Red Sea and Mediterranean Sea; and the Turkish Straits linking the Black Sea to the Mediterranean Sea. Such narrow points are critically important to world trade because physically they are narrow and theoretically could be blocked temporarily and are more susceptible to pirate attacks and shipping accidents.

UNCTAD (2004) reported the growth rates for merchandise trade measured in value for most of the Asian countries were impressive. The average export and import growth rates for 40 selected economies reached 14.8% in 2003. Asian countries are major players in world maritime transport, with sizeable shares in several activities. These countries accounted for 35.8% of containership ownership, 45.7% of containership operation, 60.4% of seamen, 62.3% of container port throughput, 64.7% of container port operators, 83.2% of containership shipbuilding and 99% of ship demolition. In addition to being one of the focuses of the main east-west shipping routes articulated around world port leaders such as Hong Kong (China) and Singapore, it is also the focus of an intensive and significant intra-Asian shipping trade.

Figure 1. should be around here

Sea Navigation in the Asia Pacific Region

At present, three routes (Malacca, Sunda and Lambok straits) are in operation (Middlebury College 2007) for sea navigation between the Indian Ocean and the South China Sea (Figure 2). The Sunda route is very long as compared to Malacca for the world's giant traders like China, Japan, South Korea and the Middle East countries. The Malacca route is most common and very busy for east-west trade. Malacca is a passage between Sumatra and the Malay Peninsula covering 900 km long distance with a width of 350km to 3 km . The shallowest depth of the strait is reported to be 25 meters (Kuppuswamy 2004). By the Malacca route, a mass of refined and crude oil, iron ore, raw materials as well as readymade products pass west to east and vice versa on a daily basis. VLCC/DEPP Draft CR, Tanker Vessel, LNG/LPG Carrier, Cargo Vessel, Container Vessel, and Bulk Carrier are the major means of shipping transportation in the strait (Table 1). Passenger vessels, government/navy vessels, fishing vessels also use the route. Container vessels and tanker vessels are more prominent users of the strait. The sea traffic passing through the Malacca Strait was counted as 43.9 thousand vessels in the year 1999 with an average of 120 vessels per day. The traffic greatly increased setting a record of 194 vessels per day in 2007. Traffic has been growing gradually in the Malacca Strait with the exceptions of slight slowdown in 2005. Reduction in tanker vessels and the passenger ships caused the slow growth in 2005. However, continues growth in all types of traffic except a sharp declining of passenger vessels after 2001, made the strait more crowded and vulnerable in recent years.

Figure 2. should be around here.

Table 1. should be around here.

Environmental and Social Consequences

Mitropoulos (2004) reported that ship movements carrying one quarter of the world's commerce and half the world's oil pass through the Straits of Malacca each year. It shows that traffic is increasing heavily in the Malacca Strait and Singapore seaport, which will exceed beyond all capacity in the next few decades if alternative setups are not introduced for sea navigation. At present, due to heavy traffic the strait is fascinating for its environmental problems, ship building and demolition, and oil spillages for example. In 2007, VLCC/DEPP Draft CR and Tankers accounted for 10 and 41 vessels per day on an average, respectively. These types of shipping are considered as source of oil spills. Collision and oil spillage are major environmental threats in the Strait of Malacca. Oil spills happen more frequently in certain parts of the world. The Oil Spill Intelligence Report 1999 listed Malaysia and Singapore as hot oil spill spots from vessels accounting, for 39 cases since 1960 (UNEP 2005).

In 1993, the 255,312-ton Singapore-registered tanker *Maersk Navigator* collided with the empty tanker *Sanko Honour* in the Andaman Sea en route from Oman to Japan. It was carrying a cargo of nearly 2 million barrels of oil. The ruptured tanker leaked burning oil and spread a slick up to 35 miles (56 km) long off Sumatra, drifting towards India's Nicobar Islands (Mariner Group 2005). Oil spills on water devastates the marine environment. The *Treasure* accident can be taken as an example of an oil spill and its impact on marine environment. In the early morning of 23 June 2000, the bulk ore carrier MV *Treasure* sank off western South Africa between Dassen and Robben islands, both are important for seabird colonies. About 19,000 oiled penguins were collected for cleaning, 150 died on the spot and about 2,000 died within the first month. In addition to the African Penguin, other endangered seabirds were at risk from the *Treasure* spill (Crawford et al. 2000).

In addition to oil, hazardous and poisonous chemicals are also transported via Malacca. It could be an environmental problem if a collision or sinking took place. An Indonesian tanker laden with a toxic chemical capsized off Malaysia's southern Johor state, just across from Singapore in 2001. The 533 ton MV *Endah Lestari* was on its way to East Kalimantan in Indonesia with some 600 tones of the poisonous industrial chemical phenol, and 18 tones of diesel. The toxic spill killed thousands of fish and cockles reared in 85 offshore cages, and the Singapore authorities warned its citizens to stay away from nearby waters. It would be tough to mop up the phenol, as it is soluble in water (Mariner Group 2005).

Leaking oil in the sea and some growing social problems like robberies are some prominent examples of socio-environmental degradation in the area. In recent years, pirate attacks seem to be more violent and sophisticated in nature (Mukundan 2008). Although, piracy and armed robbery cases rose by 10% world-wide in 2007 (ICC-IMB 2008), significant improvement in the decline of cases have been observed in the Malacca Strait (Table 2). The number of reported incidents in Indonesia, Malaysia, Singapore and Strait of Malacca has fallen to 62 in 2007, a steady and yearly decline from 156 in 2003. Attacks in the Malacca Strait, previously known as a hotspot, as well as in Singapore, have continued to drop since 2004. The littoral states (Malaysia, Indonesia and Singapore) started a coordinated patrolling in the middle of 2004. This might be a cause for the fall of piracy and armed robbery cases in the strait (Permal 2006).

Table 2 should be around here.

However, sea piracies, robberies and hijackings are kinds of social illnesses which are difficult to predict in the current situation of growing worldwide terrorism. The security concern should always be given high priority in such a bottleneck and economically strategic waterway. As more than 70 thousand ships sail this waterway each year, where approximately one third of the world's trade and half of the world's oil passes to countries such as China, Korea and Japan. Terrorist attacks in such places would have the potential to cause large-scale economic impact, not just regionally but on a global scale.

Considering heavy traffic and its pressure on the environment in the coming decades, research and negotiations for seeking an alternative to reduce the volume of traffic in Malacca Strait are underway in Thailand and Malaysia. The Land Bridge Project and Kra-Canal Project in the South Thai Isthmus and the Trans-Peninsula Pipeline Project in Northern Malaysia for oil transportation (Permatasari 2007) are some of the prominent alternatives being debated in the South East Asian region. The Land Bridge (Krabi-Khanom) project consisting of a highway, railway and oil pipeline was approved for constructed in 1993 by the Thai government. The project was initially started but has now completely stopped because of some environmental concerns raised in the South Thai territory. Similarly, a recent announcement of an ambitious plan for constructing a pipeline in Northern Malaysia is being debated in Malaysia. The proposed Trans-Peninsula Pipeline will provide a shortcut oil shipment route for the exporting countries in the Middle East to importing East Asian nations, bypassing the Malacca Straits (Khalid 2007; Permatasari 2007). It will reduce a significant number of VLCC and oil tankers currently passing through Malacca and transportation cost as well, if the project is implemented. But it requires a detailed feasibility study that clearly addresses several issues, for example, environmental, socio-economic, investment, security and geopolitical. These processes will certainly take considerable time for making decisions on the fate of the pipeline project in the peninsula. A potential shipping route passing through the Indo-Chinese Peninsula in the south Thai Isthmus as an alternative to lower the volume of traffic in the Strait of Malacca has been studied since the 19th century (VIC 2002).

GIS based potential sites assessment for shipping canal in the Kra Isthmus, South Thailand

Recent status in Thailand

Some historical efforts seeking an alternative shipping route for Malacca Strait were found in Thailand. The idea of constructing a shipping canal in Southern Thailand to link the Pacific and Indian Oceans was started, 300 years ago during the reign of King Narai (ES 2002). Lots of studies on the project have been done since then. It has been considered many times under various Thai cabinets. For instance, King Narai was the first to suggest building a canal across the Kra Isthmus, requesting the French engineer De Lamar to conduct a survey to test the feasibility of connecting the existing waterway out of Songkla in the Gulf of Thailand to Marid (Myanmar). The Kra Isthmus, southern Thailand is narrower Isthmus in Thailand, which separates the Indian and the Pacific oceans. About 300 year old dream to build a canal across this isthmus has been revived many times, as in the mid-1950s, early 1970s, 1990s and 2000s (Pasertsri 2005). However, the project was dropped but it has been surfaced periodically ever since.

After comparing different routes of the canal, the TAMS (1973) suggested that the Satun-Songkhla route was the most suitable, which is similar to the most recent research of the Mitsubishi Research Institute and Global Infrastructure Fund (MRI-GIF), Japan (TED 2005). The MRI-GIF study proposed a king-sized canal to run from Satun to Songkhla near the Thai-Malaysian border capable of handling 150,000 dwt vessels going in both directions and the construction of seaports and major industrial facilities at both ends of the canal (VIC 2002). The engineering suitability highlighted that the size and depth of canal should be 380 and 23 m, respectively. The study concluded that the canal project is feasible both in terms of economics and engineering, but it needs a detailed study on canal alignment, environment, economics, engineering aspects, including a public hearing, to identify the most suitable route.

The aim of this paper is to analyze the sea transportation situation in the Strait of Malacca and evaluate suitable sites in the South Thai Isthmus (Kra Isthmus) for a potential shipping canal using physiographic spatial data.

Study area, database and method

The southern region of Thailand covering 14 administrative provinces was selected for assessing the potential sites of shipping route (Fig. 3). Malaysian and Burmese (Myanmar) spaces were excluded in this study. The region consists of a narrow isthmus located in the peninsula running roughly north to south. The isthmus connects Myanmar and Central Thailand to the north and Malaysia to the south. It has a varied topography including basins, hills, mountains and coast between the Andaman Sea of the Indian Ocean to the west and the South China Sea of the Pacific Ocean to the east. This region spans about 700 km long from north to south and ranges from 40 to 200 km in width from east to west. The study area covers about 71000 km^2 of land surfaces with the highest elevation of 1,800 m. In recent years, the isthmus is called Kra Isthmus refering to whole region of the south Thailand, although the name is used locally to describe the narrowest part of the region in Ranong and Chumphon provinces.

Geographically referenced data, namely contour (20 m), ocean charts of the Andaman Sea and Gulf of Thailand, geology, soils and river systems were considered as preliminary physiographic parameters while assessing the suitable site. Several visits were made to different locations of the study area to observe and verify the research results. A digital elevation model was developed using contour data. Hardness of rock, depth of soils and flow of major rivers play vital roles while digging the land surfaces for the potential canal. Rock age, often reflecting the gradient of the hardness of rock, was analyzed using a geological map. Deeper soil is easier to excavate than shallow soils because shallow soils often cover hard rock materials. Therefore, a soil depth map was prepared for analyzing the distribution of soil depth. Similarly, a map of the major river systems was prepared considering major alterations in the agriculture, ecosystem and sediment loadings. Altogether, five geographic layers, i.e. digital elevation model, geology, soils, rivers and sea charts were evaluated one by one using map overlaying techniques with the criteria (Table 3) in the GIS environment. The results were further verified and refined several times and discussed at several meetings with experts of related fields (soils, geology, water modeling, etc.). The rule-of-thumb of 'the shorter the distances the better the suitability' was considered while making the final decision on selecting suitable sites for the potential canal route. Figure 4 shows a general flow chart applied while assessing the land.

Figure 3. should be around here.

Figure 4. should be around here.

Spatial variables of evaluation criterions (Table 3) were setup based upon the requirement of shipping, excavation difficulties and sedimentation problems. All the maps with the selected criterions were overlaid in an ArcGIS environment and carefully evaluated to derive the potential sites for the construction of the shipping canal. After evaluating the potential areas, we computed the distance of the potential canal over land as well as at sea.

Table 3 should be around here

Results and discussion

Figure 5 demonstrates the general relief patterns of the Isthmus, whereas Fig. 6 shows sample reference maps (Andaman Sea, in the west, and Gulf of Thailand, in the east) of the study area used while assessing the site. About two thirds of the land in the isthmus is found to be less than 100 m in elevation. A large proportion of low land lies in the east of Chumphon connected to Surat Thani-Krabi-Trang. In the east, undulating terrain down to a flat coastal plain is in between Nakhon Sri Thammarat, Phathalung and Songkhla. Low-lying, gently undulating terrain lies between and alongside the mountain chains over nearly one third of the region.

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Figure 6. should be around here.

The mountains form a series of separate ridges aligned at a slight angle to the region rather than a single backbone. Three major mountain ranges with different shapes and aspects are observed in the isthmus. The northern mountain range runs from Ranong-Chumphon to Phangnga-Phuket, which has small, narrow ridge with a low land valley in the northern part, in between the border of Ranong and Chumphon provinces. This group completely disappears in the Krabi and central plain of the Surat Thani provinces. The middle range of mountains runs as a narrow, hilly chain from the south-east of Surat Thani province along the middle of Nakhon Sri Thammarat, Trang-Phattalung and Satun-Songkhla provinces. This mountain range has a large area of lowland basin as a costal plain on both east and west sides. Some low land areas like a neck (less than 100 m) in the range, are found in Nakhon Sri Thammarat province near the Trang provincial border and Satun-Songkhla joint border. The highest peak in southern Thailand called Khao Luang (1,835 m), is also located in the mountain range of Nakhon Sri Thammarat province. Another mountain chain in the southern part of the isthmus runs from the south-west of Songkhla close to the Malaysian border, mostly in Yala province following to the line of the Narathiwat province.

Geologically, South Thailand is part of an old stable landmass known as the Sunda Platform that extends south to east through Malaysia to the Indonesian island and Borneo (CCOP EPF 2004). The shallow South China Sea is part of this platform and was dry land during the Ice Age (Plesistocene) (Harper 1999). In the Kra Isthmus, 14 different types of rocks are found with age groups: Q-C (Quaternary-Cenozoic); TR-C (Tertiary-Cenozoic); C-M (Cretaceous-Mesozoic); J-M (Jurassic-Mesozoic); T-M (Triassic-Mesozoic); P-P (Permian-Palaeozoic); CA-P (Carboniferous-Palaeozoic); D-P (Devonian-Palaeozoic); S-P (Silurian-Palaeozoic); O-P (Ordovician-Palaeozoic); C-P (Cambrian-Palaeozoic); PRCAM (PreCambrian); N-C (Neogene-Cenozoic); and -M (Mesozoic-period is unknown).

Figure 7. should be around here

Figure 7 illustrates the spatial distribution of the rocks by age group in the isthmus. Geographically, the northern mountain group of the south region of Thailand is formed by the oldest rock called Palaeozoic. The Palaeozoic is very hard in nature spreading from Phuket through the common border of the Phangnga-Surat Thani and Ranong-Chumphon provinces in the northern mountains of the region. A large part of Surat Thani and Chumphon provinces are covered by Palaeozoic rock. The rock covers a significant part of the mountain area in Yala province, whereas partial existence is found in the middle part of the region such as in Trang, Phathalung and Nakhon Sri Thammarat provinces. The Cenozoic aged rock (most young age and soft in nature in the study area) is widely distributed. The rock is found on both sides of the coastal plain in the region including the central plain of Surat Thani province. Most areas of Surat Thani and Nakhon Sri Thammarat provinces are formed by Cenozoic-age rock. This rock is also found with Mesozoic-age rock in some areas of the southern provinces. A small portion of the area is covered by Mesozoic rock. The rock is also found as igneous in some places. The Mesozoic age rock expands in Surat Thani, Krabi, Trang and Songkhla provinces. Very few areas of Nakhon Sri Thammarat province are found to have this rock. The Mesozoic igneous rock spreads linearly as a strip along the common border of Trang-Phathalung and Satun-Songkhla. Mixture of Mesozoic-Cenozoic (igneous) rock have been found in the Nakhon Sri Thammarat mountains and some eastern landscapes of the northern and southern mountains of the region at relatively lower elevations. Other rock, such as Pre Cambrian, is nominally found in Nakhon Sri Thamarat province. Some land of Songkhala province is covered by water.

The Figure 8 illustrates the soil depth distribution in the south region of Thailand. Four types of depths, deep, medium deep, shallow and very shallow, are identified. The distribution map shows more than half of the region has deep soil that spreads over both side of the coastal plain and lower mountain basin in the whole region. The major concentration of deep soil is observed over the central plain of Surathani, Krabi, Trang provinces and along the eastern coastal plain started from Nakhon Sri Thammarat to Narathiwat. Despite coastal plains, a huge coverage of deep soil runs continuously over the eastern Surat Thani coastal plain to the western coastal plain of Krabi and Trang provinces. Medium deep soil is found in very few areas such as near the north-east coast of Chumphon and the middle part of Satun provinces. Shallow depth soil covers the lower upland basin of the northern and middle mountain ranges of the region, mostly in Chomphon and Satun provinces, respectively. All the mountain ranges in the region have very shallow soil on top and palaeozoic rock material as an inner formation. The soil depth of the lagoon of Songkhla Lake is unknown.

Figure 8. should be around here

Figure 9 illustrates the rivers in the Isthmus. The largest rivers in the region are the Tha Tapho and Lang Suan in the north, Ta Pi, Phum Duang and Trang in the centre and Pattani, Sai Buri, Bang Nara and Ko Lok in the southern part of the region. Most other rivers are small, especially on the west coast where mountains are close to the sea and gradient is very steep. Many intermittent streams in the region originate from upland and create flash floods to the lowland basin during the rainy season. The river Pakchan flows along the border of Myanmar and northwest of Chumphon and Ranong provinces and joins the Andaman Sea. Similarly, Tha Taphao river and Lang Suang river drain the eastern part of the northern hillocks and are submerged to the east coast of Chomphon province (Gulf of Thailand).

Figure 9. should be around here

The big river called Phum Duang unites with the Ta Pi river, runs from the western mountains of Surat Tahani province irrigating the central lowlands towards the east coast. Originally, it was the result of the unification of four outlets of water from east to south-headed mountain watersheds, namely the Yan, Sang, Sok and Phanom in Surat Thani province. The Ta Pi river drains the middle western mountains of Nakhon Sri Thammarat province and flows through the central plain of Surat Thani. The river amalgamates with the Phum Duang before few kilometers to the east coast of Surat Thani province. These rivers have significantly contributed to the agriculture ecosystem in Surat Thani. Pak Phanang, perennial in nature, is the only river in the Thammarat lowland basin that provides water requirement for inhabitants and agriculture activities.

Some other small short streams also exist near to the east coast of the Nakhon Sri Thamarat province. Trang River originates from the western Thammarat mountains and supples the water to the Trang costal plain. The river flows a north-south direction and ends at the Andaman Sea nearby the middle-west coast of the Trang province. On the eastern coastal plain of Songkhla and Pak Phanang provinces, several rivers contribute to U Taphao River and the Na Thanri flows into the complex channels of the Songkhla Lake. Satun province has La Ngu as its main river. The Thepha, Pattani, Sai Buri, Bang Nara and Ko Lok rivers drain the southern mountains of the region and flow to the east coast.

An interesting relationship has been observed in the three spatial variables, soil depth, elevation and rock age. For example, in the mountain range in the Isthmus higher elevation produces the oldest rock material (palaeozoic) which is covered by soils ranging from shallow to very shallow. In the basin, rocks are young, having low elevation and deep soils. The relationship is higher the elevation, older the rock age and lower the soil depth.

After carefully evaluating spatial data of topography, sea charts, rock age, soil depth and river system (Figs. 5 to 9) using multi-criteria decision (Table 3) analysis, we were able to derive five potential sites for the shipping canal (Fig. 10) in the Isthmus. As compared to the total distance of Sites A to E, Site B located in southern part of Chomphon and Ranong provinces, is the shortest one (Table 4). Whereas Site C passing through Surat Thani, sharing the border of Phangnga and Krabi and exiting at Phuket waters, is the longest. As to the considered land surfaces, Site A, located in northern part of Chomphon and Ranong provinces, is the shortest one, whereas Site D passes through Nakhon Sri Thammarat and Trang becomes the longest compared to other sites.

Site A has to share the border with Myanmar (Burma) in the west which posess a long dredge because of the Pakhan river and data unavailability in the Myanmar area. As compared to the total dredge, the dredge of Site E (east coast of Songkhla and west coast of Satun) and Site C (east coast of Surat Thani and south coast of Phangnga) are found to be very long. Due to different construction requirements for dredge and land surfaces, the length of dredges are notable. Some longer time dredging may become costly for excavation and recycling of wastes than on the lands.

Figure 10. should be around here

Table 4 should be around here

Although Sites C and D seem very long, variables such as topography and soils, are favorable because of the low elevation with deep soils which may be easier for excavation. But at site C, a large river (Phum Dung) becomes a major barrier. Mixing the river into the canal may cause sediment loading problems in canal which can raise the daily operating cost of the canal. It may also cause serious problems to the ecosystem in the surrounding area and irrigated land. However, tunneling of river may be possible regardless of cost. The site B looks the shortest one but the existences of hard rock at higher elevations may make excavation more difficult as well as the costs of recycling the wastes. More zigzag courses are observed in Sites A and B than in the other sites. It is because of the mountainous topography. Such snaking may result more risky navigation as compared to a straight and smooth route.

Conclusions

Globalization processes, economic integration and expansion of international trade have extended considerably the need for international transportation. A big share of world trade depends on the international shipping industries. Half of the world's oil passes through the Strait of Malacca every year. It is one of the busiest narrow channels in the world, where 194 vessels were recorded per day in 2007. Because of continues growth of sea traffic, the strait is facing many challenges in environment and safe navigation such as oil spills, shipping collisions, air pollution and piracy and armed robbery. Construction of a new shipping canal in the South Thai (Kra) Isthmus as an alternative option has been studied since the 19th century. In this paper, we attempted to assess potential sites for a shipping canal based on geophysical parameters, i.e., elevation, sea charts, geology, soils and river systems. Several bottle neck decision criteria were checked while evaluating the sites. The case study revealed five suitable geographic sites including the required length within the subset of multi-criteria decisions for potential shipping canal on the Isthmus. Furthermore, these five potential sites present the right length for a shipping canal on both land and sea. However, a detail feasibility study is necessary into environmental impact, safety measures, socio-economic aspects, and international geopolitics. A detailed topographic survey, rocks and soils samples, land use, including socioeconomic variables are sought to be included in next phase of the study.

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Table 1 Shipping traffic in the Malacca Strait (1999-2007)

Traffic type	1999	2001	2003	2005	2007
VLCC/DEPP Draft CR	2027	3303	3487	3788	3753
Tanker Vessel	11474	14276	15667	14759	14931
LNG/LPG Carrier	2473	3086	3277	3099	3413
Cargo Vessel	5674	6476	6193	6340	8467
Container Vessel	14521	20101	19575	20818	23736
Bulk Carrier	3438	5370	6256	7394	9684
RORO/Car Carrier	1229	1764	2182	2515	3137
Passenger Vessel	1919	3151	3033	2299	1870
Others*	1210	1787	2664	1609	1727
Total	43965	59314	62334	62621	70718
Average traffic per day	120	163	171	172	194

*Includes livestock carriers, TUG/TOW vessels, government/navy vessels, fishing vessels, etc.
Source: MDM (2008). STRAITREP ship reporting system in the Strait of Malacca and Singapore has been operating since December 1998. The statistics cover only the Malacca Strait from One Fathom Bank to Iyu Kechil.

Table 2 Piracy incidents in Indonesia, Malaysia, Singapore and Malacca Straits

Places/Year	2001*	2002*	2003	2004	2005	2006	2007
Indonesia	72	103	121	94	79	50	43
Malaysia	9	14	5	9	3	10	9
Singapore	4	5	2	8	7	5	3
Malacca Straits	11	16	28	38	12	11	7
Total	96	138	156	149	101	76	62

Source: ICC-IMB (2008). *Compiled based on the piracy maps available online http://www.icc-ccs.org/prc/piracyreport.php.

Table 3 Decision criteria setup for physiographic variable evaluation

SN	Spatial variables	Criteria
1.	Canal size	400 meters (requirements for VLLC carrier)
2.	Canal depth	25 meters (requirements for VLLC carrier)
3.	Elevation	Ground: <200 meters (construction difficulties) Sea: >25 (requirements for VLLC carrier)
4.	Geology	Rock age: young ~ old (excavation difficulties)
5.	Soils	Depth: deep ~ shallow (excavation difficulties)
6.	Rivers	Avoid major rivers (ecosystem and sediment loadings)

Table 4 Length of canal in potential sites

Site	Land	Dredge			Total Length
		West	East	Total	
A	94.56	63.18	15.25	78.43	172.99
B	76.09	31.38	35.50	66.88	142.97
C	126.19	35.34	73.10	108.44	234.63
D	141.87	21.24	38.51	59.75	201.62
E	107.12	57.77	42.15	99.92	207.04

Note: Units in kilometers, West (Andaman Sea) and East (Thai Gulf).

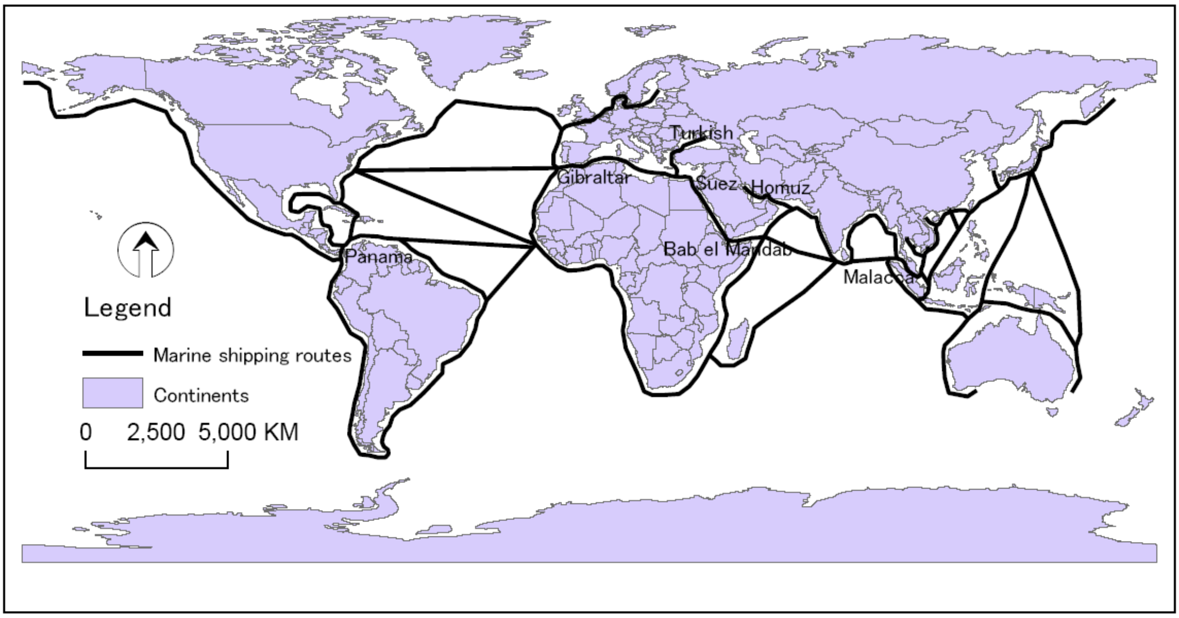

Figure 1 World trading – marine shipping routes

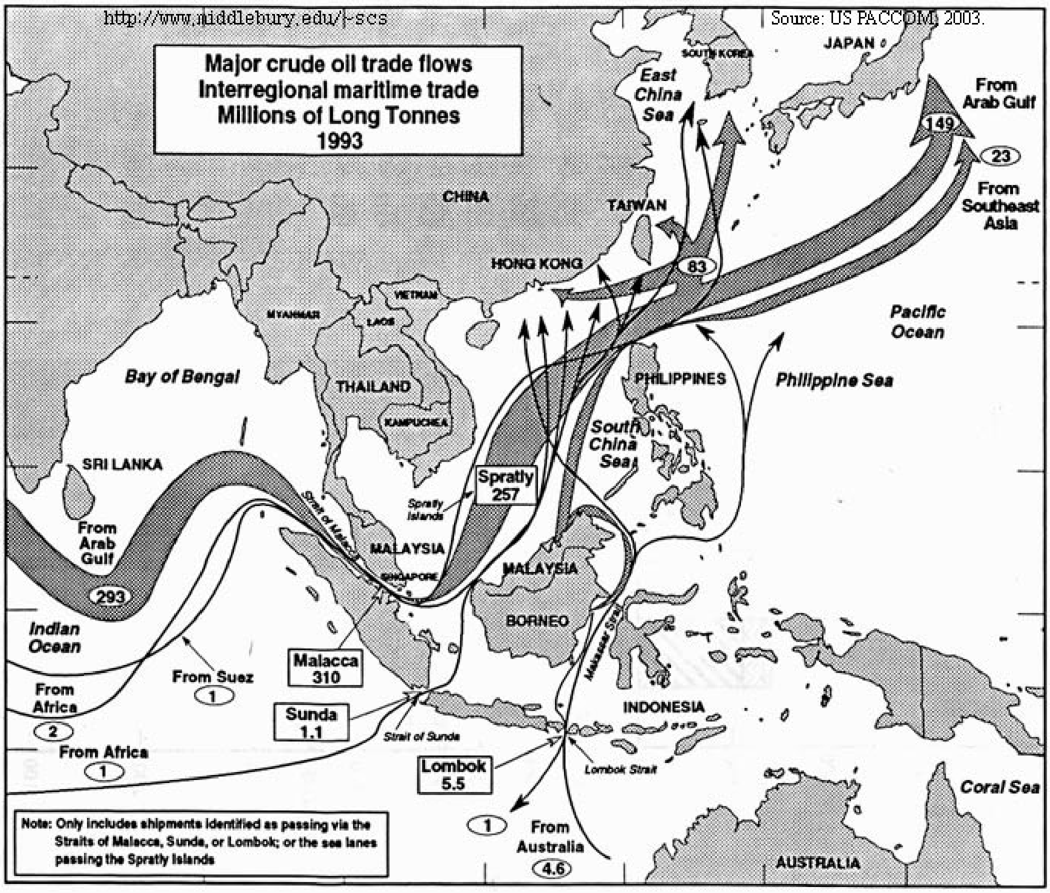

Figure 2: Sea Navigation Asia-Pacific (Middlebury College 2007)

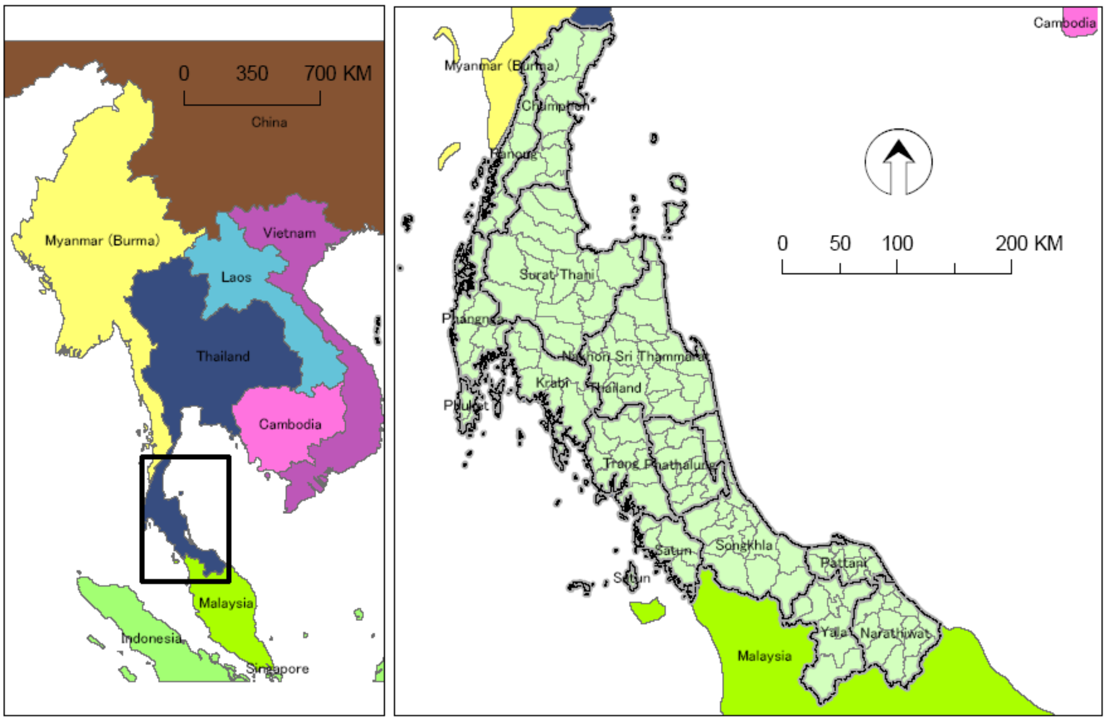

Figure 3: Study area – South Thailand (Kra Isthmus)

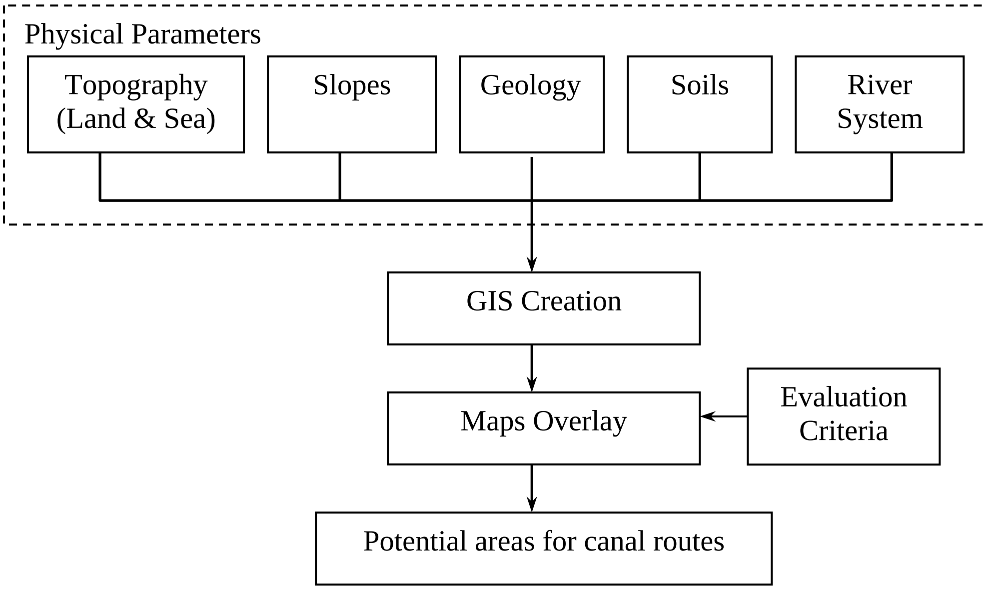

Figure 4: A logical framework for potential sites assessment

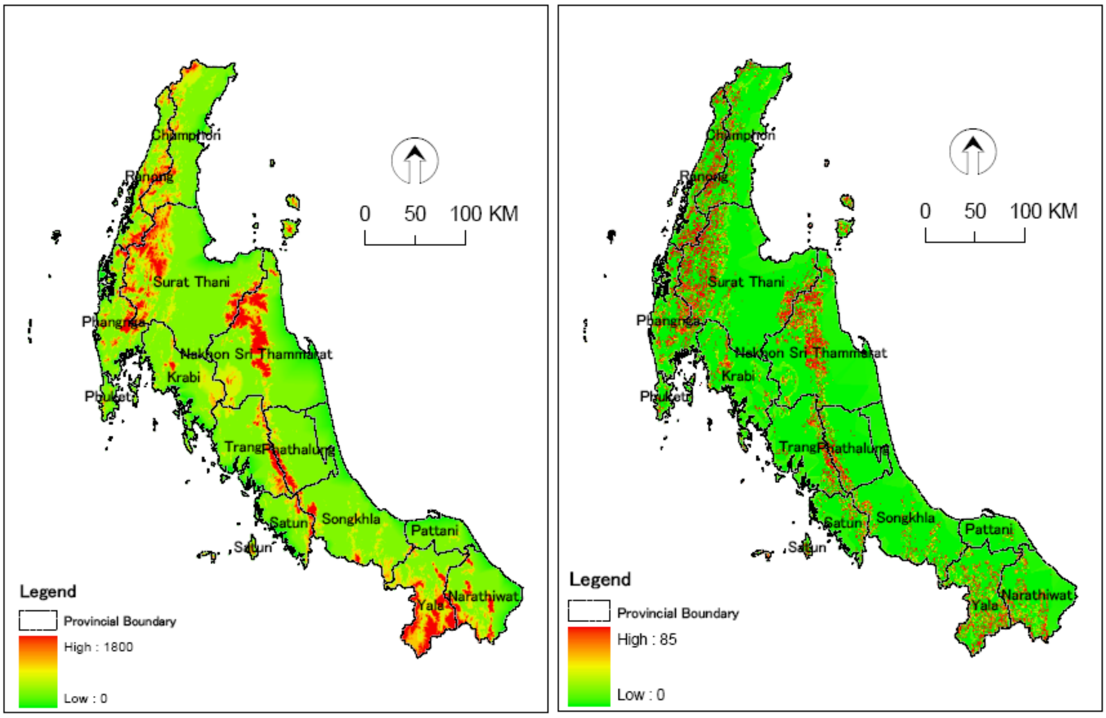

Figure 5: Relief pattern – elevation in meters (left) and slopes – in degree (right)

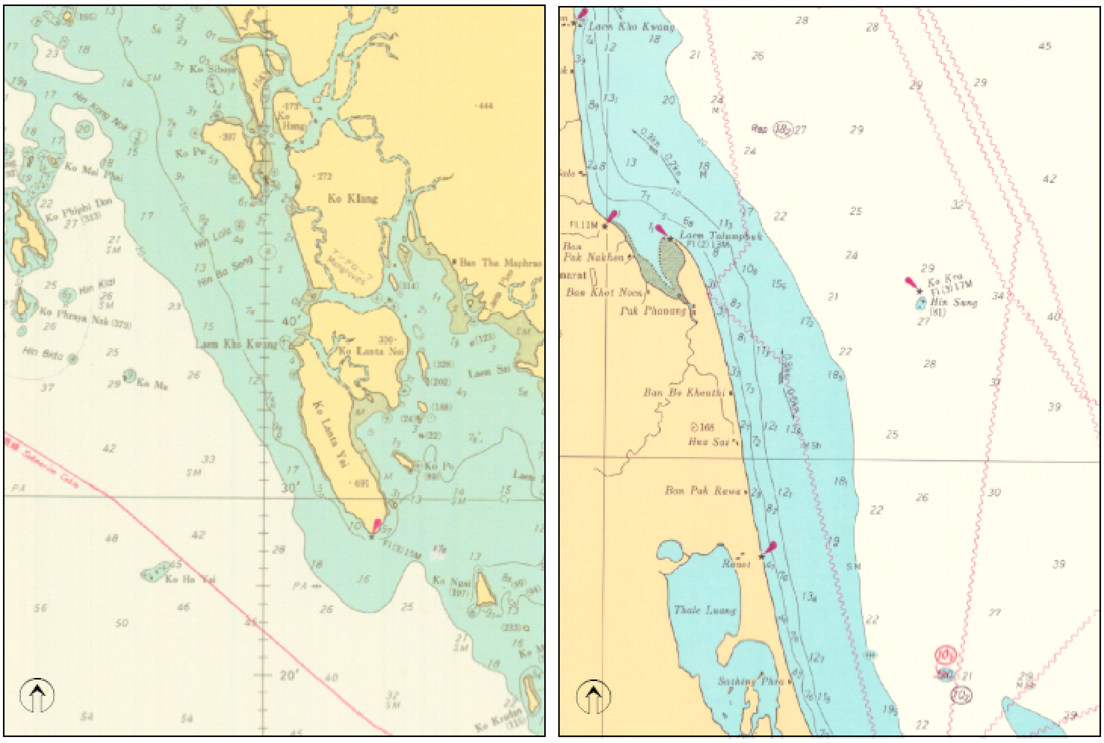

Figure 6: Sea chart as a sample reference – Andaman Sea (left) and Gulf of Thailand (right).

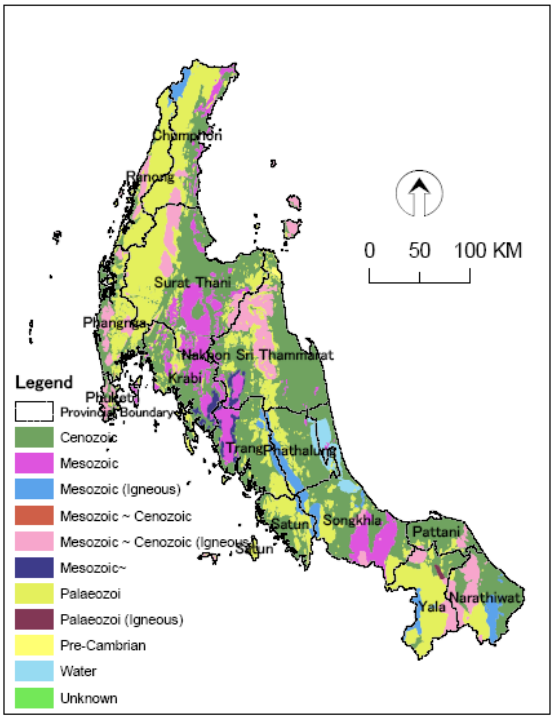

Figure 7: Geology – distribution of rock age

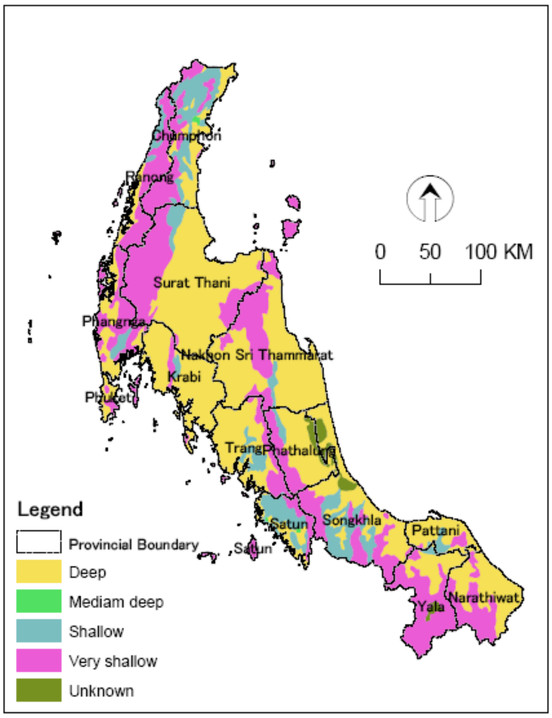

Figure 8: Soils – distribution of soil depth

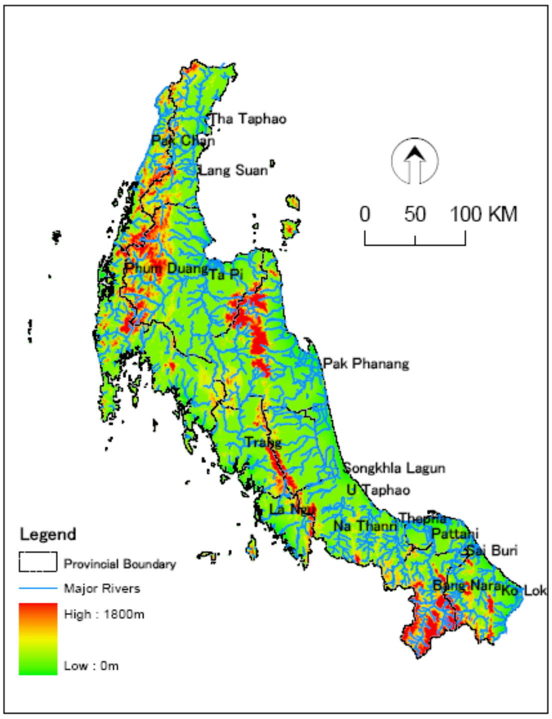

Figure 9: River system with DEM background

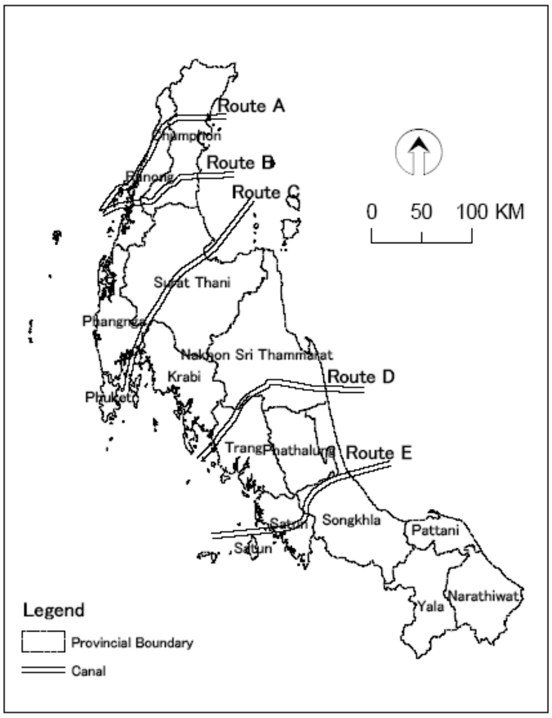

Figure 10: Potential sites for shipping canal