PRE-FEASIBILITY OF MALACCA STRAIT CROSSING

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ABSTRAK

Perkembangan perdagangan antara masyarakat dunia usaha di pulau Sumatera (Indonesia) dengan Malaysia dan Singapura terus menunjukkan peningkatan. Prasarana transportasi di sekitar selat Malaka saat ini hanya dilayani oleh kapal laut. Untuk mengimbangi perkembangan perdagangan, maka pemerintah Indonesia bermaksud memfasilitasi pembangunan infrastruktur atau suatu ruas jalur penghubung (fix-link), suatu lintasan jembatan antara pula Sumatera dan Malaysia. Jembatan Selat Malaka (JSM) antara Indonesia dan Malaysia merupakan bagian dari ruas jalan Trans Asia yang sudah sejak beberapa waktu yang lalu direncanakan. Untuk mendukung perencanaan tersebut saat ini perlu dilakukan telaahan dalam suatu kajian pre-feasibility. Kegiatan pre-feasibility ini melibatkan beberapa disiplin ilmu khususnya untuk jalan, transportasi, jembatan, geoteknik, pantai, lingkungan dan sosial-budaya-kebijakan. Pra-FS ini menunjukkan modal akan kembali (Break Event Point), yaitu antara 25 dan 30 tahun berdasarkan metoda Benefit Cost Ratio (BCR) bila memilih Koridor I dari Dumai-P.Rupat-P.Medang-Malaysia, menggunakan jembatan cable stayed, suspension dan girder. Span terpanjang jembatan cable stayed dan suspension masing-masing adalah 2600 m dan 1280 m. Pemilihan koridor ini harus didiskusikan secara intensif tentang penyerapan teknologi dan faktor keamanan, integrasi jaringan dengan jalan Tol, teknologi fundasi bawah laut, sumber daya manusia dalam pemeliharaan, serta psikologi dan kenyamanan bagi pengguna. Konsesi kepada Operator dapat diberikan dalam waktu 30-40 tahun.

Kata kunci: *Studi kelayakan awal, strait crossing (penyeberangan), strait bridge, strait tunnel, jembatan Selat Malaka, BCR*

ABSTRACT

Indonesian trading development rapidly shows an improvement with neighbour countries such as Malaysia and Singapore. Even though the transportation infrastructures arround Malacca Straits are currently just provided by boats. For balancing the develpoment trading reasons, Indonesian Government concerns to facilitate the building of transportation infrastructures or a fix-link infrastructure, a crossing bridge between Sumatera island (Indonesia) and Malaysia. Malacca Strait Bridge (MSB) between Indonesia and Malaysia is a part of Trans Asia road link, has been planned since years ago. To support the current planning, the Research and Development Agency – Ministry of Public Works – Republic of Indonesia (Badan Penelitian dan Pengembangan, Kementerian Pekerjaan Umum, Indonesia) needs to make a reviewing on a pre-feasibility study (Pre FS) for MSB. Pre FS activity involved many disciplines of knowledge especially for road/corridor, transportation, bridge, geotechnical, sea shore, environment, and social-economic-culture-policy. Pre-FS results that break event point for Corridor I among Dumai-P.Rupat-P.Medang-Malaysia may be expected between 25 and 30 yeras based on Benefit Cost Ratio methode, using cable stayed and suspension bridges and girders. The longest span for cable stayed and suspension bridges are 2600 m and 1280 m respectively. The selected corridior must be intensively discussed about technology absorbed and safety factor, resources capability for maintenance, integration within toll road network, foundation technology in the sea, and users psychology and comfort. Consession for operator may apply for 30 to 40 years.

Keywords: *Pre-feasibility study, Strait crossing, Strait bridge, Strait tunnel, Malacca strait bridge, Benefit cost ratio (BCR)*

INTRODUCTION

Malacca Strait Bridge (MSB) is a part of Asian and Asean Highway building, has been planned long time ago, and connects Malaysia and Indonesia, so the road at the north sea shore and the east sea shore of Sumatera Island may strategicaly be part of the Asian Highway. See Figure 1.

Trading progress among Indonesia (Sumatera Island), Malaysia and Singapore in World Trade Community indicated an increase. Other than by aeroplane, the transportation either by boats or Roro (roll in and roll out) is provided by 8 to 10 journeys per day, for tourists from Malaysia and Singapore to Sumatera Island and vice-versa.

If no effort to built bridge or tunnel at Malacca Strait, and new Ferries are not supplied, and traffic growth 3% per year, the traffic density crossing the strait will increase (idle time increases), potensially traffic accidents increases, and illegal activities may not be overcomed.

This paper will be used for policy consideration by Ministry of Public Work in providing steps according to current technology development. Some proposals involving the crossing between Sumatera Island and Malaysia are viewed, for both bridge and tunnel expected.

This paper describes a pre-feasibility of bridge/tunnel crossing Malacca Strait, conforming with technical aspect, financial, economic, social, policy and security, to gain some recommendations for project preparation and implementation.

The objective of this Pre-FS is:

- To provide direct service passing Malacca Strait to Sumatera island (in Riau Province) by building Bridge/ Tunnel from Malaysia, or via small islands in Riau Islands Province by building bridge from Malaysia/ Singapore.
- To facilitate traffic demand among Sumatera Island, Malaysia, and Singapore
- To develop potensial agro-industry area in Sumatera Island.

Figure 1. Asian Highway Network

LITERATURE STUDY

The study follows the guidance for pre-FS available in Indonesia (Puslitbang Jalan dan Jembatan, 2005), covers the policy design fotmula, scope of study, traffic, road and bridge engeneering, tunnel, safety and environmental aspek, economy aspect includs social, security and policy, economical evaluation, selection of alternative, and recommendation.

Conjuction with the proposal of Malacca Strait Bridge from Malaysia, the Ministry of Public Works, Republic of Indonesia is being studied in building the Fix-Link as the infrastructure design of bridge or tunnel between Dumai (Indonesia) and Johor (Malaysia). This issue is as the counter to respon Malaysia proposed by Mr. Tan Sri Ibrahim. (SOMX, 2007). Malaysia proposes 2 options, Option A (full bridge), the main span length is 2300 m, and option B (bridge and tunnel) where the tunnel length is 18,69 km and, total bridge length includes girders is 30 km. Both options have 71,24 km road length follows the east sea shore of Rupat Island. The cost is US$ 16 Billion (SOMX, 2007) funded by Malaysian Financial Group.

Guide Specification for Vessel Colission Design of Highway Bridges (AASHTO, 2008), states that the selection of single span for navigation line should be 2-3 time to the longest of ship dimension, minimum 1220 m. The width of line is also depend on the deepest sea condition, so the horizontal free space should be studied. The bridge width depend on slim effect of the selected single span length and comply with ideal road capacity. If the length of the bridge is 2300 m, the width needed of the bridge should be 1/60 or 40 m.

Table 1 shows comparison between the main span length (L) and tower height (H) used world wide arround 1:6 to 1:9, while span length (L) to width (B) arround 1:50 to 1:60. Malacca strait bridge may use 1:8 for tower height (325 m) and width 1:53 (48,7 m).

HYPOTESIS

Building the infrastructure of Malacca Strait Bridge is feasible.

METODOLOGY

The metodology of this pre-fesibility study is to compare the three alternative corridors, benefits and cost based on the intangible and tangible, and feasibility analysis involves the aspects of environmental, social, economic and financial aspects, including land aquisition, cost and maintenance, finaly are summaried using Multi Criteria Analisys (MCA). The scope of works generally consists of preparation and literature study, survey, data reviews of digital map, statistical data of trading activities, evaluation of study and discussion.

The scope are foccused to, as follows:

- Bridge, consists the study of long span bridge, location based on geotechnical analysis and requirements, sea shore/ocean/ swampy area and environment, shipping line, typical bridges, alternative route in three corridors to be selected, and cost
- Tunnel, consists the study of location based on geotechnical analysis and requirements, typical tunnel, alternative route at selected corridor, and cost.

Table 1. World Wide Bridge Dimension Suspension Type

Bridge Name	Length Span (m)	Tower (m)	Width (m)	L/ H	L / B	Cost
	L	H	B			
Messina	3300	382.4	55	8.63	60.00	US$m 7,515.3
Akashi Kaikyo	1991	297.4	35.5	6.69	56.08	US$m 4,300.0
Great Belt [a)]	1624	254	31	6.39	52.39	US$b 21,4
Humber [b)]	1410	155.5	28.5	9.07	49.47	£ 400

Source : http://www.giritech.com/int/content/view/full/2138, 31-5-2010

- Geotechnique, consists the analizing of corridor route map such as sattelite image, ocean, lands and sea shore geological map, geological fault analysis, surveys and ground checking for primary data and validation.
- Sea shore, consists the study of sea shore region, hydrology and drainage, and winds and waves behaviour.
- Traffic and environment consists of route planning study at all corridors (geometric), spatial and environment aspects, and economical-technique analysis.
- Roads, consists of highway route planning study at all corridors based on soil requirements, technical analysis, typical roads, and cost.
- Social-economic-culture-policy, consists of study of route planning at all corridors, input of economical-technique analysis, and review study of social, economic, policy and security.

The three corridors are shown in Figure 2: Corrdidor I, bridge, tunnel or both bridge and tunnel, passes Rupat. Corridor II, bridges from Danai (Indonesia) passes some islands to Johor (Malaysia). Corridor III, bridges from Danai passes small islands to Singapore.

Recommendations based on three conditions in this analysis, i.e.:

- Not feasible if $\frac{Benefit\ Tangible}{Cost\ Tangible} < 1$.
- Economicaly feasible if $\frac{Benefit\ Economic}{Cost\ Tangible} \geq 1$

intangible OK

- Financially feasible if $\frac{Benefit\ Financial}{Cost\ Tangible} \geq 1$

if intangible OK.

Notes:

- Benefit intangible: Environment, SosEcCult.
- Benefit tangible: Economic, financial.
- Benefit economic: User Cost, Time value.
- Benefit financial: Toll, utility revenue.
- Cost intangible: Environment, SosEcCult.

Cost tangible = Cost economic = Cost financial: Land Aquisition, Construction cost, maintenance.

RESULT AND ALTERNATIVES

To gain an efficient alternative within minimal impact based on current topography, geological and geotechnical, three alternative routes in Figure 2 that are designed as a shortest distance within three corridors may be selected.

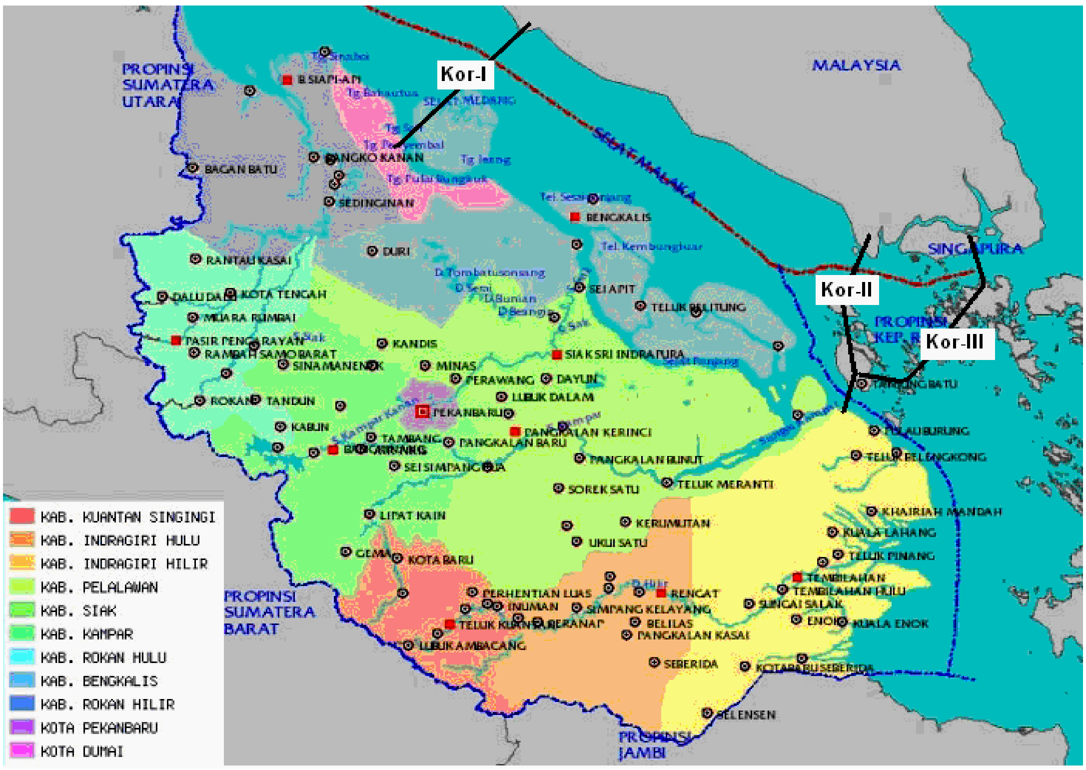


Figure 2. Corridor I, II and III

Corridor I: Road, Bridge, and/or Tunnel: from Dumai – Rupat island – Teluk Gong (Malaka, Malaysia) with four options: A, B, C and D respectively ilustrated in Figure 3a, i.e.:

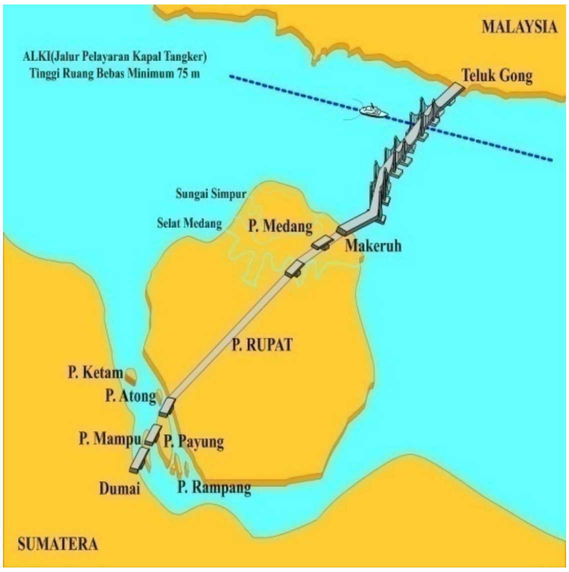
- Option A: Dumai-P.Payung - Straight road through the middle of P.Rupat-Makeruh (P.Medang) - Bridge toTeluk Gong (Malaysia);
- Option B: Dumai-P.Payung-follows East beach road of P.Rupat - Makeruh (P.Medang) - Bridge to Teluk Gong (Malaysia);
- Option C: Dumai-P.Payung-Straight road through the middle of P.Rupat-Makeruh (P.Medang) - Tunnel to Teluk Gong (Malaysia);
- Option D: Dumai-P.Payung-follows East beach road of P.Rupat - Makeruh (P.Medang) - Tunnel to Teluk Gong (Malaysia).

Corridor II : Road and Bridge from Danai – P.Kundur - P.Karimun – P.Rangsang – Small Islands – Johor (Malaysia), ilustrated in Figure 3b.

Corridor III : Road and Bridge from Danai – P.Kundur – P. Bulan - P.Batam - Small Islands – Singapore, ilustrated in Figure 3c.

The following description of alternative corridors and traffic prediction are:

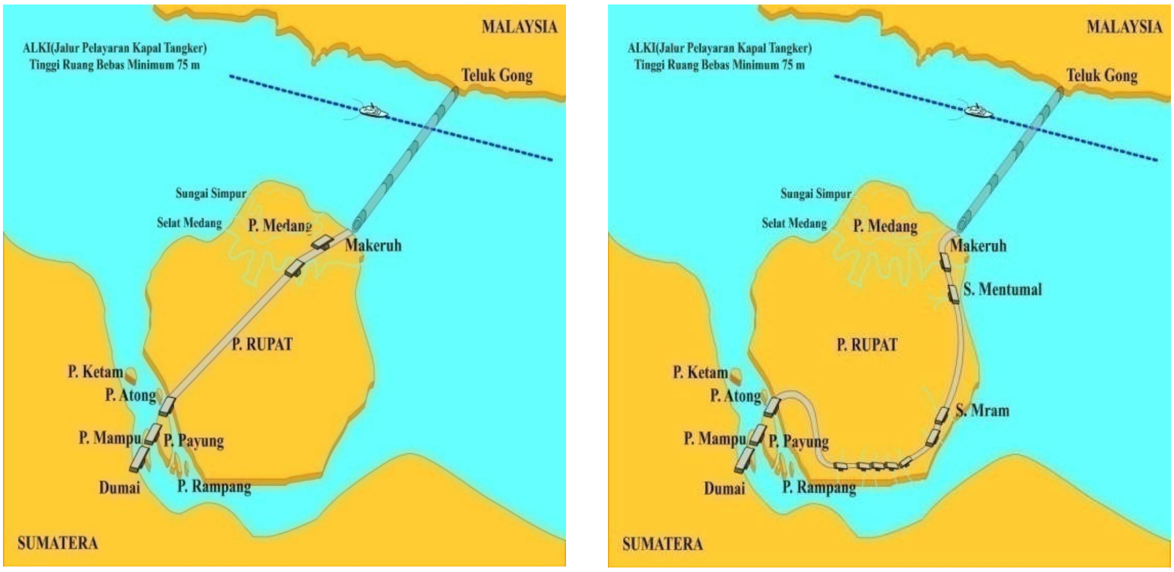
- The new road links to be built, or the existing road links to be improved as connecting road to and from above corridors are excluded.
- Some Ferries may be operated for crossing the motor cycles, passengers, sea tourism object, bridge maintenance, and any other may be removed to any other harbour needed.
- Traffic counting, passangers and goods are calculated within two ways, i.e. ground check using local querries with assumptions, and based on development pattern model of Toll roads in Indonesia correlated within PDB. The result may be predicted as follows:
  - Corridor I: 12.251 vehicles per day
  - Corridor II and Corridor III: 9.604 vehicles per day.



Option-A (bridge, straight road)

Option-B (bridge, beach road)

Figure 3a. Corridor I: Dumai-Rupat island-Malaysia, with 4 Options: Bridge for Option A dan and B, Tunnel for Option C and D.



Option-C (tunnel, straight road) Option-D (tunnel, beach road)

Figure 3a. Corridor I: Dumai-Rupat island-Malaysia, with 4 Options: Bridge for Option A dan and B, Tunnel for Option C and D (continuation)

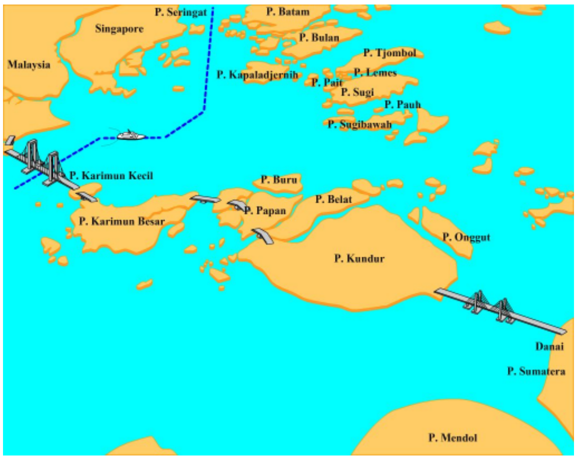


Figure 3b. Corridor II (bridges): Danai-Kundur-Karimun-Malaysia

Figure 3c. Corrdor III (bridges): Danai-Kundur-Batam-Singapore

- If the bridge to be built with 6 lanes for two directions at Corridor I, in the begining of bridge opened on 2035, all of vehicles crossing will be served within 10 years (2045) at level of service (LOS) of A, LOS B upto 2055, LOS C upto 2065, and LOS C-D upto 2135. Corridor II and III will be LOS A upto 2055, LOS B-C upto 2065, and LOS C upto 2135. See Figure 4a. If Corridor II and III 4 lanes for two direction, LOS may be decreased one step respectively. See Figure 4b.

The type of bridges, location, cross section dimension and cost are presented in Table 2a to Table 2d for Corridor I with 4 options i.e. option A, B, C and D respectively. The type of bridges, locations, cross section dimension and cost are presented in Table 2e and Tabel f for Corridor II and Corridor III respectively. The cost of tunnels for Option B and Option C in Corridor I are to Selat Sunda Strait (Sindur M, 2000), see notes in Table 2g of Tabel 2h. The length of roads, bridge, and tunnel, including construction cost (year of 2008) are shown in

Table 2g, with assumption for all corridors using 2 x 3 road lanes. The calculation either done with assumption that at Corrdior II and Corridor III are analised by 2 x 2 road lanes, due to the traffic prediction at both corridiors are relativelly lower than Corrdior I. See Table 2h. From both tables shows that the cost for bridge is relatively very high, while the cost or road and tunnel arround 3% and 64% of bridge cost respectively (year of 2008).

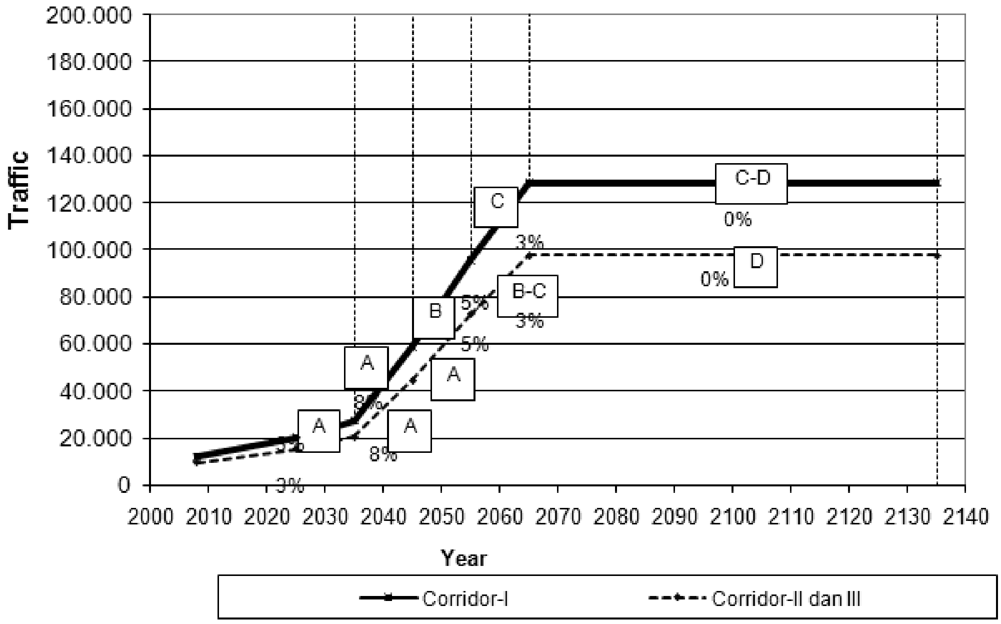


Figure 4a. Traffic prediction all Corridor, opened on 2035, 2 x 3 road lanes

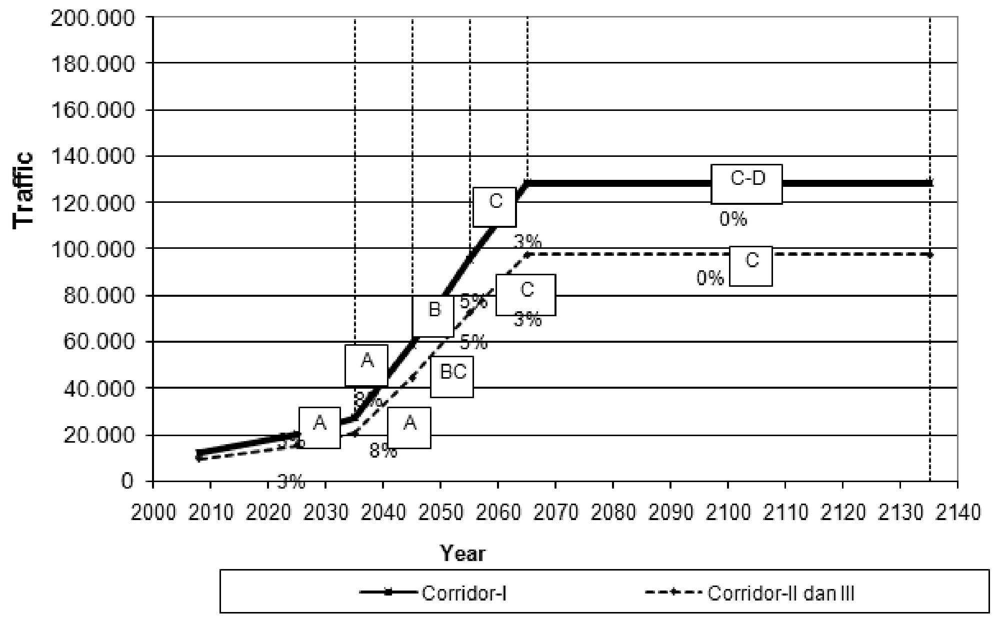


Figure 4b. Traffic prediction, opened on 2035, 2 x 2 road lanes at Corridor II and III

Table 2a. Corridor I Option-A

No.	Bridge	Location	Bridge Length (Km)	Longest Span (Km)	Width (m)	Cost (IDR Billion)
1	Box Girder	Dumai - P. Mampu	1,935	0,20	41,5	2649,94
2	Box Girder	P.Mampu - P. Payung	2,608	0,20	41,5	3572
3	Box Girder	P. Payung - P. Rupat	1,882	0,20	41,5	2576,76
4	Box Girder	Selat Medang	0,174	0,10	41,5	238,77
5	I Girder	Sungai 1	0,070	0,07	41,5	69,72
6	4 Box Girder	P. Medang - Teluk Gong (Malaysia)	40,210	0,20	41,5	55067,6
	2 Cable Stayed		4,280	1,28	41,5	27531,1
	1 Suspension		4,200	2,60	48,7	71589
			55,359		Total cost	163.294,890

Table 2b. Corridor I Option-B

No.	Bridge	Location	Bridge Length (Km)	Longest Span (Km)	Width (m)	Cost (IDR Billion)
1	Box Girder	Dumai - P. Mampu	1,935	0,2	41,5	2.649,940
2	Box Girder	P.Mampu - P. Payung	2,608	0,2	41,5	3.572,000
3	Box Girder	P. Payung - P. Rupat	1,882	0,2	41,5	2.576,760
4	8 I-Girder	Sungai 1s/d6-S.Mram-S.Mentumal	0,260	0,05	41,5	258,960
5	Box Girder	Selat Medang	0,150	0,15	41,5	205,430
6	4 Box Girder		40,210	0,2	41,5	55.067,600
	2 Cable Stayed	P. Medang - Teluk Gong (Malaysia)	4,280	1,28	41,5	27.531,100
	Suspension	Selat Medang	4,200	2,6	48,7	71.589,000
			55,525		Total cost	163.450,79

Table 2c. Corridor I Option-C

No.	Bridge	Location	Bridge Length (Km)	Longest Span (Km)	Width (m)	Cost (IDR Billion)
1	Box Girder	Dumai - P. Mampu	1.935	0,2	41,5	2649,94
2	Box Girder	P.Mampu - P. Payung	2.608	0,2	41,5	3572
3	Box Girder	P. Payung - P. Rupat	1.882	0,2	41,5	2576,76
4	Box Girder	Selat Medang	0,174	0,1	41,5	238,77
5	I Girder	Sungai 1	0,07	0,07	41,5	69,72
			6.669		Total cost	9107,19

Table 2d. Corridor I Option-D

No.	Bridge	Location	Bridge Length (Km)	Longest Span (Km)	Width (m)	Cost (IDR Billion)
1	Box Girder	Dumai - P. Mampu	1,935	0,2	41,5	2649,940
2	Box Girder	P.Mampu - P. Payung	2,608	0,2	41,5	3572,000
3	Box Girder	P. Payung - P. Rupat	1,882	0,2	41,5	2576,760
4	8 I-Girder	Sungai 1s/d6-S.Mentumal	0,26	0,05	41,5	258,960
5	Box Girder	Selat Medang	0,15	0,15	41,5	205,430
			6,835		Total cost	9263,09

Table 2e. Corridor II

No.	Bridge	Location	Bridge Length (Km)	Longest Span (Km)	Width (m)	Cost (IDR Billion)
1	Box Girder	Danai (Riau) - P. Kundur	6,340	0,2	30,1	6.297,52
	Cable Stayed		0,818	0,434	30,1	2.142,10
	Box Girder		6,340	0,2	30,1	6.297,52
2	Box Girder	P. Kundur - P Papan	1,374	0,2	30,1	1.364,36
3	Box Girder	P. Papan - P. Tulang	0,261	0,2	30,1	259,22
4	Box Girder	P. Tulang - P. Parit Kecil	0,240	0,1	30,1	238,05
5	Box Girder	P. Parit Kecil - P. Parit Besar	0,218	0,1	30,1	216,23
6	Box Girder	P. Parit Besar - P. Karimun Bes	3,032	0,2	30,1	3.011,69
7	Box Girder	P. Karimun Besar - P.Karimun I	2,014	0,2	30,1	2.000,51
8	Box Girder	P. Karimun Kecil - P.Kukup	5,931	0,2	30,1	5.890,77
	Suspension		4,200	1,2	48,7	71.589,00
	Box Girder		5,931	0,2	30,1	5.890,77
9	Box Girder	P. Kukup - Malaysia	0,361	0,2	30,1	358,83
		Total	37,060			105.556,57

Table 2f. Corridor III

No.	Bridge	Location	Bridge Length (Km)	Longest Span (Km)	Width (m)	Cost (IDR Billion)
1	Box Girder	Danai (Riau) - P. Kundur	6,657	0,25	30,1	6.612,40
	Cable Stayed		0,818	0,434	30,1	2142,1
	Box Girder		6,657	0,25	30,1	6.612,40
2	Box Girder	P. Kundur - P. Onggut	1,021	0,25	30,1	1014,18
3	Box Girder	P. Onggut - P. Sugibawah	11,870	0,25	30,1	11.790,47
	Suspension		4,200	3,7	48,7	71.589,00
	Box Girder		7,610	0,25	30,1	7.559,01
4	14 Box Girder	P. Sugibawah - Pp Kcl-P.Anak Sambu	25,266	0,25	30,1	25095,5
5	Box Girder	P. Anak Sambu - P. Sakijang Pelepah	2,770	0,25	30,1	2751,44
	Suspension		4,200	3,2	48,7	71.589,00
	Box Girder		2,770	0,25	30,1	2.751,44
6	Box Girder	P. Sakijang Pelepah - Singapura	4,500	0,25	30,1	4.469,85
		Total	78,339			213976,79

Table 2g. Technical data at Corridor I, II and III, Malacca Strait Crossing
(All corridors with 2 x 3 road lanes, Cost per 2008)

No.	Route	Length (Km)				Total length . (km)	Construction Cost, IDR (Triliun)				Total Cost, IDR (Trilun)
		Bridge	Road to P.Baru	Road	Tunnel		Bridge	Road to PBaru	Road	Tunnel	
Corridor-I	Option-A	55,4	135,0	53,8	0	244,1	163,3	4,1	1,6		169,0
	Option-B	55,5	135,0	96,9	0	287,5	163,5	4,1	2,9		170,4
	Option-C	6,7	135,0	53,8	42,4	237,8	9,1	4,1	1,6	143,2	158,0
	Option-D	6,8	135,0	96,9	42,4	281,2	9,3	4,1	2,9	143,2	159,5
Corridor-II	Danai-Malaysia	37,1	245,0	225,4		507,5	105,6	7,4	6,8		119,7
Corridor-III	Danai-Singapore	78,3	245,0	197,2		520,5	214,0	7,4	5,9		227,2

Source : Tunnel cost reffers to Selat Sunda Strait (Sindur M, 2000), 26 Km, USD 1,5 - 2 M per Tunnel/fase, and Maintenance of USD 4 Billions Pa. Est 30 years.

Table 2h. Technical data at Corridor I, II and III, Malacca Strait Crossing
(All corridors with 2 x 2 road lanes, Cost per 2008)

No.	Route	Length (Km)				Total length. (km)	Construction Cost, IDR (Triliun)				Total Cost, IDR (Triliun)
		Bridge	Road to P.Baru	Road	Tunnel		Bridge	Road to P.Baru	Road	Tunnel	
Corridor-I	Option-A	55,4	135,0	53,8	0	244,1	163,3	2,8	1,1		167,3
	Option-B	55,5	135,0	96,9	0	287,5	163,5	2,8	2,0		168,3
	Option-C	6,7	135,0	53,8	42,4	237,8	9,1	2,8	1,1	143,2	156,3
	Option-D	6,8	135,0	96,9	42,4	281,2	9,3	2,8	2,0	143,2	157,4
Corridor-II	Danai-Malaysia	37,1	245,0	225,4	0	507,5	105,6	5,1	4,7		115,4
Corridor-III	Danai-Singapore	78,3	245,0	197,2	0	520,5	214,0	5,1	4,1		223,3

Source : Tunnel cost reffers to Selat Sunda Strait (Sindur M, 2000), 26 Km, USD 1,5 - 2 M per Tunnel/fase, and Maintenance of USD 4 Billions Pa. Estimates 30 years.

Suspension bridges and Box Girders are applied with the width of bridge is 60 m, 2 x 3 road lanes, provided by 2 emergency road lanes, and utility for gas/oil/water lines, fiber optic cable line, electricity line etc. See Figure 5a.

Tube tunnel model is applied under sea bed with minimum depth. See Figure 5b. The road lane is designed on two deck floors and utility line for gas/oil/water lines, fiber optic cable line, electricity line, etc. are placed at the base floor of tunnel.

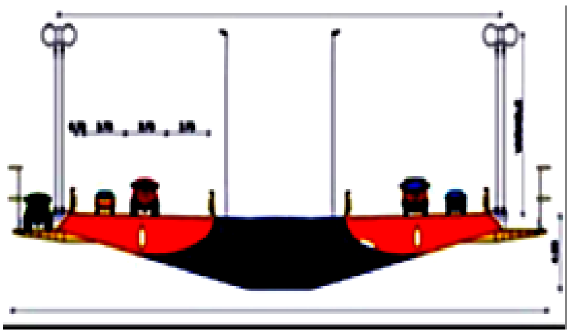


Figure 5a. Typical bridge cross section

Figure 5b. Typical tunnel cross section

Financial analysis assumption in Table 3:

- Started (base year) in 2025, Construction 10 years (2025-2035), Service life: 100 years (2035 - 2135);
- Traffic Growth:
  - Do nothing: (2008-2055: 3%), (2055-2135: 0%);
  - Bridge/Tunnel: (2008-2035: 3%), (2035-2045: 8%); (2045-2055: 5%), (2055-2065: 3%), (2065-2135: 0%);
- Toll Fare (average, 2025) Bridge: IDR 400.000 /veh,
- Toll Fare (average, 2025) Tunnel: IDR 300.000 /veh;
- Investment excluded construction cost consists of Land Aquisition, Toll Equipment, Feasibility Study, Environmental Analysis, Interest During Construction, Project Administration, Contingency, Supervision, Discount-rate, Inflation, Over Head, Total 62%. See Table 2.
- Cost Estimate based on prices per 2008, then projected to 2025.
- Financial Analysis based on B/C Ratio shown in Table 3.

Comparison of B/C ratio for 2 x 2 road lanes and 2 x 3 road lanes are relatively and significantly not different due to the cost of road is only 3% of bridge cost.

Table 3. B/C Ratio and cost of bridge, tunnel, with 2 x 2 road lanes at Corridor II and Corridor III

Alternative Route	BENEFIT (Billion IDR)		COST (Billion IDR)						Investation Excld Constr'n	B/C Ratio
	Utility	Toll	Bridge		Tunnel		Road			
			Constr'n	Maint'ce	Constr'n	Maint'ce	Constr'n	Maint'ce		
Corr-I Option-A: Bridge, Dumai-P.Rupat-P.Medang-Malaysia (Bridge. 55,4 Km, 60 m; HW 2 x 2 Lane)	12.291	1.653.628	322.976	8.493			2.234	2.848	201.630	3,10
	1.665.920		331.469				5.081		201.630	
Corr-I Option-B: Bridge, Dumai-P.Rupat-P.Medang-Malaysia (Bridge 55,5 Km, 60 m; HW 2 x 2 Lane)	19.666	1.605.464	323.285	8.516			4.026	2.848	202.933	3,00
	1.625.131		331.801				6.874		202.933	
Corr-I Option-C: Tunnel+Bridge, Dumai-P.Rupat-P.Medang-Malaysia (Tunnel 47 km; Bridge. 6,7 Km, 60 m; HW 2 x 2 Lane)	19.666	1.787.765	18.012	463	283.318	18.196	2.115	9.968	188.210	3,47
	1.807.431		18.475		301.514		12.084		188.210	
Corr-I Option-D: Tunnel+Bridge, Dumai-P.Rupat-P.Medang-Malaysia (Tunnel 47 km; Bridge 6,8 Km, 60 m; HW 2 x 2 Lane)	19.666	1.787.765	18.321	474	283.318	18.196	3.813	9.968	189.512	3,45
	1.807.431		18.795		301.514		13.781		189.512	
Corr-2: Bridge, Danai - P. Kundur - P. Karimun-Malaysia (Bridge 37,1 Km, 60 m; HW 2 x 2 Lane)	21.081	1.258.631	197.704	2.571			9.363	1.559	135.246	3,69
	1.279.712		200.276				10.922		135.246	
Corr-3: Bridge, Danai - P. Kundur - P. Batam - Singapura (Bridge 78,3 Km, 60 m; HW 2 x 2 Lane)	24.583	1.258.631	423.218	5.435			8.191	1.897	262.395	1,83
	1.283.214		428.653				10.087		262.395	

Asumption:

Started on 2025 (based year), 10 Years Construction, Design Life for Bridge 100 Years (2035-2135)

Traffic growth: (2035-2045: 8%), (2045-2055: 5%), (2055-2065: 3%, (2065-2135:0%);

Toll Fare (Avg): Bridge, IDR 400.000/unit; Tunnel IDR 300.000/unit

Investation excluded Construction: Land Aq, Toll Equip'nt, Pre-FS, FS, Envi An, IDR, Proj Adm, Conting'cy, Supervision, disc't-rate, inflation, OH (Total 62%)

Diverted Traffic 80%, Generated Traffic 40% at Corridor-II

Diverted Traffic 70%, Generated Traffic 30% at Corridor-III

*) Biaya investasi di luar biaya konstruksi meliputi antara lain pembebasan lahan, peralatan Tol, Pra-FS, FS, Amdal, FED, Administrasi Proyek, kontingensi, disount-rate dan inflasi serta overhead sekitar 62%

Sources: Laporan Pra Studi Kelayakan Jembatan Selat Malaka (Puslitbang Jalan dan Jembatan, 2007)

Economical Analysis by calculation and assumption based on investment duration of 35 years, 50 years, 75 years, and 100 years, the analysis may be predicted into 4 alternatives selected as follows:

- Alternative 1: Corridor I, Option-A or Option -C, crossing Rupat islands.
- Alternative 2: Corridor I, Option B or Option -D: passing through east sea shore of Rupat islands.
- Alternative 3: Corridor II: Bridge crossing some small islands to Karimun island and Malaysia.
- Alternative 4: Corridor III: Bridge crossing some small islands to Batam island and Singapore.

The project is stated feasible if BCR $\geq$ 1. BCR = 1 if benefit is equal to the cost. The duration is stated as Break Event Point (BEP). The project is feasible if the IRR as revenue is higher than the opportunity cost of capital or available discount rate in the market, and feasible if the NPV or income is more or equal to the cost and stated positive value.

Based on the four alternatives above, may be concluded that the third and the fourth alternatives are economicaly feasible, due to the result of feasibility test gives indicators as follows:

- B/C more than 1 (1,83 – 3,69)
- NPV is positive (3,9% – 12,3%)
- IRR more than 12% social discount rate (13,25% - 14,37%).

Direct benefits may be felt are shorter travel time and cheaper toll fare. Indirect benefit may be gained by industrial increase, distributes industries that may absorb resources and unemployments in Sumatera island, increases of tourism area and may find new natural sources. Economic development of industry, farms, mining, etc. are directed to regional expantional zone, to gain optimal outcomes of Malacca Strait Bridge for both Malaysia and Indonesia.

The ranking scores based on Multi Criteria Analysis (MCA) in Table 4 shows the selected score based on technical and non-technical considerations. The result scores for 2 x 3 road lanes and 2 x 2 road lanes gives the equal value.

Corridor I Option-C, uses Bridge and Tunnel is an efficient alternative that gives benefit for both Indonesia and Malaysia.

DISCUSSION AND SPECIAL CONSIDERATION

Points in Tabel 5 involves with social impact, land accusition and land settlement to be considered between Corridor-I and both of Corridor-II and Cordior-III.

Table 4. Ranking Scores Based on MCA

Corridor Number and Options		General	Eco-Tech Bridge	Eco-Tech Tunnel	Eco-Tech Road	Traffic Potensial	Construction Cost	SosEc...-Environment				An Economy	BC Ratio (An.Finc'l)	Total *)
								Psychlogy	Business	Road Acces	Eff			
I	Option A: Bridge	1	1	-	1	1	4	3	1	1	1	4	4	22
	Option B: Bridge	1	2	-	1	1	5	3	1	1	1	2	5	23
	Option C: Bridge and Tunnel	1	1	1	2	1	2	4	1	1	1	4	2	21
	Option D: Bridge and Tunnel	1	2	1	2	1	3	4	1	1	1	2	3	22
II	Bridge	2	3	-	3	3	1	1	2	2	2	1	1	21
III	Bridge	3	4	-	4	2	6	2	3	2	3	3	6	38

Note:
Score based on the degree of difficulties and cost. More difficult and expensive have large score.
*) Small number scores shows the best selection.

Table 5. Points Considered for Setting Recommendation

Corridor-I	Corridor-II and Corridor-III
✓ Difficulties due to the potensial social constraint of the local community at the very dense settlement and the risk of disturbed to industrial activity is relatively very high.	✓ Relatively no too risk for community business life and their majority community economical life.
✓ Difficulties in land accuisition due to the dense building resident settlement and communities.	✓ More easier in land accuisition procces due to the land area to be accuisitoned consists of farm, sleeping, and empty settlement area.
✓ Land accuisition impact to economical community business may be larger.	✓ Easier in land accuisition procces due to the land of community building to be accusitioned is no too dense and the population relatively lower than Corridor-I.
✓ Negoisiation with local communies may pottentially more difficult due to have to face with many different variable selves importance. Negosiation would be more easier to be if the collective deccision may be gained.	✓ Easier in relocation of the temporary people farm land and no too dense of population.
✓ By collective deccision, nogosiation procces may be more simple and may save the time.	✓ Land provided for relocation is sufficient
✓ Speculant involvement will be sophisticated and difficult in proccesing of land accuisition. The better land accuisition will be if there is no strong speculant imvolvement in land accuisition.	✓ Relocation may be done in the short time and the polemic may not be too large
	✓ The land accuisition cost would be secure and more efficient.
	✓ Potensial social conflict in land accuisition or may be lower and land preparation more better in land accuisition procces.

Special consideration to be warned in feasibility study on MSB is as follows:

– Bridge technology:
  - Wind at cross section should be calculated into account.
  - Light material may be considered.
– Tunnel technology:
  - Safety/security:
    - Fire protection technology;
    - Ventilation technology;
    - Floods handling.
  - Transportation.

The following assumptions for analisys to select the best corridor, based on study and general analisys for each area such as traffic, bridge, geotechnical, road and tunnel may be described fot setting recommendation for traffic, bridge, road pavement and tunnel respectively.

Traffic

a) Diverted traffic from air transport moda (passanger arround 50%) and ship transport moda (passanger by 70%-80%, goods 80%-100%) to the land transport moda.
b) Traffic flow tends increased from Indonesia to Malaysia/Singapore arround 30%-40%.
c) Malacca Strait Bridge may be more benefit after Sunda Strait Bridge is built in advance.
d) The selection of corridor depends on which area to be developed. Base on current analised potensial traffic (generated and diverted), the best corridor ranking is Corridor I, Corridor III and Corrdior II.
e) Due to the opening of Trans Asian Highway (TAH), traffic between Sumatera island and Malaysia and Singapore may be increased.

Bridge

a) Corridor I, the bridge design relatively longer and subgrade soil is not located on the swampy area;
b) Corridor II and III, the bridges design is relatively short but may face the swampy area problems, and the total length of bridge occured to be longer.
c) Corridor I, the main bridge type is better using Suspension type.
d) Vertical space from sea level on highest occasional must be according to the IMO requirements (> 75 m), and the length of span among pylon must follows the dimension of very large crude carrier (VLCC).
e) Bridge technology of MSB has the light difficult level compared by Sunda Strait Bridge (SSB), mainly from geografic condition and earthquake. The idth naviagtion link must be considered due to the current limited maximum length (technology) versus horizontal space needed. The Malacca strait is very busy and needs anticipation a projection to the future mainly for very large ship dimension.
f) Bridge design may consider some points as follows:
  - The bridge is completed with the first type of the rigid pylon system, including the deck supported by rigid and heavy frame, it may resist to aerodynamic effect.
  - The bridge is better using Pylon tapped to the bottom of the sea, by finds the deepest sea location. This is due to the current length bridge in Indoneisa is not built yet using the length span more than 1000 meter.

Geotechnical

a. Corridor I, by option from Malaysia Government plans using Artificial Island at the middle of Malacca Strait then connected with Tunnel, but regional aspect must be viewed.
b. Geotechnical aspect for MSB is relatively not sensitive to the fault and earthquake, so far the Tunnel technology may be considered.
c. Problems of the deep soft soil more than 30 meter, the lower subgrade strength, on the large areas.
d. Due to the soft soil is relatvely very deep, it may be considered using pile slab construstion.
e. Information of geotechnical in Malaysia and Singapore is needed for condition consideration design.

f. The height of embankment, up-lift an d horizontal forces on the bridge foundation are needed to take into account.
g. Tunnel and bridge are neccesary to be built at the fix location, based on the geotechnical evaluation result.
h. Design selection of bridge and tunnel constructions need the primary data interpretation of the under sea, marine data such as the magnitude of waves, occasion level, sea flows and wind force.
i. Design selection of road alignment for tunnel and bridge is based on the primary data evaluation, secundary data, and study of geological data, by learning some points as follows:
   - Bridge construction must take into account the suporting power of foundation (abutment and pile), in which their magnitude is depend on the soil/stone type and the forces works on that foundation.
   - Tunnel construction must take into account the overburden force at the design tunnel depth and to strengthen the structure at the sensitive areas due to the active fault influences.
   - Approach bridge/channel needs consideration of stratification soil and stone condition at the sea shore.

Road Pavement

a) Roads pavement construction may be more simple to be identified in the field compared with bridge and geotechnical problems.
b) Roads pavement is designed to be Class I, according to the vehicle dimension and axle load.
c) Other than soft soil/swampy area in Sumatera island, the characteritics to be identified is the environment and the forest conservation, and quarry materials for road pavement.
d) The soil subgrade condition must be taken into account in implementing for the rigid pavement or flexible pavement type. Rigid pavement is assumed more benefit, viewed to the long term maintenance.
e) The MSB is designed using double tracks, 2 x 2 road traffic lanes, and utility space.
f) Drainage must be a priority during road pavement construction.

Tunnel

Tunnel concept may be selected, i.e. tube and arc tunnel type. Some tunnel built in the world almost 85% using train moda for crossing vehicles, goods and passangers. Tunnel dimension is very depend on the need and transport moda that will be opperated. Tunnel model will be implemented and be considered such as Smart Tunnel in Malaysia, that using road way and vehicle as a transport moda. The tunnel type may be modified using highway, but must be viewed the psychological and comfortable for passanger/driver, and rest area infrastructure inside.

CONCLUSION AND RECOMMENDATIONS

Based on the study and analysis generally be concluded and recommended as follows:

Conclusion

1) Break event point (BEP) by building the bridge and tunnel:
   - Corridor-I Option-C, Option-D in 25-30 years (2072-2074)
   - Corridor-I Option-A, Option-B in 35-40 years (2075-2078).
   - Corridor-II in 35 years (2070);
   - Corridor-III in 60 years (2095).
2) The ranking of alternatives based on MCA:
   - Corridor-I Option-C, or Corridor II;
   - Corridor-I Option-A, or Corridor-I Option-D
   - Corridor-I Option-B,
   - Corridor-III.

Recommendation

The selection of tunnel and bridge at Corridor-I Option-C and Corridor-I Option-D should be intensively discused with appropriate stakeholder, concerning with the following factors:

– Technology absorbed and safety factor;

– Resources capability, especially for maintenance;
– Users/drivers psychology and comfort.

If bridge were selected, the best route should be discused by viewing some points:
– Foundation technology at the bottom of the sea;
– Integration of Toll Road Network.

Consession for operator may be recommended and be applied for 30 to 40 years.

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