Chapter 5 EXAMINATION OF ALIGNMENT AND SUITABLE CROSSING ALTERNATIVES FOR THE CAM RIVER

5.1 Review of Road Alignment

5.1.1 Suitable crossing alternative for Nguyen Trai Bridge

Structural crossing alternatives, including tunnels, for the Cam River are examined in this Section.

To the extent possible, quantitative estimates and assumptions were used for the comparison, and economy, constructability, and environmental impact were considered in order to select the best from the many crossing alternatives.

This comparison focuses on the route selection for the approach road on the south side of Nguyen Trai Bridge since this area requires widening the road and new construction in the existing densely populated residential area. The following factors were taken into account when making the comparison:

- Ensuring safe and comfortable ride quality on the urban road over Nguyen Trai Bridge
- Ensuring good connectivity between the main urban areas along the train line and the urban road network
- Consideration of an alignment, structural direction and width which minimizes the relocation of residents to the extent possible
- Minimizing environmental and socio-economic impact during construction

The alternatives shown in Table 5.1-2, including the "zero option" alternative of constructing no new crossing (in case the project is not implemented), were considered in the comparison. The Cam River is a physical barrier which restricts traffic, and if the "zero option" is adopted and a crossing is not constructed, the section will likely become a significant bottleneck for the urban transport network. The crossing is also needed in light of the future socio-economic development and urban planning of Hai Phong City. From the traffic demand analysis, if the "zero option" is adopted, the traffic capacity of Binh Bridge will be exceed in 2021.

Based on the comparison results, the bridge is recommended as the best alternative in comprehensive view of its impact on the natural environment and the buildings along the existing Nguyen Trai Street, as well as economy, constructability, and environmental impact. From the discussions with HPPC and VSIP about the alternatives and alignment including the bridge type, the Arch bridge and the alignment which connects to the Nguyen Trai Street are decided. Table 5.1-2 shows the details of the comparison and evaluation of alternatives. Conditions for each structure type are shown below.

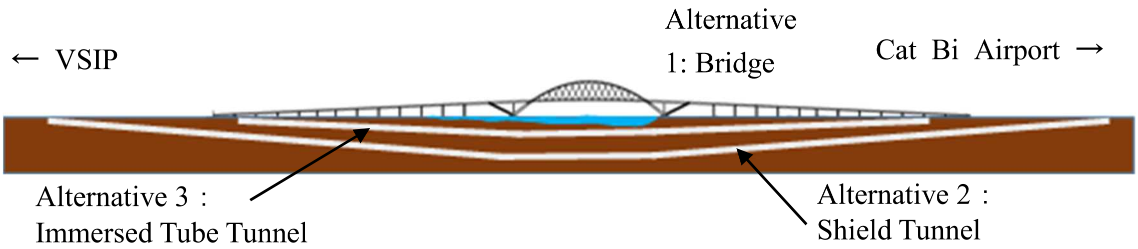


Figure 5.1- 1 Alternative Closing Method of Nguyen Trai Bridge

Table 5.1- 1 Assumed Condition for Comparison of Nguyen Trai Bridge

	Bridge	Shield tunnel	Immersed Tube Tunnel
Structure Length	1,350m	2,176m	1,256m
River and Navigation Clearance	Navigation clearance h x w; 25m x 80m	River depth -8.4m	River depth -8.4m
Road Conditions	Gradient 4% (80km/h) Width/Direction 2 lane x 3.75m + 1 bikeway x 3.0m(/direction)	Gradient 4% (80km/h) Width/Direction 2 lane x 3.75m + 1 bikeway x 3.0m(/direction)	Gradient 4% (80km/h) Width/Direction 2 lane x 3.75m + 1 bikeway x 3.0m(/direction)
Other Conditions	Cable stayed bridge Center span 280m	Earth cover 1.5 x D* *Diameter of tunnel	Earth cover 3.0m

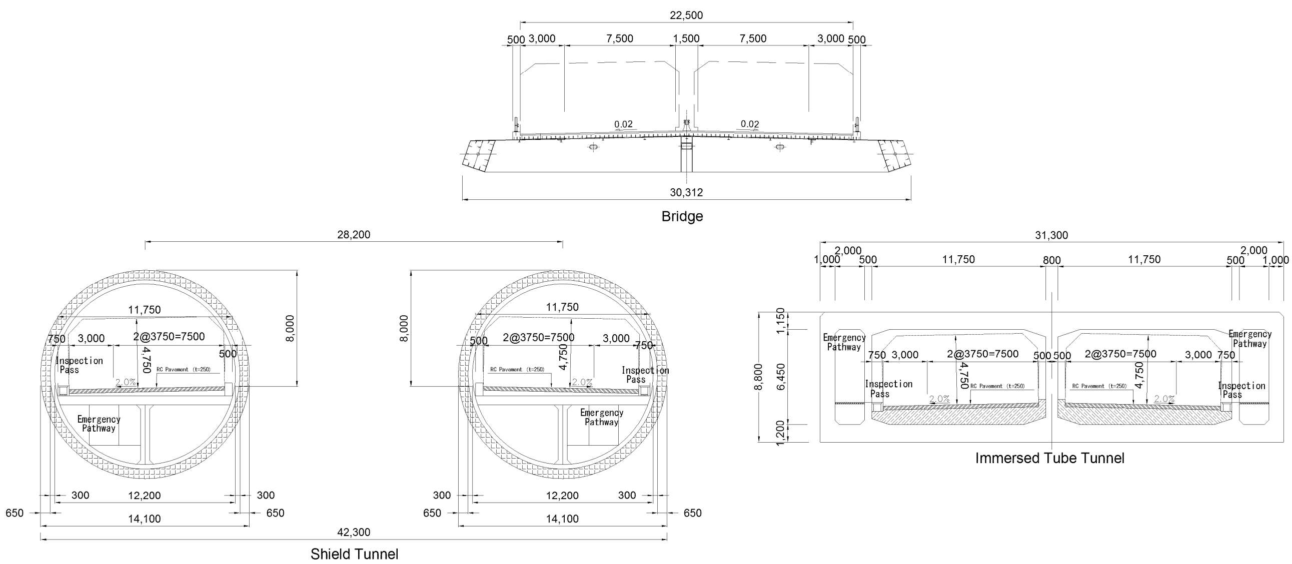


Figure 5.1-2 Typical Cross Section of Structure

Table 5.1- 2 Comparison and Evaluation of Alternatives for Nguyen Trai Bridge

Evaluation ◎ : Best alternative, ○ : Second-best alternative, △ : Possible if no other alternative, × : Unsuitable alternative

Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Summary and aim	Status quo, no construction (no environmental or social impact).	Alternative 1 involves the construction of a new bridge over the Cam River to cope with increased traffic associated with the development of new residential and industrial areas on the north river side and the opening of Lach Huyen Port. (Main structure: 600m bridge)	Alternative 2 involves the construction of a shield tunnel under the Cam River to cope with increased traffic associated with the development of new residential and industrial areas on the north river side and the opening of Lach Huyen Port.	Alternative 3 involves the construction of an immersed tube tunnel under the Cam River to cope with increased traffic associated with the development of new residential and industrial areas on the north river side and the opening of Lach Huyen Port.
Social impact	◎ No relocation of residents or houses, and no new land acquisition required.	○ The total length of the proposed bridge with access roads is approximately 1,350m. This requires the relocation of around 160 houses and the acquisition of around 1,360m^2 of land on the south river side. On the north river side, no houses have to be relocated, but the acquisition of around 5,000m^2 of land including aquaculture facilities and agricultural land is needed. Alternative 1 requires the least land acquisition and relocation, and has a social impact similar to Alternative 3 and less than Alternative 2.	× The total length of the proposed shield tunnel with access roads is approximately 2,180m which is the longest of all alternatives. The land acquisition and relocation needs on both river sides are expected more than 8,400m^2 which is higher than for Alternative 1 and Alternative 3. Dozens of houses along the extended access roads and around the excavation sites and tunnel openings are expected to be affected. On some sections, the use of underground areas requires surface rights to be considered. However, the present functions of the port can be kept unchanged.	△ The total length of the proposed immersed tube with access roads is approximately 1,260m. This requires the relocation of around 160 houses on the south river side, as well as the acquisition of around 8,400m^2 of land including aquaculture facilities and agricultural land on both river sides. The social impact is less than for Alternative 2 and similar to that for Alternative 1. On some sections, the use of underground areas requires surface rights to be considered. However, the present functions of the port can be kept unchanged.

Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Impact on mangrove forests and wetlands	◎ Status quo, no impact.	○ Since the bridge structure will be “transparent” after completion, the impact on surface currents and groundwater flow which may affect the wetlands and mangrove forests on the north side of Cam river is expected insignificant.	○ After completion, a 250m area around the tunnel opening and the adjoining earthwork section will obstruct the surface currents and groundwater flow, which negatively affects the wetlands and mangrove forests.	△ After completion, a 250m area around the tunnel opening and the adjoining earthwork section will obstruct the surface currents and groundwater flow, which negatively affects the wetlands and mangrove forests.
Impact on living environment / pollution	× Worsened traffic congestion leads to reduced average travel speed and increased stop-start traffic even with current traffic volume. This in turn results in increased fuel consumption and air pollutant emissions. Houses along the roadside will also suffer from more noise pollution.	◎ Although more regional traffic is expected to increase roadside air pollution, noise and vibration, such emissions and noise are diffused and the impact on the living environment is therefore less than for Alternative 2 and Alternative 3.	○ Since a ventilation tower with a concentrated ventilation system will be employed, it is unlikely that there will be high concentrations of emissions in the areas near the tunnel openings. Regarding noise around the tunnel openings, a noise absorption system should be employed to satisfy Vietnamese noise regulations. However, the noise level at the tunnel openings will be higher compared with Alternative1: Bridge.	○ Since a ventilation tower with a concentrated ventilation system will be employed, it is unlikely that there will be high concentrations of emissions in the areas near the tunnel openings. Regarding noise around the tunnel openings, a noise absorption system should be employed to satisfy Vietnamese noise regulations. However, the noise level at the tunnel openings will be higher compared with Alternative1: Bridge.

Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Impact on socio-economic activity and regional development	× Decreased traffic flow and safety negatively affects socio-economic activity, which limits the development of the entire Hai Phong area.	△ Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income. Limits on navigational clearance will negatively impact river traffic depending on ship height. Construction of bridge piers will occupy much of the busy river area, temporarily affecting river traffic.	◎ Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income.	○ Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income. Construction will occupy much of the busy river area, affecting river traffic for a long time.
Project cost	◎ No land acquisition or construction costs.	○ The project cost is lower than for Alternatives 2 and Alternative 3.	× The project cost is 2.0 times higher than for Alternative 1, and the highest of all alternatives.	△ The project cost is 1.3 times higher than for Alternative 1.
Maintenance costs	◎ No maintenance costs.	○ Although bridges have many structures such as slope protection facilities which require maintenance, the maintenance costs are only 1/5 of those for Alternative 3.	△ Tunnel facilities include lighting, ventilation, surveillance and fire protection equipment, all of which require maintenance. Maintenance costs are therefore expected to be about 5 times higher than for Alternative 1.	△ Tunnel facilities include lighting, ventilation, surveillance and fire protection equipment, all of which require maintenance. Maintenance costs are therefore expected to be about 5 times higher than for Alternative 1.

Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Overall evaluation	×	◎	○	△
		Alternative 1 is expected to improve the living environment, road transportation system, and socio-economic activity. Since the social impact and project cost are lower than for Alternative 2, and the impact on the natural environment and project cost are lower than for Alternative 3, the bridge is recommended as the best alternative.		

5.1.2 Location of Nguyen Trai Bridge

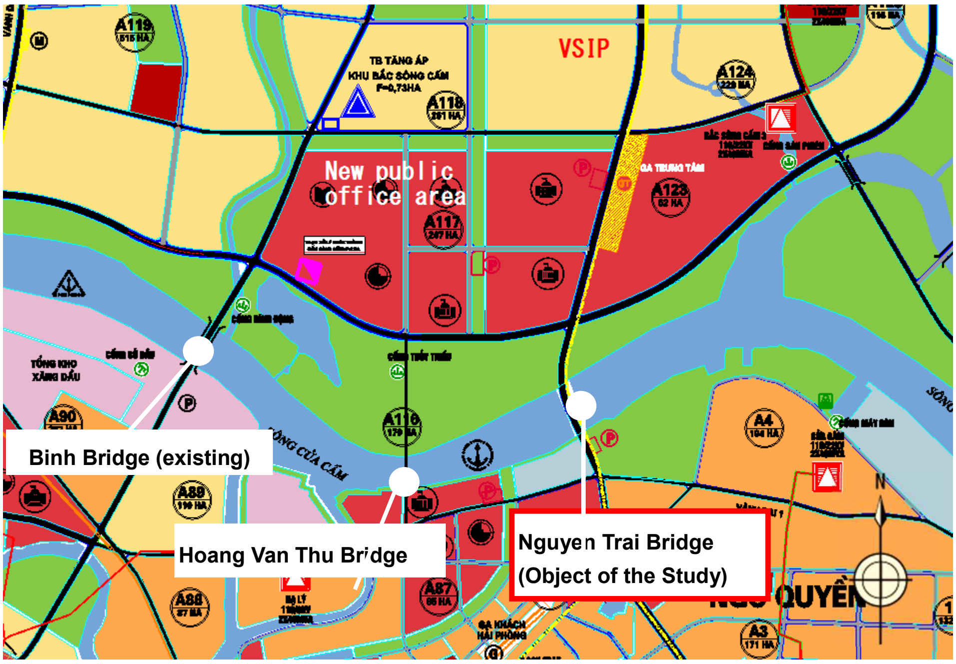
Nguyen Trai Bridge is planned as a connection between the existing old part and the planned new part of the city. For this purpose, the crossing point was examined in the “Amendment of Hai Phong City Master Plan to 2025, Vision for 2050” which includes plans for two bridges (Nguyen Trai Bridge and Hoang Van Thu Bridge). Except for the Master Plan, according to the Urban construction and development PMU, the future urban area plan includes Tuyen Dai Trung Tam Tunnel between the 2 bridges. The bridge sites in the Hai Phong City Master Plan are shown in Figure 5.1-3.

The planned location of Hoang Van Thu Bridge is about 1km upstream of Nguyen Trai Bridge. Of these 2 bridges, the Hai Phong City urban area plan gives higher priority to Nguyen Trai Bridge (interviewed by JICA mission in September 2015). The reason for the higher priority is the urgency and importance of constructing a route to connect Cat Bi Airport and the center of the VSIP area. About the construction plan of Hoang Van Thu Bridge and influence of the bridge is shown in Appendix A2.

In the view of connection road to the bridge, the road has already been widened in accordance with the Master Plan until a point 100m from the south end of the Nguyen Trai bridge (Figure 5.1-4), and the bridge will be a road which connects it to Nguyen Trai Street. Since construction is not progressing on the roads connected to the south of Hoang Van Thu Bridge and there are no connection road to main roads, the benefits of construction of the bridge are considered to be low at present.

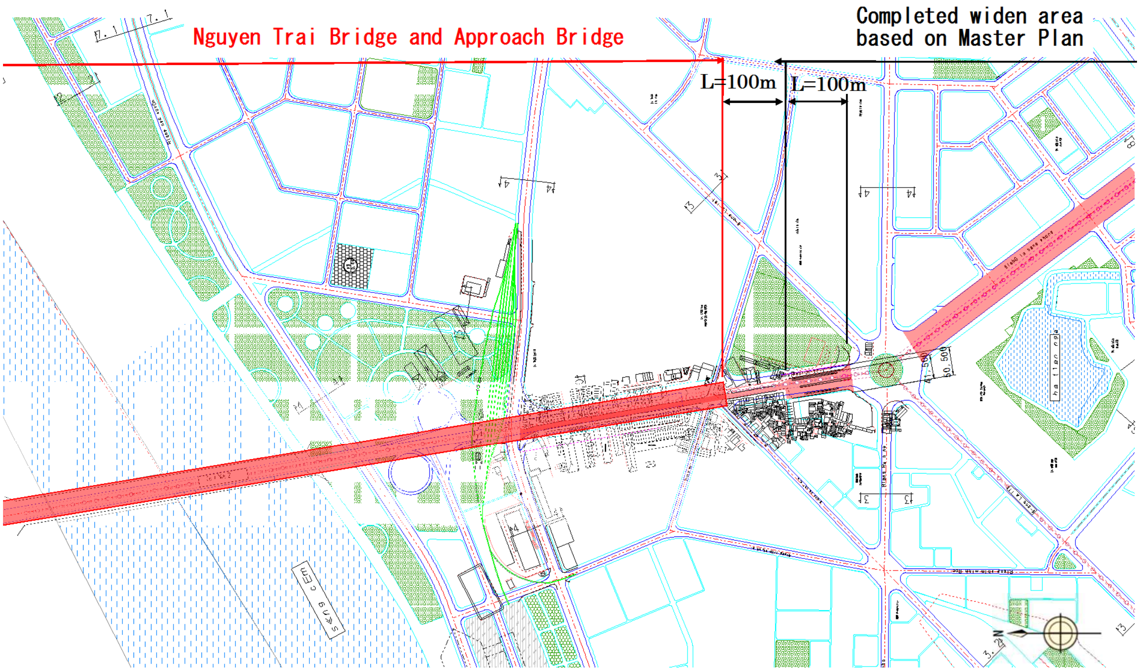
As for the north side of Nguyen Trai Bridge, there are mangrove trees along the north side of the Cam River. And it is necessary to cut down part of the mangrove forests on the north bank when the Nguyen Trai Bridge will be constructed. Also, the north side of Nguyen Trai Bridge is basically not residential area, so there is no protection targets, residents or houses, from CO2 emission and other pollutant.

Based on the above planning in the Master Plan, progress of connection road, and the impact on the environment, the Nguyen Trai Street line extension will be used as the crossing point in accordance with the urban area plan.



The bridge location is written based on HPPC Master Plan by study team.

Figure 5.1- 3 Planned Bridge Crossings over the Cam River



Source: Study team

Figure 5.1- 4 Completed Widening Section of Nguyen Trai Street

5.1.3 Suitable crossing alternative for Vu Yen Bridge

The developing company Vin Group is planning to build a golf course as well as a residential and recreational area on Vu Yen Island where the approach road on the north side of Vu Yen Bridge is to be located. The Hai An Port container yard and oil storage facilities are located close to where the south side approach road is to be built, and the construction of a tunnel crossing is also considered instead of the bridge alternative. The following factors were taken into account when making the comparison:

- Main logistics line for the connection between VSIP and the newly planned port facility
- Ensuring good connectivity between the main urban areas along the train line and the urban road network
- Consideration of an alignment and structural direction which avoids the relocation of residents and facilities to the extent possible
- Minimizing environmental and socio-economic impact during construction

The alternatives shown in Table 5.1-4, including the "zero option" alternative of constructing no new crossing (in case the project is not implemented), were considered in the comparison. The Cam River is a physical barrier which restricts traffic, and if the "zero option" is adopted and a crossing is not constructed, the section will likely become a significant bottleneck for the urban transport network. The crossing is also needed in light of the future socio-economic development and urban planning of Hai Phong City. From the traffic demand analysis, if the "zero option" is adopted, the traffic capacity of Binh Bridge will be exceed in 2023 and Nguyen Trai Bridge will exceeded in 2024.

Based on the comparison results, the bridge is recommended as the best alternative in comprehensive view of its impact on the natural and socio-economic environment during construction, its characteristic as the logistics road, as well as economy, constructability, and environmental impact. From the discussions with HPPC and relevant organizations such as PETEC, Hai An Port, and Vin Group about the alternatives and the alignment including the bridge type, the Cable stayed bridge and the alignment which minimizes the impact on the existing port are chosen as the optimal plan. Table 5.1-4 shows the details of the comparison and evaluation of alternatives.

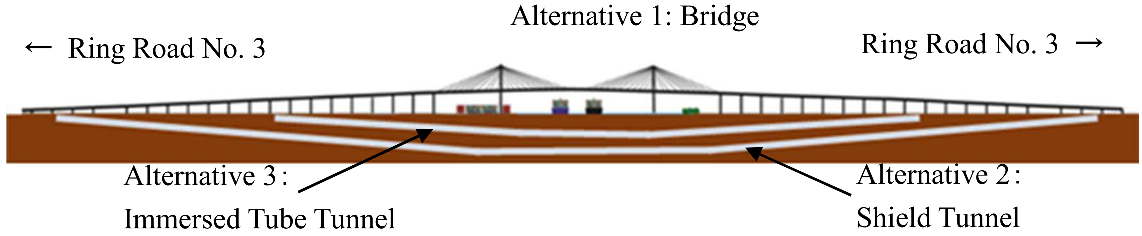


Figure 5.1- 5 Alternative Closing Method of Vu Yen Bridge

Table 5.1- 3 Assumed Condition for Comparison of Vu Yen Bridge

	Bridge	Shield tunnel	Immersed Tube Tunnel
Structure Length	2,520m	2,176m	1,256m
River and Navigation Clearance	Navigation clearance h x w; 45m x 80m	River depth -8.0m	River depth -8.0m
Road Conditions	Gradient 4% (80km/h) Width/Direction 2lane x 3.75m + 1 bikeway x 3.0m(/direction)	Gradient 4% (80km/h) Width/Direction 2lane x 3.75m + 1 bikeway x 3.0m(/direction)	Gradient 4% (80km/h) Width/Direction 2lane x 3.75m + 1 bikeway x 3.0m(/direction)
Other Conditions	Cable stayed bridge Center span 340m, approach length 920m per side	Earth cover 1.5 x D* *Diameter of tunnel	Earth cover 3.0m

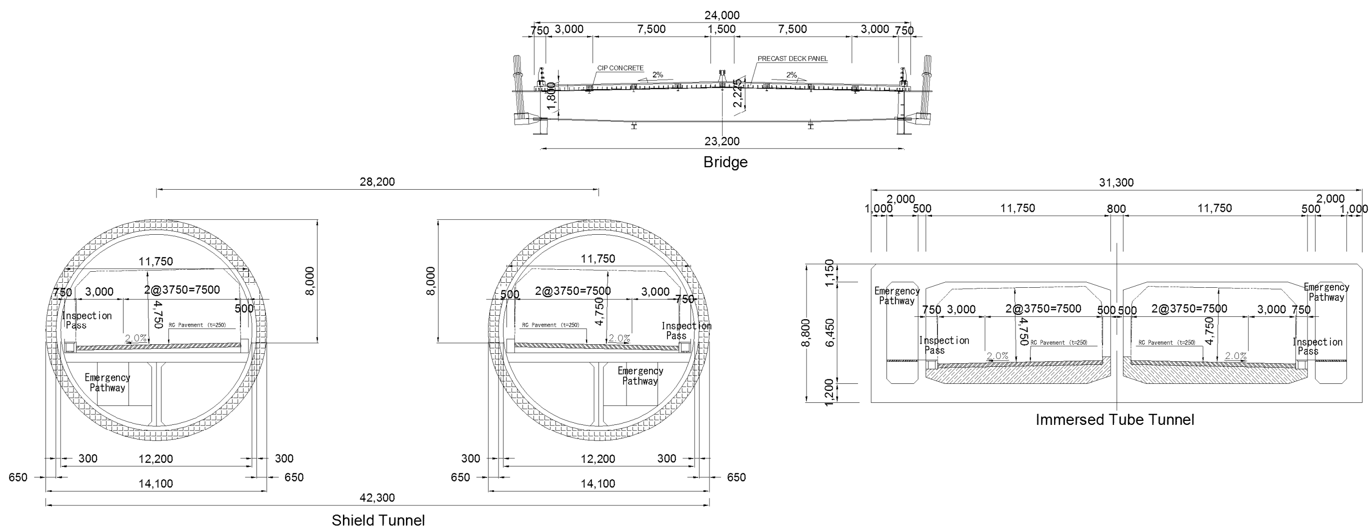


Figure5.1-6 Typical Cross Section of Structure

Table 5.1-4 Comparison and Evaluation of Alternatives for Vu Yen Bridge

Evaluation ◎ : Best alternative, ○ : Second-best alternative, △ : Possible if no other alternative, × : Unsuitable alternative

Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Summary and aim	Status quo, no construction (no environmental or social impact).	Alternative 1 involves the construction of a new bridge over the Cam River to cope with increased traffic and improved logistics associated with the opening of Lach Huyen Port. (Main structure: 600m bridge)	Alternative 2 involves the construction of a shield tunnel under the Cam River to cope with increased traffic and improved logistics associated with the opening of Lach Huyen Port.	Alternative 3 involves the construction of an immersed tube tunnel under the Cam River to cope with increased traffic and improved logistics associated with the opening of Lach Huyen Port.
Social impact	◎	△	○	○
	No land acquisition (existing or new) required.	Bridge construction does not require the relocation of houses, but land acquisition including some aquaculture facilities and agricultural land is needed. The total length of the proposed bridge with access roads is approximately 2,520m which is the longest of all alternatives. Land acquisition of 50,000m^2 on the north river side and of 30,000m^2 on the south river side is required, and the social impact is therefore larger than for all the other alternatives.	Areas around the tunnel openings require land acquisition including some aquaculture facilities and agricultural land. However Vu yen Tunnel will not affect the oil storage base near construction site. The total length of the proposed shield tunnel with access roads is approximately 2,180m. Land acquisition of more than 12,000m2 is required, the social impact is less than for Alternative 1 but larger than for Alternative 3.	Areas around the tunnel openings require land acquisition including some aquaculture facilities and agricultural land. However Vu yen Tunnel will not affect the oil storage base near construction site. The total length of the proposed shield tunnel with access roads is approximately 1,260m which is the shortest of all alternatives. Land acquisition of 12,000m^2 is required, and the social impact is therefore less than for Alternative 1 and Alternative 2.
Impact on mangrove forests and wetlands	◎	○	△	△
	Status quo, no impact.	Since the bridge structure will be "transparent" after completion, the impact on surface currents and groundwater flow which affect the wetlands and mangrove forests on the north side of the Cam River is limited.	After completion, a 250m area around the tunnel opening and the adjoining earthwork section will obstruct the surface currents and groundwater flow, which negatively affects the wetlands and mangrove forests on Vu Yen Island.	After completion, a 250m area around the tunnel opening and the adjoining earthwork section will obstruct the surface currents and groundwater flow, which negatively affects the wetlands and mangrove forests on Vu Yen Island.

Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Impact on living environment / pollution	× Future increases in traffic volume will most likely lead to more traffic congestion on the south side of the Cam River. Traffic congestion leads to reduced average travel speed and increased stop-start traffic even with current traffic volume. This in turn results in increased fuel consumption and air pollutant emissions. Houses along the roadside will also suffer from more noise pollution.	◎ Although more regional traffic is expected to increase roadside air pollution, noise and vibration, such emissions and noise are diffused and the impact on the living environment is therefore less than for Alternative 2 and Alternative 3.	○ Since a ventilation tower with a concentrated ventilation system will be employed, it is unlikely that there will be high concentrations of emissions in the areas near the tunnel openings. Regarding noise around the tunnel openings, a noise absorption system should be employed to satisfy Vietnamese noise regulations. However, the noise level at the tunnel openings will be higher compared with Alternative1: Bridge.	○ Since a ventilation tower with a concentrated ventilation system will be employed, it is unlikely that there will be high concentrations of emissions in the areas near the tunnel openings. Regarding noise around the tunnel openings, a noise absorption system should be employed to satisfy Vietnamese noise regulations. However, the noise level at the tunnel openings will be higher compared with Alternative1: Bridge.
Impact on water environment during construction phase	◎ Status quo, no impact.	○ The steel pipe sheet pile methods which is environmental friendly method will be used as a pier foundation. A working area and construction period is suppressed to the minimum, and an amount of discharged soil is small. The earth retaining wall has also high water-tightness, and the impact on the water environment containing a water quality, an ecosystem, a flood, etc. is very small. And the bridge structure will be "transparent" after completion, the impact on surface currents and groundwater flow which affect the wetlands and mangrove forests is limited.	○ Basically there is no impact on the surface currents, but the groundwater flow will be impacted.	× Since immersed tunnel is required large-scale excavation and longtime construction in the river, the impact on the water environment such as the water quality or river ecosystem will be large.

Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Road transport system	×	◎	○	○
	Increased traffic volume leads to congestion with a resulting drop in traffic flow and safety.	Sufficient traffic capacity ensures traffic flow and safety. Not only cars but also pedestrians can use the bridge.	Sufficient traffic capacity ensures traffic flow and safety, but there are several negative impacts on pedestrians and bicycle/motorbike traffic such as the concentration of car emissions in the tunnel, high oppressive feeling, and etc.	Sufficient traffic capacity ensures traffic flow and safety, but there are several negative impacts on pedestrians and bicycle/motorbike traffic such as the concentration of car emissions in the tunnel, high oppressive feeling, and etc.
Impact on socio-economic activity and regional development	×	△	◎	○
	Decreased traffic flow and safety negatively affects socio-economic activity, which limits the development of the entire Hai Phong area.	Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income. Construction of bridge piers will occupy much of the busy river area, temporarily affecting river traffic.	Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income.	Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income. Construction will occupy much of the busy river area, affecting river traffic for a long time.
Project cost	◎	○	×	○
	No land acquisition or construction costs.	The project cost is lower than for Alternative 2, and roughly the same as for Alternative 3.	The project cost is 1.7 times higher than for Alternative 1, and the highest of all alternatives.	The project cost is 1.1 times higher than for Alternative 1.
Maintenance costs	◎	○	△	△
	No maintenance costs.	Although bridges have many structures such as slope protection facilities which require maintenance, the maintenance costs are only 1/5 of those for Alternative 2 and Alternative 3.	Tunnel facilities include lighting, ventilation, surveillance and fire protection equipment, all of which require maintenance. Maintenance costs are therefore expected to be about 2.6 times higher than for Alternative 1.	Tunnel facilities include lighting, ventilation, surveillance and fire protection equipment, all of which require maintenance. Maintenance costs are therefore expected to be about 2.6 times higher than for Alternative 1.

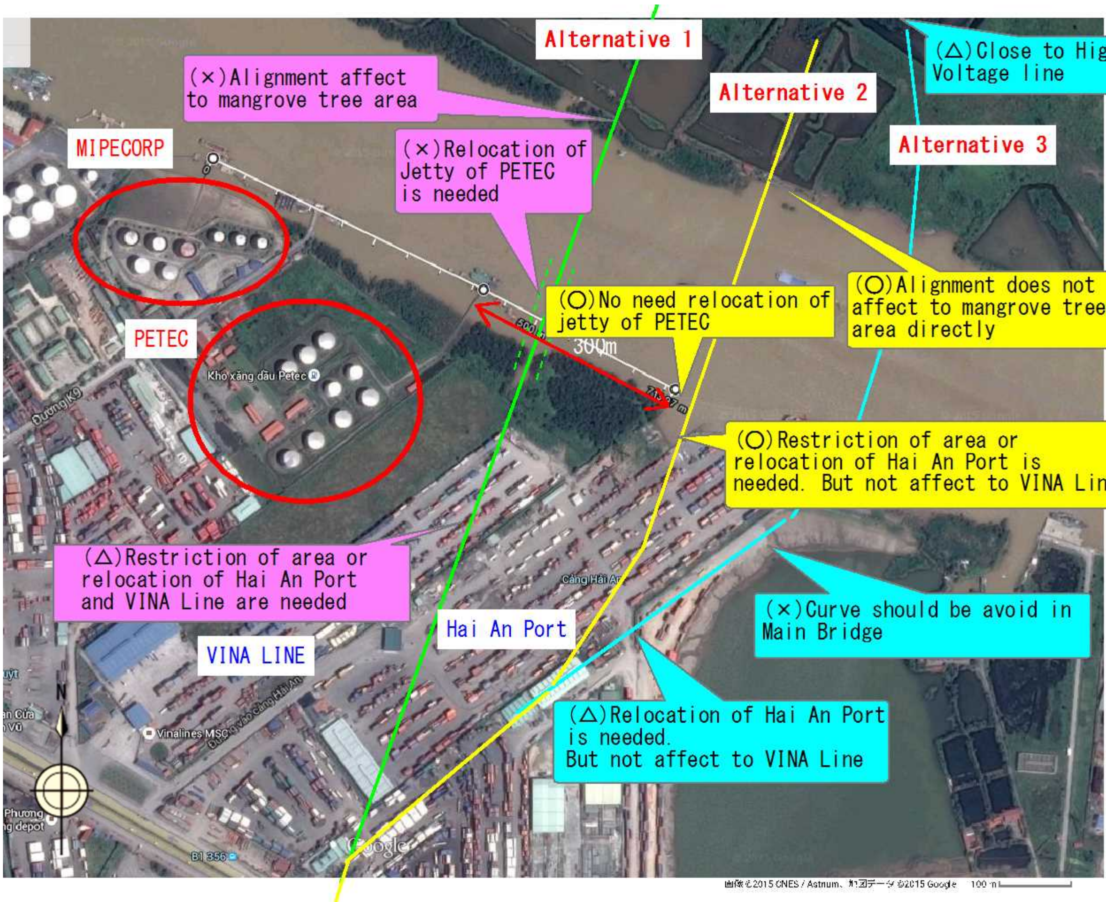
Alternative	Alternative 0 : No structure	Alternative 1 : Bridge	Alternative 2 : Shield tunnel	Alternative 3 : Immersed tube tunnel
Overall evaluation	×	◎	○	△
		Alternative 1 is expected to improve the living environment, road transportation system, and socio-economic activity. Since the impact on the living environment and project cost are lower than for Alternative 2, and the impact on the natural environment and project cost are lower than for Alternative 3, the bridge is recommended as the best alternative.		

5.1.4 Location of Vu Yen Bridge

Three alternatives were compared for the location of Vu Yen Bridge. The conditions used for the comparison are as follows.

- Impact of bridge construction on existing port facilities.
- Safety of nearby petroleum facilities.
- Consideration of the nearby ecological system, especially mangrove forests.
- Impact on bridge structure and trafficability.

To ensure the safety of the nearby petroleum facilities and minimize the impact on the existing port facilities, Alternative 2 was chosen.



Base image from Google Earth, 2015

Figure 5.1-7 Alternative Crossing Route of Vu Yen Bridge

Table 5.1-5 Comparison and Evaluation of Alternatives for Vu Yen Bridge Route

	Alternative Route 1	Alternative Route 2	Alternative Route 3
Concept	Shortest route.	300m safety distance from petroleum facilities (PETEC) can be ensured.	Impact on existing container yard can be minimized.
Safety of oil facilities	It's necessary to relocate the petroleum facilities (PETEC) since a 300m safety distance, distance by Decree No.13/2011/ND-CP cannot be ensured. ×	A 300m safety distance, defined by Decree No.13/2011/ND-CP, can be ensured. ◎	A 300m safety distance, defined by Decree No.13/2011/ND-CP, can be ensured. ◎
Safety of ship navigation	Safe since the piers will be constructed on land. ◎	Safe since the piers will be constructed inside of water's edge. ◎	Safe since the piers will be constructed on land. ◎
Road serviceability	Shortest route with good trafficability. ◎	Although there is an S-shaped curve on the south side, trafficability is no problem according to the road standard. ○	Although there is a big S-shaped curve on the south side, trafficability is no problem according to the road standard. △
Difficulty of construction	The main bridge has a straight alignment so construction is no problem. ◎	The main bridge has a straight alignment so construction is no problem. ◎	Since the main bridge is curved, it's difficult to use a cable-stayed bridge. ×
Social impact	Two port facilities (VINA LINE, Hai An Port) are affected. The facilities can be used also after completion of construction except around the pier location. △	VINA LINE is not affected. It's necessary to relocate the wharf facilities of Hai An Port about 50m downstream. The facilities can be used also after completion of construction except around the pier location. ○	VINA LINE is not affected. Hai An Port has to be closed since the route goes through above ship approaching facility. △
Pollution impact including CO_2, etc.	Because there are not residential area in both side of the bank, there is basically no impact for the residents. However workers of two port facilities on the south bank are slightly affected. △	Because there are not residential area in both side of the bank, there is basically no impact for the residents. However workers of two port facilities on the south bank are slightly affected. △	Because there are not residential area in both side of the bank, there is basically no impact for the residents. However workers of two port facilities on the south bank are slightly affected. △
Environmental impact	It is necessary to cut down part of the mangrove forests on the north bank. △	There is basically no need to cut down the mangrove forests. ○	There is basically no need to cut down the mangrove forests. ○
Evaluation	△	◎	△

Evaluation ◎ : Best, ○ : Second-best, △ : Possible if no other, × : Unsuitable

5.1.5 Ring Road 3

Haiphong RR3 serves as a main road connecting Cat Bi airport, VSIP industrial area, new administrative area, and QL10, and there are many households, rice fields, and culture pond over the planning site of the RR3. Since the construction of RR3 involves widening and newly construction in a dense residential area, the following factors were taken into account when making the comparison:

- Ensuring safe and comfortable ride quality as the urban road.
- Ensuring good connectivity between main urban areas and the urban road network.
- Consideration of an alignment and structural direction which avoids the relocation of residents and facilities to the extent possible.
- Minimizing the environmental and socio-economic impact during construction.

The alternatives shown in Table 5.1-6, including the "zero option" alternative of constructing no new road (in case the project is not implemented), were considered in the comparison. Alternative 1: the route minimizing the land acquisition and relocation, Alternative 2: the route by shortest cut, and Alternative 3: the route effectively utilizing the current road.

The road connecting between Vu Yen Island and Thuy Nguyen district is important and necessary for the development plan of Haiphong city according to the construction of the Vu Yen Bridge, and if the "zero option" is adopted and the RR3 is not constructed, the section will likely become a significant bottleneck for the urban transport network.

Based on the comparison results, the route which is minimize the land acquisition and relocation is recommended as the best alternative in comprehensive view of its impact on the housing and the buildings along the existing rural road and distribution of the rice field and culture pond, as well as economy, constructability, and environmental impact. F/S of this section has been done by HEZA. From the discussion with the PMU about the road alignment, the route which is not pass the high residential density area is preferred and consented. Table 5.1-6 shows the details of the comparison and evaluation of alternatives.

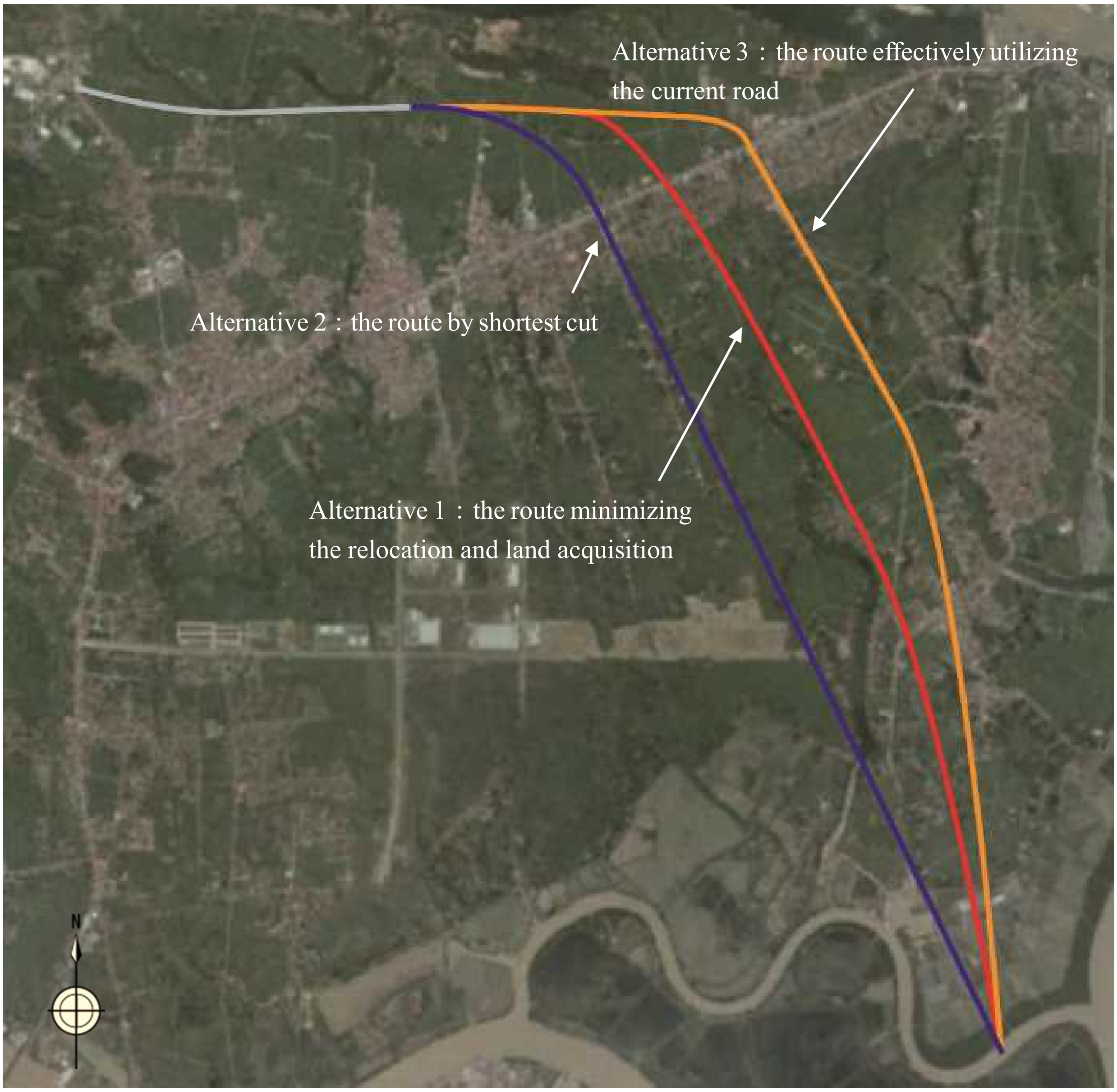


Figure 5.1-8 Route Alternatives with Respective Merits

Table 5.1-6 Comparison and Evaluation of Alternatives for RR3

Evaluation ◎ : Best alternative, ○ : Second-best alternative, △ : Possible if no other alternative, × : Unsuitable alternative

Alternative	Alternative 0 : No structure	Alternative 1: Route minimizing relocation and land acquisition	Alternative 2: Shortest route	Alternative 3: Route effectively utilizing the existing road
Summary and aim	Status quo, no construction (no environmental or social impact).	Minimize the number of relocation households without road alignment and loss of network function. Road length: 13km	Connect the starting point (Vu Yen Island) and ending point (QL10) using the shortest route. Road length: 11.6km	Use and widen the existing road to the extent possible. Road length: 13.5km
Social impact	◎ No land acquisition (existing or new) required.	○ Relocation of 500 households and land acquisition of 650,000m^2 is required, but the social impact is the smallest of all the other alternatives (except the zero-option). The possibility of small-scale community segmentation since the road hinders pedestrian traffic between residential areas, agricultural areas and public facilities.	× Relocation of 100 households more than Alternative 1 and land acquisition of 580,000m^2 are required. The possibility of small-scale community segmentation since the road hinders pedestrian traffic between residential areas, agricultural areas and public facilities.	× Since this route widens the exiting road and takes a roundabout route, the road becomes long (1~2km). Also houses are densely packed along the existing road and number of relocation will be100 households more than Alternative 1. Furthermore, the land acquisition of 675,000m^2 which is the largest area of all alternatives is required. The possibility of small-scale community segmentation since the road hinders pedestrian traffic between residential areas, agricultural areas and public facilities.
Impact on natural environment (mangrove forests)	◎ Status quo, no impact.	○ 8,650m^2 of the mangrove forests and part of the wetlands are affected by excavation or construction during the construction period.	○ 8,650m^2 of the mangrove forests and part of the wetlands are affected by excavation or construction during the construction period.	○ 8,650m^2 of the mangrove forests and part of the wetlands are affected by excavation or construction during the construction period.

Alternative	Alternative 0 : No structure	Alternative 1: Route minimizing relocation and land acquisition	Alternative 2: Shortest route	Alternative 3: Route effectively utilizing the existing road
Impact on living environment / pollution	×	◎	◎	○
	There is no effect on the planned site, but for Hai Phong City, worsened traffic congestion leads to reduced average travel speed and increased stop-start traffic even with current traffic volume. This in turn results in increased fuel consumption and air pollutant emissions in Hai Phong City.	Although more regional traffic is expected to increase roadside air pollution, noise and vibration, such emissions and noise are diffused.	Although more regional traffic is expected to increase roadside air pollution, noise and vibration, such emissions and noise are diffused.	Although more regional traffic is expected to increase roadside air pollution, noise and vibration, such emissions and noise are diffused. This route is planned to pass existing settlements, and the impact on the living environment is therefore more than for Alternative 1 and Alternative 2.
Road transport system	×	○	◎	△
	Since there is no traffic connection between Vu Yen Island and Thuy Nguyen district, the traffic flow from Vu Yen Island to the south side of the Cam River is cut off.	Sufficient traffic capacity ensures traffic flow.	Sufficient traffic capacity ensures traffic flow. Especially the linear road alignment has better traffic functions.	Sufficient traffic capacity ensures traffic flow, but the route along the existing road alignment may cause traffic congestion.
Road safety during construction	◎	○	○	△
	Status quo, no impact.	Capable of causing traffic accidents by traveling vehicles on the newly-built road.	Capable of causing traffic accidents by traveling vehicles on the newly-built road.	Capable of causing traffic accidents due to widening of the existing road. Safety measures need to be develop in a built-up area.
Impact on socio-economic activity and regional development	×	◎	◎	◎
	Decreased traffic flow and safety negatively affects socio-economic activity, which limits the development of the entire Hai Phong area.	Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income.	Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income.	Smooth and safe traffic promotes socio-economic activity and regional development. More employment opportunities for local workers and consumption during the construction period will also lead to increased regional income.

Alternative	Alternative 0 : No structure	Alternative 1: Route minimizing relocation and land acquisition	Alternative 2: Shortest route	Alternative 3: Route effectively utilizing the existing road
Project cost	◎ No land acquisition or construction costs.	△ The resettlement cost is the smallest, but land acquisition costs are larger than for Alternative 3. Since the road length is longer than for Alternative 2, the construction cost is also higher than for Alternative 2.	○ The land acquisition cost is the smallest, but resettlement costs are larger than for Alternative 1 (but still smaller than for Alternative 3). Since the road length is the shortest, the construction cost is lower than for Alternative 1.	△ By widening the existing road, land acquisition costs are reduced. But the resettlement cost is larger than for Alternative 1 and 2. Since the road length is the longest, the construction cost is the highest of all alternatives.
Maintenance costs	◎ No maintenance costs.	○ The whole length is paved with asphalt, and structures such a bridges and slope protection systems are relatively small. Maintenance costs are relatively low compared with the other alternatives.	○ The whole length is paved with asphalt, and structures such a bridges and slope protection systems are relatively small. Maintenance costs are relatively low compared with the other alternatives.	○ The whole length is paved with asphalt, and structures such a bridges and slope protection systems are relatively small. Maintenance costs are relatively low compared with the other alternatives.
Overall evaluation	×	◎ Alternative 1 is expected to improve the living environment, road transportation system, and socio-economic activity. Since the impact on the living environment is the lowest of all alternatives, the route which minimizes relocation is recommended as the best alternative.	○	△

5.2 Preliminary Design for Bridge Crossing

5.2.1 Study of Main Span Length

(1) Location of Substructure for Nguyen Trai Bridge

1) Available Area for Substructure Construction and Main Span Length

On the south side of the Cam River on the Nguyen Trai Bridge section, there are currently operational container terminals and a shipbuilding yard. According to DOT, the port facilities will be relocated to another location, and the timing of the relocation and the construction of Nguyen Trai Bridge will therefore likely overlap. For this reason, the location of a newly constructed pier (main bridge tower) should not affect the navigation channel closer to port terminal for safety of construction and navigation. Therefore, no pier (tower) should be constructed in the Cam River between the south bank and the existing navigation channel, whereas the area between the north bank and the navigation channel has no restrictions on the use of the water surface. In addition to these conditions for the determination of the main span length of Nguyen Trai Bridge, the space required for pier construction should be considered. Figure 5.2-1 shows the current navigation channel and alternative location of pylon.

The main span length alternatives can be compared using the plans listed below.

PLAN 1 : Span length L =280m (minimum span length, which has same navigation space with Binh Bridge located at 3km upstream)

PLAN 2 : Span length L=420m (a tower on land.)

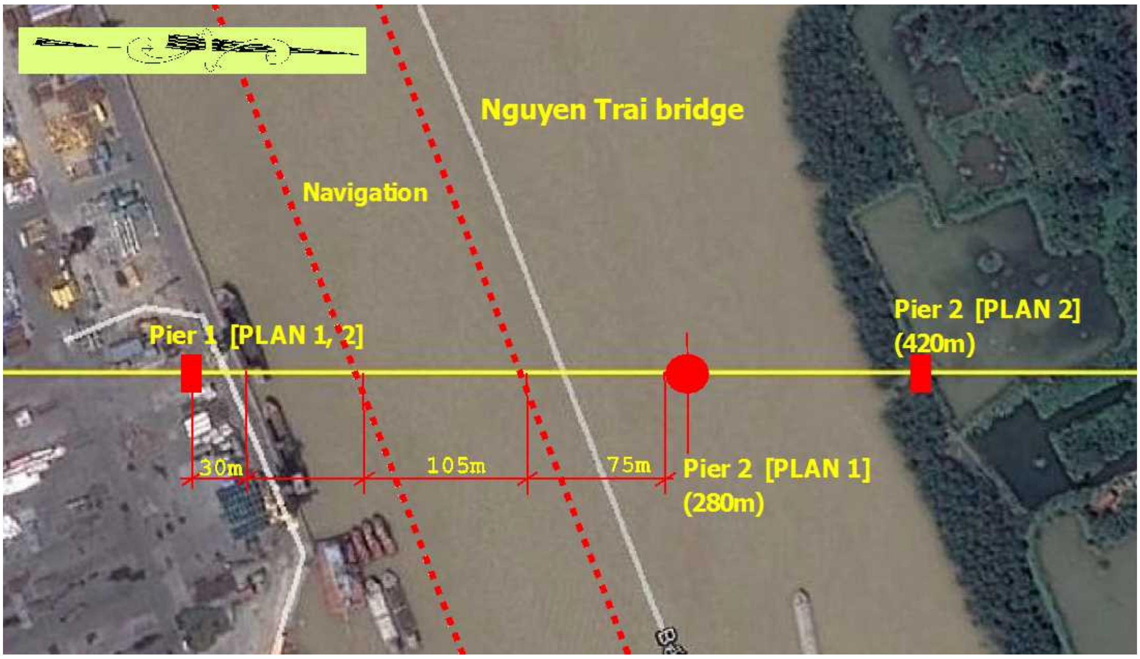


Figure 5.2-1 Available Area for Substructure Construction and Main Span Length

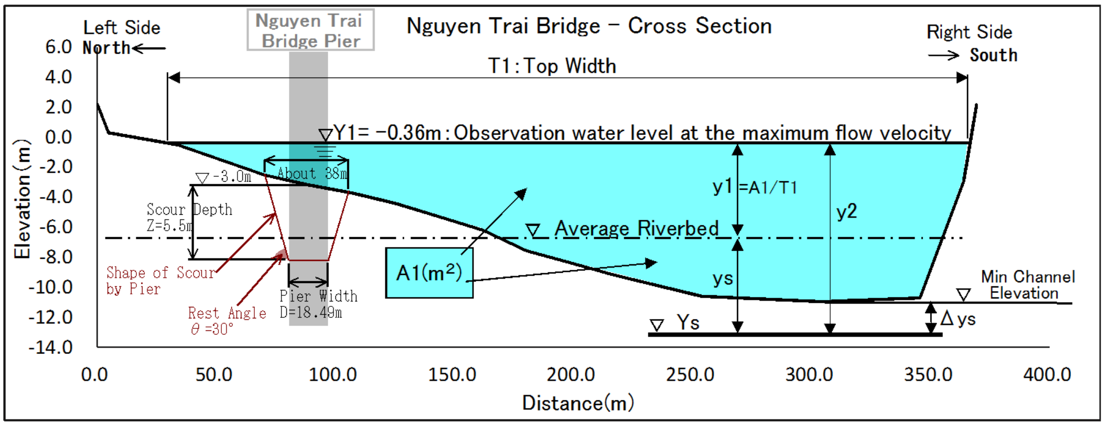


Figure 5.2-2 Substructure of Nguyen Trai Bridge – Cross Section

2) *Comparison Study of Pier Location: In-river vs. On-land*

The 280m span length which has the same navigation space as Binh Bridge is considered the minimum span length. This span length was accepted by the Marine Administrator of Hai Phong and the Vietnam Maritime Safety-North in related hearings.

PLAN 1 aims to achieve the shortest center span for Nguyen Trai Bridge. Because of this, the plan requires the construction of a pier (main bridge tower) in the Cam River. The pier needs to be designed against the vessel collision impact force of a 7,000 DWT vessel because of the h=25.0m navigation clearance of Nguyen Trai Bridge. As a result of stability analysis of the pier foundation, it is confirmed that vessel collision impact is not the dominant factor for determination of foundation dimensions in contrast to Vu Yen Bridge which requires a 50,000 DWT design vessel in water.

PLAN 2, on the other hand, uses an on-land pier. The superstructure reaction force on the pier is larger than that of PLAN 1 because of the difference in span length. Therefore, it is clear that the pier construction cost of PLAN 1 is the lowest since it has the smallest superstructure reaction force.

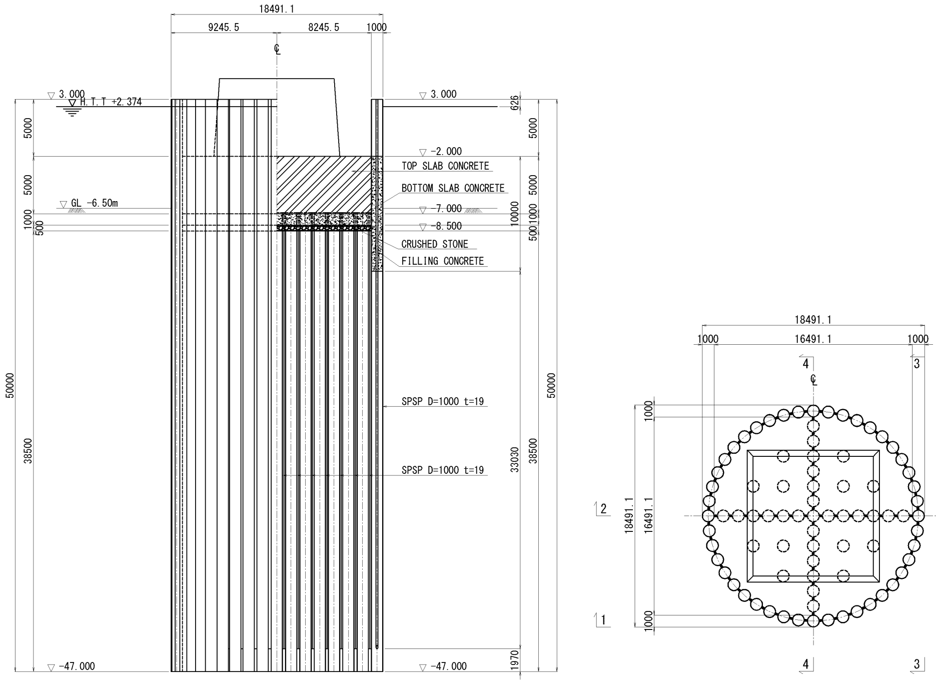


Figure **5.2-3 Minimum Dimensions of In-river Pier (Superstructure: Arch Bridge)**

3) Influence to river flow

As natural condition study in Chapter 3, maximum water flow speed is 0.95m/sec.

In case that pier set in water, effect to river flow and scour is considered. According to guideline for structure for river administration facilities in Japan, target ratio of structure area to river area is less than 5% to not disturb to river flow. The ratio of Nguyen Trai Bridge is 3.5% which is smaller than target ratio.

{(18.491 x 5.0m)+(4.95 x 4.0m)} /3,203m2 =3.5%

(Area of main bridge + Area of approach bridge)/River area

And the center span length is smaller than Binh Bridge (260m) which is located at 3km upstream. It is considered that influence by pier to the river flow is small.

Local scour calculated in Chapter 3 shall be considered in structure design.

(2) Location of Substructure for Vu Yen Bridge

1) Available Area for Substructure Construction and Main Span Length

On the south side of the Cam River on the Vu Yen Bridge section, there are currently operational oil terminals and container terminals, which will also be in use after the construction of Vu Yen Bridge. For this reason, the location of a newly constructed pier (main bridge tower) should not affect the navigation channel closer to port terminal for safety of construction and navigation. Therefore, no pier (tower) should be constructed in the Cam River between the south bank and the existing navigation channel, whereas the area between the north bank and the navigation channel has no restrictions on the use of the water surface. In addition to these conditions for the determination of the main span length of Vu Yen Bridge, the space required for pier construction should be considered. Vietnamese regulations require a clearance of 30m between the navigation channel and any nearby structures. Figure 5.2-4 shows the current navigation channel and alternative location of pylon..

The main span length alternatives can be compared using the plans listed below.

PLAN 1 : Span length L = 280m (Tower in the river and shortest span length.)

PLAN 2 : Span length L = 340m (Tower on land and shortest span without vessel collision.)

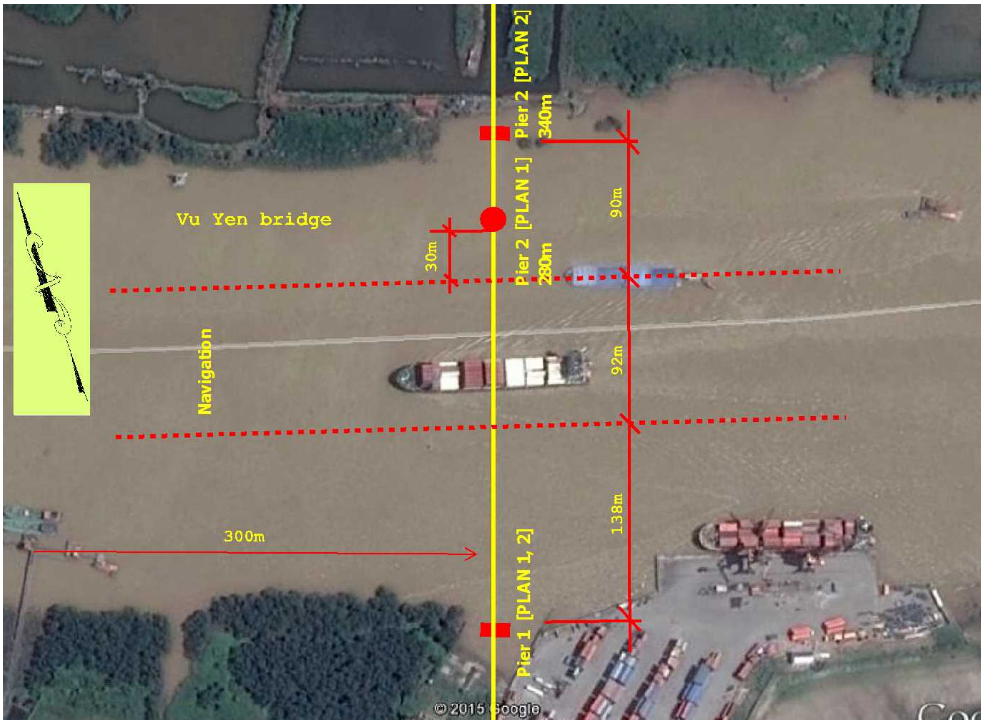


Figure 5.2-4 Available Area for Substructure Construction and Main Span Length

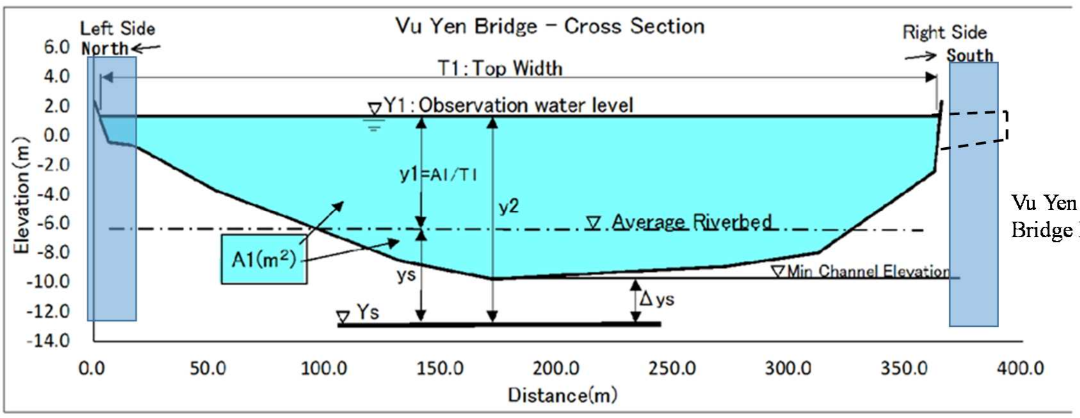


Figure 5.2-5 Vu Yen Bridge - Cross Section

2) Comparison Study of Pier Location: In-river vs. On-land

PLAN 1 aims to achieve the shortest center span for Vu Yen Bridge. Because of this, the plan requires the construction of a pier (main bridge tower) in the Cam River. The pier needs to be designed against the vessel collision impact force of a 50,000 DWT vessel based on the accumulated record of vessel traffic on the Cam River. As a result of stability analysis of the pier foundation, it is confirmed that vessel collision impact is the dominant factor for determination of the foundation dimensions.

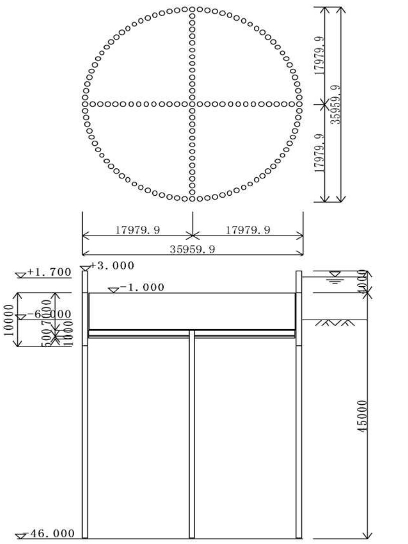
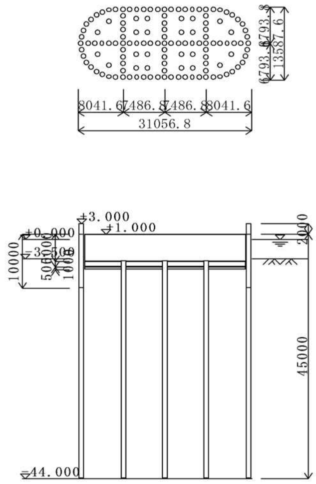
PLAN 2, on the other hand, uses an on-land pier which does not require consideration of vessel collision impact, and the superstructure reaction force on the pier foundation is therefore dominant in this regard.

Table 5.2-1 shows the results of the stability analysis and the rough construction costs. The results indicate that the application of collision impact force (50,000 DWT) requires significantly larger foundation dimensions compared to a foundation with increased superstructure reaction force due to the extension of the center span from 280m to 340m.

Regarding the construction cost, it is confirmed that the direct cost of the in-river tower (PLAN 1) is 680 million Japanese yen (approx. 123 billion Vietnamese dong) more expensive than the on-land tower (PLAN 2) according to a rough cost estimate made by the JICA Study Team.

In view of impact to river condition, since both pier is located inside of riverbank, PLAN 2 does not affect to river flow.

Table 5.2-1 Comparison Study: In-river Tower vs. On-land Tower for Vu Yen Bridge

Options				Location: Beside the Navigation Channel Main Span L=280m Vessel Collision: 50,000DWT				Location: Near Riverbank (far from the Navigation Channel) Main Span L=340m Vessel Collision: 2,000DWT			
Diagram				 Pile Length 45.0 (m) Nos of Piles = 141 (nos)				 Pile Length 45.0 (m) Nos of Piles = 109 (nos)			
Calculation Result	Item	Mark	Unit	Longitudinal direction		Trans. Direction		Longitudinal direction		Trans. Direction	
				Dead+Live Road	Vessel impact	Dead+Live Road	Vessel impact	Dead+Live Road	Vessel impact	Dead+Live Road	Vessel impact
	Reaction force at bottom surface of top slab	N	kN	268,460	253,792	268,460	253,792	201,269	201,793	201,269	201,269
		H	kN	6,000	66,000	0	120,000	−2,056	−11,480	0	−21,890
		M	kN.m	60,000	222,000	0	324,000	−116,163	−22,563	-61,268	-64,333
	Max. vertical reaction force	Rmax	kN/nr	2,385	3,530	2,217	5,231	1,557	1,569	1,566	1,923
		Ra	kN/nr	4,273	6,409	4,273	6,409	2,303	3,455	2,303	3,455
	Min. vertical reaction force	Rmin	kN/nr	2,049	662	2,217	−1,039	1,516	1,512	1,506	1,150
		Pa	kN/nr	-966	−1531	-966	−1531	−705	−1,076	−705	−1,076
	Horizontal Displacement	δ 2	cm	0.20	1.19	0.00	2.51	5.19	6.53	1.42	11.86
		δ 2a	cm	5.00	5.00	5.00	5.00	50.00	50.00	50.00	50.00
	Stress in steel pipe pile	σ max	N/mm2	43.0	105.5	34.4	179.5	52.8	57.7	44.1	79.4
		σ a	N/mm2	140.0	210.0	140.0	210.0	140.0	210.0	140.0	210.0
Cost	Item	Unit		Qty	Unit Price	Amount (1000 JPY)		Qty	Unit Price	Amount (1000 JPY)	
	Weight of steel piles	ton	1000 ¥	3,347.7	350.0	1,171,699		2,157.4	350.0	755,090	
	Indirect costs	%	1000 ¥	45%		527,265		45%		339,791	
	Construction cost	−	1000 ¥	−		1,698,964		−		1,094,881	
	Ratio	−	−	1.55				1.00			
Result		−	−					O			

○: High applicability, △: applicable, ×: low applicability

3) Location of North Pylon

Considering navigational safety and the huge cost of constructing the substructure on water, PLAN 2 with the 340m main span length is recommended. Hearings conducted with the Navigation Authority and Marine Safety also indicate that this span length has been accepted. The exact position of the north pylon will be determined based on total construction cost and environmental considerations such as protection of nearby mangrove forests.

5.3 Policy of Road Basic Design

5.3.1 Scope of the Project

An outline of the road design for the Project is shown in Table 5.3-1.

Table 5.3-1 Outline of Project Road Design

	Length/Location	Number of lanes	Notes
Ring Road No.3	L=16.8km	4 lanes	Including Vu Yen Bridge
Vu Yen Bridge	L=3.2km across Cam River	4 lanes	Main Bridge + Approaches
Nguyen Trai Bridge	L=1.81km across Cam River	4 lanes	Main Bridge + Approaches

A location map of the Project is shown in Figure 5.3-1.

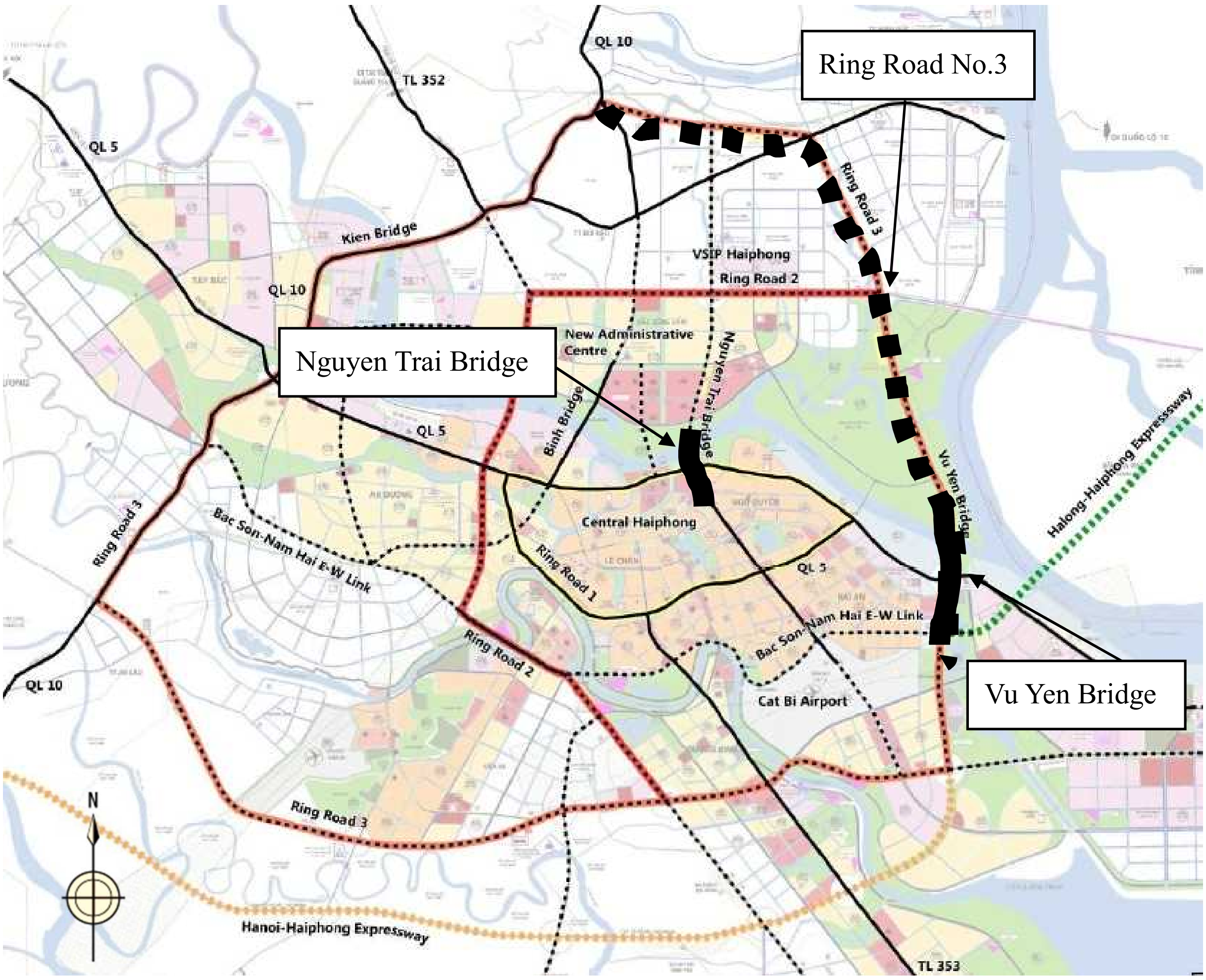


Figure 5.3-1 Location Map of the Project

5.3.2 Design Criteria

The road design was carried out based on Vietnamese design criteria, which are shown in Table 5.3-2. However, Japanese design criteria were also taken into consideration for the road design following confirmation with HPPC.

Table 5.3-2 Vietnamese Design Criteria

TCXDVN 104-2007	Urban Road – Specifications for Design
TCVN4054-2005	Highway - Specifications for Design

The design criteria for each road were determined according to each type of road classification shown in Table 5.3-3 to Table 5.3-4.

(1) Nguyen Trai Bridge, Ring Road No.3 Urban Areas

Table 5.3-3 Design Criteria (1/2)

Road terrain conditions	Urban Area
Design criteria	TCXDVN 104-2007
Urban category	Special urban, Class I Main urban road – Primary
Road type	Main urban road – Primary
Design speed	80km/h

(2) Vu Yen Bridge, Ring Road No.3 Non-Urban Areas

Table 5.3-4 Design Criteria (2/2)

Road terrain conditions	Non-Urban Area and Farm Area
Design criteria	TCVN4054-2005
Urban category	Special urban, Class I Main urban road – Primary
Road type	Grade III (Provincial road)
Design speed	80km/h

The classification of each route is shown in Figure 5.3-2.

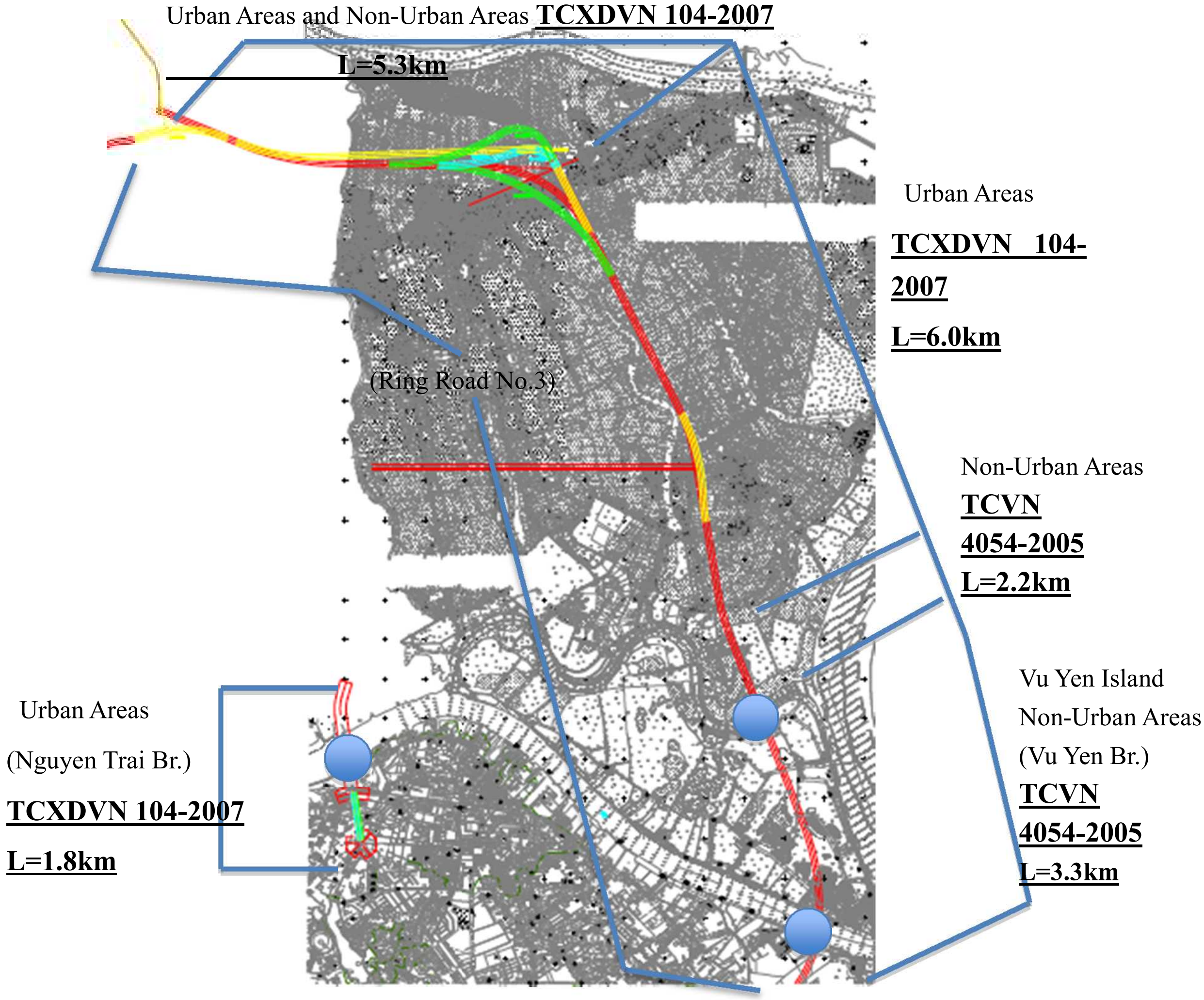


Figure 5.3-2 Road Classification

5.3.3 Basic Design for Road Classification

(1) Design Speed

1) Nguyen Trai Bridge and Ring Road No.3 Urban Areas

Table 5.3-5 List of Road Classifications and Design Speed

Urban Category		Special urban, Class I		Class II, III		Class IV		Class V	
Topography (*)		Flat	Mountain	Flat	Mountain	Flat	Mountain	Flat	Mountain
Urban expressway		100, 80	70, 60	-	-	-	-	-	-
Main urban road	Primary	**<u>80</u>**,70	70,60	80,70	70,60	-	-	-	-
	Secondary	70,60	60,50	70,60	60,50	70,60	60,50	-	-
Access urban road		60,50	50,40	60,50	50,40	60,50	50,40	60,50	50,40
Internal road		40,30,20	30,20	40,30,20	30,20	40,30,20	30,20	40,30,20	30,20

Source: TCXDVN 104-2007

2) Vu Yen Bridge, Ring Road No.3 Non-Urban Areas

Table 5.3-6 List of Road Classifications

Design category	Design traffic volume (PCU/day)	Major functions of highway
Expressway	> 25.000	Arterial road, in compliance with TCVN 5729:1997
I	> 15.000	Arterial road, connecting large national economic, political and cultural centers National highway
II	> 6.000	Arterial road, connecting large national economic, political and cultural centers National highway
<u>III</u>	> 3.000	**<u>Arterial road, connecting</u>** large national and regional economic, political and **<u>cultural centers</u>** National highway or **<u>Provincial road</u>**
IV	> 500	Highway connecting regional centers, depots and residential areas National highway, Provincial road, District road
V	> 200	Road serving local traffic. Provincial road, district road, communal road
VI	< 200	District road, communal road

- These values are for reference.
- **<u>Selection of road classification should be based on road function and terrain type.</u>**

Source: TCVN4054-2005

Table 5.3-7 List of Design Speeds

Design category	I	II	III		IV		V		VI	
Topography	flat	flat	**flat**	mountain	flat	mountain	flat	mountain	flat	mountain
Design speed, V_{tk} (km/h)	120	100	**80**	60	60	40	40	30	30	20

Source: TCVN4054-2005

(2) Road Width Configuration

The road width configuration of each route is proposed based on Vietnamese design criteria. The proposed road width configuration is shown in Figure 5.3-3 to Figure 5.3-5.

1) Urban Areas (Refer to: TCXDVN 104-2007)

Ring Road No.3

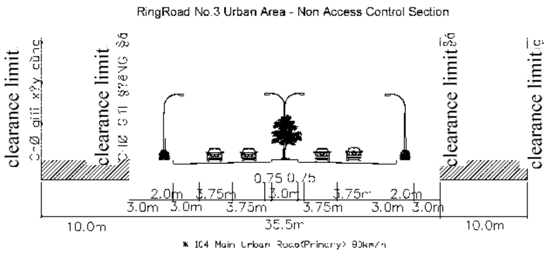


Figure 5.3-3 Road Width Configuration without Frontage Road

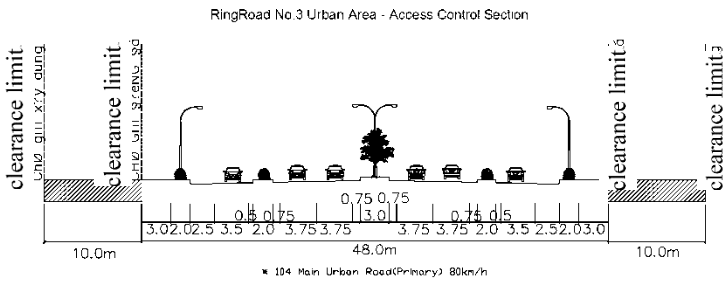


Figure 5.3-4 Road Width Configuration with Frontage Road

Nguyen Trai Bridge

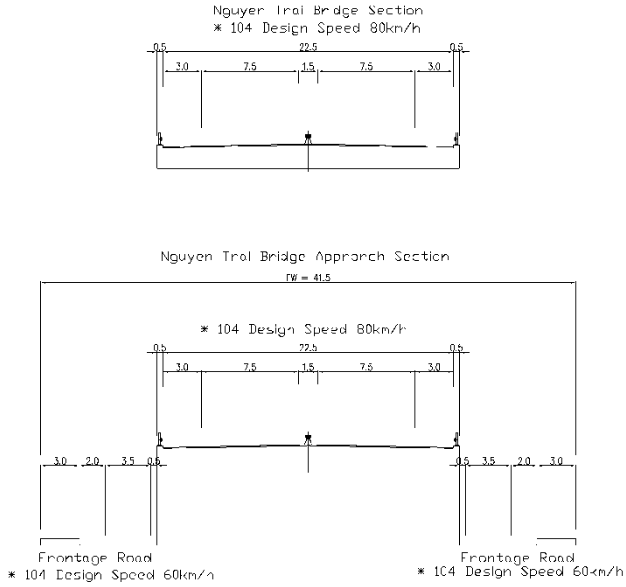
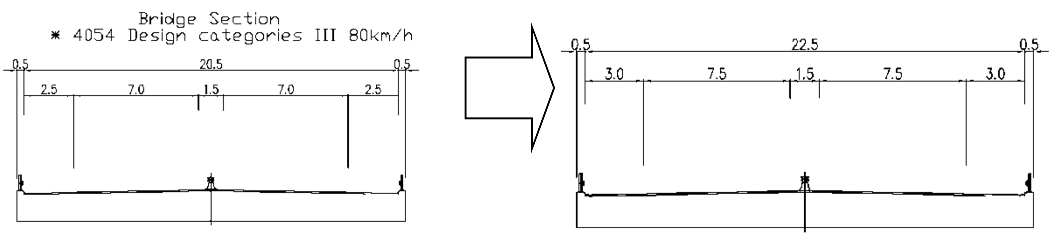


Figure 5.3-5 Road Width Configuration of Nguyen Trai Bridge

2) Non-Urban Areas

The road width configuration is normally decided based on the conditions of each road. However, the road length in non-urban areas on this project is only 5km. Since this road section is important to ensure continuity of the front and rear sections, the JICA study team proposed to adopt the same road width configuration as for the front and rear sections based on TCXDVN 104-2007 (proposed total width is 22.5m).

Vu Yen Bridge

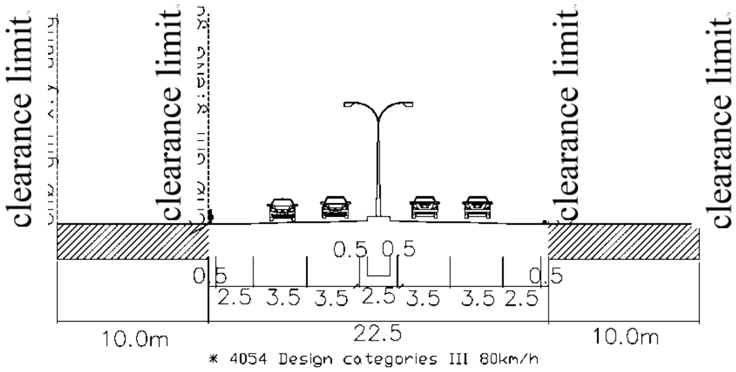


Road width configuration based on TCVN4054-2005

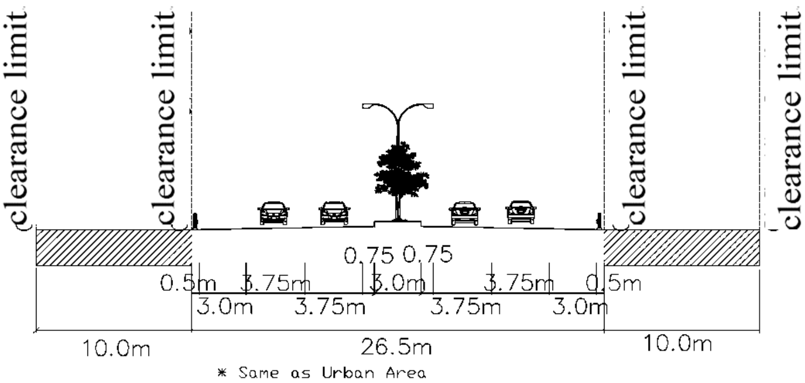
<u>Proposed road width configuration based on TCXDVN 104-2007</u>

Figure 5.3-6 Proposed Road Width Configuration for Bridge

Ring Road No.3 Non-Urban Areas



Road width configuration based on TCVN4054-2005



Proposed road width configuration based on TCXDVN 104-2007

Figure 5.3-7 Proposed Road Width Configuration for Ring Road No.3 Non-Urban Areas without Frontage Roads

(3) Design Criteria

1) TCXDVN 104-2007

Table 5.3-8 Lane Width and Minimum Number of Lanes

Type of road		***Design speed, km/h***								**Mnimum number**	***Expected lanes***
		100	80	70	60	50	40	30	20		
Urban expressway		3,75			3,50					4	6-10
Main Urban Road	Primary		3,75		3,50					6	8-10
	Secondary			3,50						4	6-8
Fontage road					3,50		3,25			2	4-6
Internal road							3,25	3,0(2,75)		1	2-4

Note

1. Lane width 2,75m is advised to apply to internal roads.
2. If internal roads in functional areas only have one lane, minimum width of lane should be 4.0m, excluding drainage.
3. Minimum lanes are advised to apply in advantageous cases or invesment phasing; in ordinary case expected lanes are suggested; in special case , calculations on economic and technical should be considered.

Table 5.3-9 Minimum Shoulder Width and Safe Line

Technical classification, km/h	***100***	***80***	***70***	***60***	***50***	***40***	***30***	***20***
Shoulder width, m	2,5 ÷3	2,0 ÷ 3	2 ÷2,5	1,5÷2,5	0,75÷1	0,5	0,5	0,3
Safe line width if:								
- Construction condition I	1,00	0,75	0,75	0,50	0,25	–	–	–
-Construction condition II, III	0,75	0,50	0,50	0,25	–	–	–	–

Table 5.3-10 Minimum Width and Type of Separator

Type of road		***Minimum width and type of separator (m)***			
		Construction condition			***Type of line***
		I	II	III	
Urban expressway		4,00 (12,00)	3,50 (9,00)	3,00 (6,00)	a2, a3, b2, b3
Main urban road	Primary	3,00 (9,00)	2,50 (6,50)	2,00 (4,00)	a2, a3, b2, b3
	Secondary	2,50 (7,50)	2,00 (5,00)	1,50 (3,00)	a1,a2, a3, b1
Regional road		2,00 (6,00)	1,50 (4,00)	1,00 (2,00)	a1, a2, b1
Internal street		-	-	-	-

Table 5.3-11 Maximum Longitudinal Slope

Design speed, km/h	100	80	70	60	50	40	30	20
Maximum longitudinal slope, %	4	5	5	6	6	7	8	9

2) TCVN4054-2005

Table 5.3-12 Minimum Width of Cross-Sectional Elements applied for Flat Rolling Terrain

Design categories	I	II	III	IV	V	VI
Design speed, (Km/h)	120	100	80	60	40	30
Minimum number of lanes for motorized vehicle, (nos)	6	4	2 ＊1	2	2	1
Width of a lane, (m)	3.75	3.75	3.5	3.5	2.75	3.5
Width of traveled way for motorized vehicle, (m)	2 ×11.25	2 ×7.50	7.00	7.00	5.50	3.50
Width of median separator[1)], (m)	3.00	1.50	0 ＊2	0	0	0
Width of shoulder and stabilized part of shoulder[2)], (m)	3.50 (3.00)	3.00 (2.50)	2.50 (2.00)	1.00 (0.50)	1.00 (0.50)	1.50
Width of roadbed, (m)	32.5	22.5	12.00	9.00	7.50	6.50

1) Width of median separator for each structure is defined in Article 4.4 and Figure 1. The minimum value is applied for separator made of pre-cast concrete or curb stone with cover and without constructing piers (poles) on separated bands. In other cases, separator width must comply with provisions in Article 4.4.

2) Number in the bracket is the minimum width of stabilized part of shoulder. If possible, it suggests to stabilize the whole shoulder width, especially when the highway without side lane for non-motorized vehicles.

*1: The number of lanes is 4. *2: Refer as below.

Table 5.3-13 Minimum Median Dimensions

The structure of separator	Separated part (m)	Safety part (stabilized) (m)	Minimum width of a median (m)	
Pre-cast concrete, curb stones with covers; no constructing piers (poles) on separator	0.50	2 × 0.50	1.50	For Bridge
Curb stones, with covers, piers (poles) on separator	1.50	2 × 0.50	2.50	For Ground
Without covers	3.00	2 × 0.50	4.00	

5.3.4 Road Design Policy

The outline alignment of Ring Road No.3 is defined in the master plan established by HPPC. A detailed alignment study has been carried out by the JICA Study Team based on the HPPC master plan in this project. The JICA Study Team proposed the road plan to HPPC in consideration of the major intersection plan, route conditions and impact on residential land.

Figure 5.3-8 Map of Road Master Plan by HPPC

(1) Alignment Design of Ring Road No.3

1) Ring Road No.3

The outline alignment of Ring Road No.3 is planned in the Hai Phong City master plan. The road design proposed by the JICA Study Team is based on the Vietnamese design criteria used on this project, and it is considered consistent with the master plan of land development projects.

Figure 5.3-9 Outline Alignment Plan of Ring Road No.3

The VSIP Industrial Maintenance and Vu Yen Island Redevelopment Plan are carried out as part of the Haiphong City master plan. In this project, the JICA Study Team discussed and shared information on these plans with HPPC.

2) Section of Vu Yen Bridge

The proposed location for Vu Yen Bridge was chosen to ensure there is sufficient distance between one of the oil facilities in close proximity and the bridge.

At the same time, the continuity with the front and rear sections was also considered. The alignment of Vu Yen Bridge proposed by the JICA Study Team was prepared so as to ensure sufficient distance (300m) to HPPC.

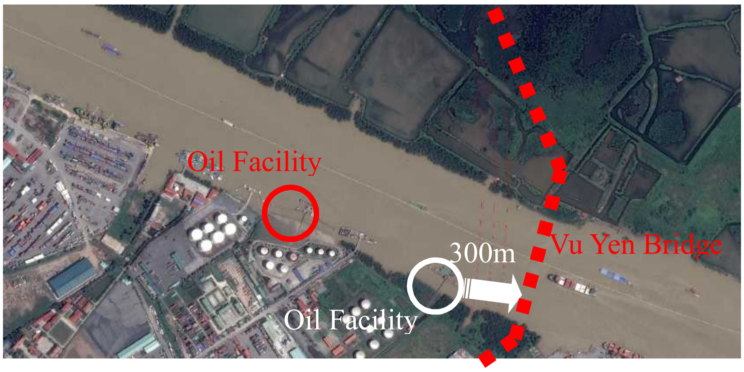


Figure 5.3-10 Map of the Vu Yen Bridge Area

3) Section from Vu Yen Bridge to L356 Intersection

The intersection of Ring Road No.3 and L356 is being designed by HPPC, and the design by the JICA Study Team on this project should therefore be consistent with HPPC's road design. As a result of various studies, the location of the intersection in the original plan should be replaced by that in the new plan. The JICA Study Team discussed with HPPC about the new plan and during these discussions, HPPC agreed to change the design based on the alignment plan prepared by the JICA Study Team. HPPC's intersection design and the proposed alignment by the JICA Study Team are shown in Figure 5.3-11.

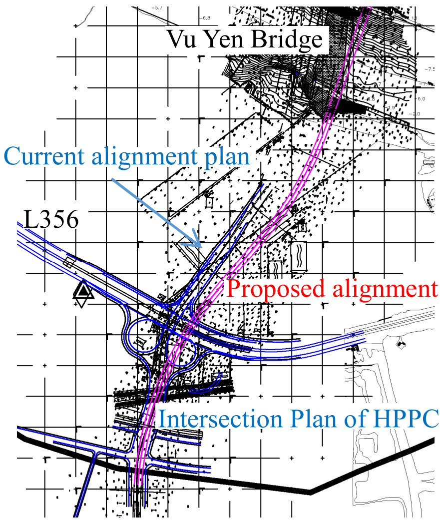


Figure 5.3-11 HPPC's Intersection Plan

(2) Major Intersections on Ring Road No.3

There are five (5) major intersections on Ring Road No.3. The JICA Study Team studied and proposed intersections for each type to HPPC. The location of major intersections is shown below:

Figure 5.3-12 Location of Major Intersections

1) No.1 Intersection

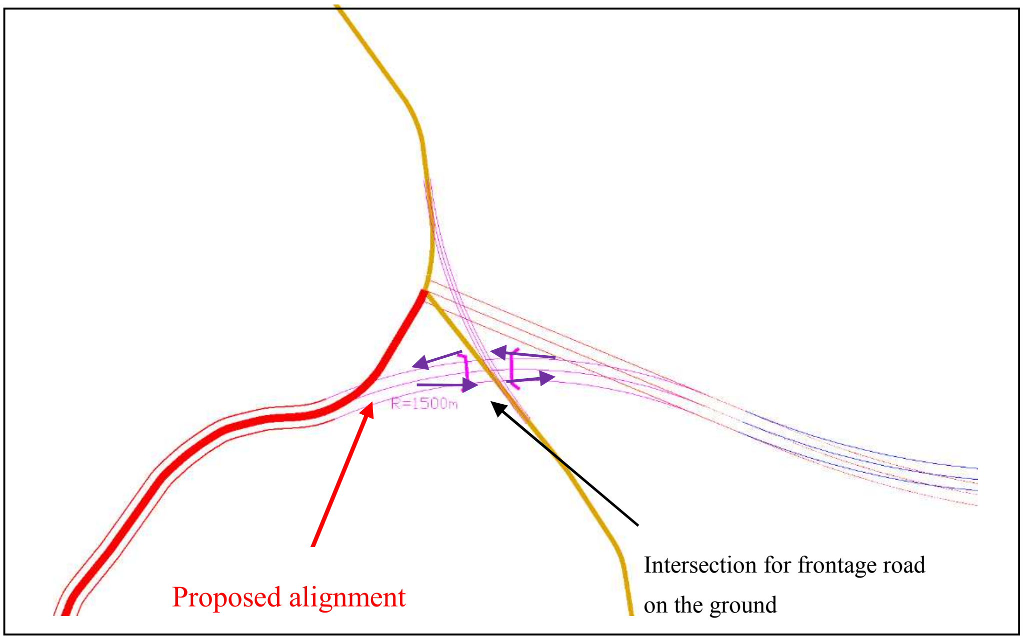


Figure 5.3-13 No.1 Intersection

2) No.2 Intersection

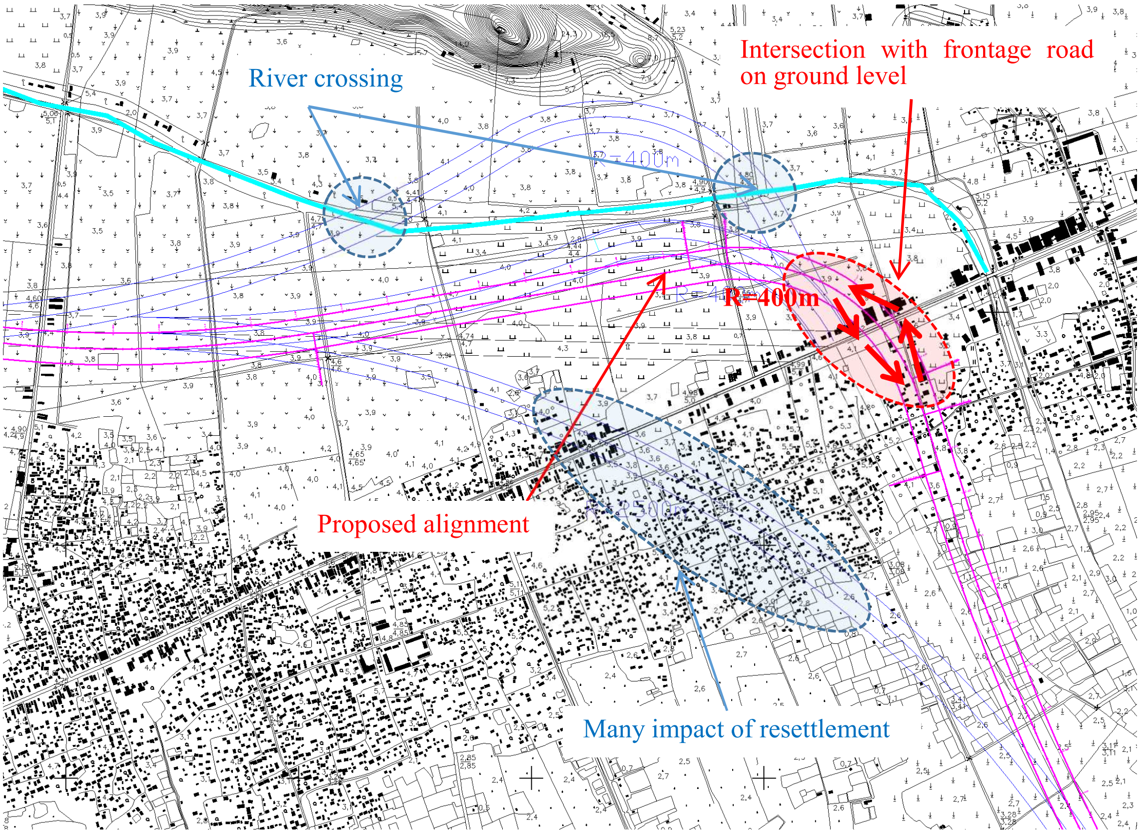


Figure 5.3-14 No.2 Intersection

3) No.3 Intersection

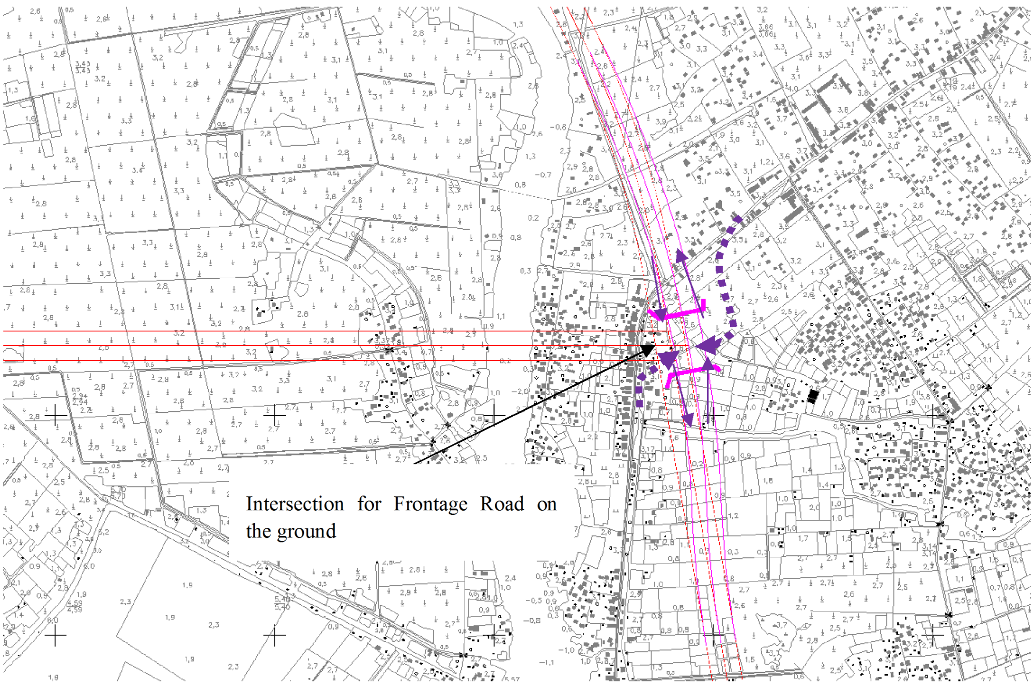


Figure 5.3-15 No.3 Intersection

4) Vu Yen Island IC

The redevelopment plan for Vu Yen Island has been implemented by the Vin Group. Therefore, it is necessary to be consistent with this redevelopment plan on the connection plan to Ring Road No.3 in this project. The JICA Study Team discussed with the Vin Group about the direction of each plan.

Figure 5.3-16 Vu Yen Island

(3) Nguyen Trai South IC

In order to avoid traffic congestion at the roundabout at the south end of the project, an interchange which distributes the traffic flow to Le Thanh Tong Street is designed south of Nguyen Trai Bridge. The effect of distributing the traffic flow is confirmed in Chapter 4. The Study Team studied the type and connection method to the street (location of connecting ramp way, with or without signals) based on discussions with PMU, DOT and DOC.

A further advantage is that the road can be partially opened for traffic if the construction of approach roads or IC ramp ways is delayed due to unexpected factors such as delayed resettlement or delayed relocation of the port facilities.

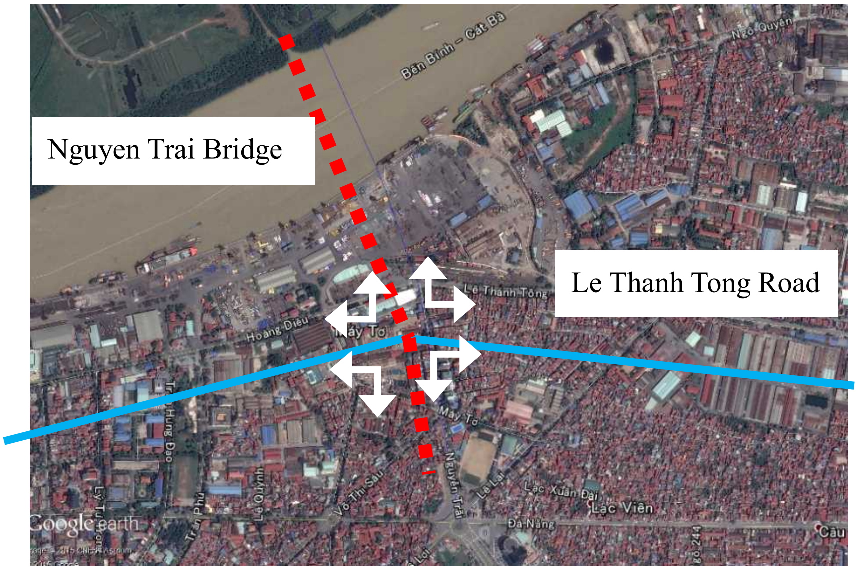


Figure 5.3-17 Nguyen Trai South IC

5.4 Evaluation of Main Bridge Structure

5.4.1 Bridge Type for Nguyen Trai Bridge

(1) Selection of Main Bridge Type

Table 5.4-1 shows the bridge types applicable for the 260-350m required span length. When choosing the best bridge alternative, economy has to be considered along with the soil conditions at the bridge site, constructability in Vietnam, aesthetics, and available maintenance technology.

Of the 6 bridge types in Table 5.4-1, extradosed bridges and PC box girder bridges will not be considered because their maximum span length is less than span length required for Nguyen Trai Bridge, and truss bridges will not be included in the evaluation because of economic considerations and the available inspection technology in Vietnam. A detailed evaluation will therefore be made of cable-stayed bridges, suspension bridges, and arch bridges.

Table 5.4-1 Examples of Bridge Types Applicable for the Cam River Crossing

	Cable-stayed Bridge	**Extradosed Bridge**	**Suspension Bridge**	**Arch Bridge**	**Truss Bridge**	**PC Box Girder Bridge**
Sample Photo	 Source: Wikipedia	 Source: Kajima Corporation	 Source: City of Osaka	 Source: Wikipedia	 Source: Wikipedia	 Source: Wikipedia
Applicable Span Length	130-900m	100-275m	150-2,000m	80-300m	60-510m	60-250m
Suitability for Soft Soil	Yes	Yes	Yes, if self-anchored	Yes, if tied-arch	Yes	Yes
Maximum Span Length (in Japan)	890m (Tatara Bridge)	275m (Kiso River Bridge)	300m (self-anchored: Konohana)	305m (Shin-Kizugawa Ohashi)	440m (Tokyo Gate Bridge)	250m (Ejima Ohashi)
Maximum Span Length (in Vietnam)	550m (Can Tho Bridge)	N/A	N/A	200m (Rong Bridge)	130m (Long Bien Bridge)	150m (Ham Luong Bridge)

The following points were considered in the comparison:

- Steel pipe sheet pile foundations are adopted in view of the constructability of the tower foundations.
- Since the bridge cannot be placed at a 90 degree angle to the river, a circular structure was adopted for the main tower foundation in the river to prevent the disruption of river flow.

A comparison study of the following three bridge types is shown in bellow.

Case 1: Cable-Stayed Bridge

Case 2: Arch Bridge

Case 3: Self-Anchored Suspension Bridge

Table 5.4-2 Comparison Study of Nguyen Trai Bridge (1/2)

Study of Bridge Type of Nguyen Trai Bridge (1/2)

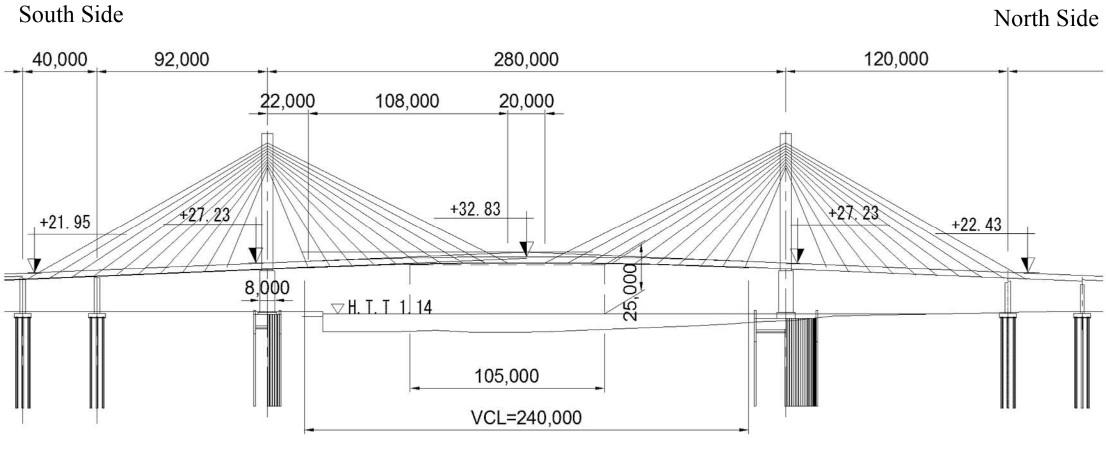
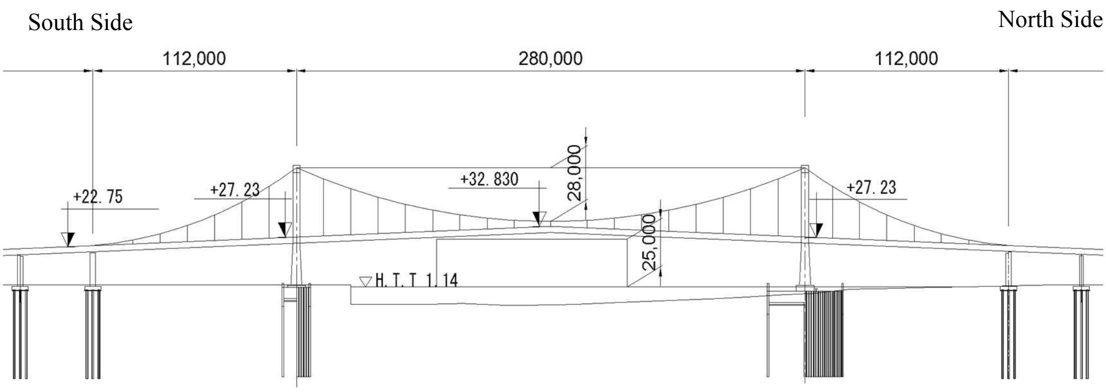
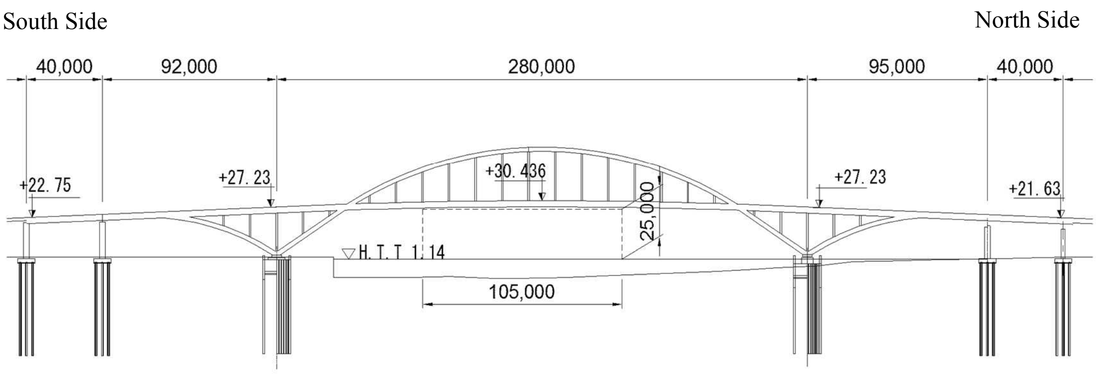
	Side view
Plan A. Cable-stayed bridge	
Plan B. Suspension bridge	
Plan C. Arch bridge	

Table 5.4-3 Comparison Study of Nguyen Trai Bridge(2/2)

Study of Bridge Type of Nguyen Trai Bridge (2/2)

	Evaluation			
Plan A. Cable-stayed bridge	Overview	• Employs concrete towers and PC girders. Same type as Binh Bridge and Kien Bridge. • Single-plane cable arrangement. Different variations such as composite girders are possible.		
	Construction cost	Main bridge superstructure (girders, cables, towers): 4.23 billion Main bridge substructure (piers, foundation): 2.80 billion Approach bridge 28m: 0.22 billion	7.25 billion(JPY) (1.00)	◎
	Maintenance	• The cable anchorages require periodic re-painting. • Special technique for inspection and additional monitoring equipment is required.		◎
	Design innovation	• Not innovative since there are already many bridges of the same type over the Cam River and elsewhere in Vietnam. • Would be the first cable-stayed bridge with wide side spans in Vietnam.		△
	Aesthetics	• The high bridge towers can be designed so that the bridge stands out as a landmark.		○
	Widening at south side approach	• Widening possible, but many structural limitations compared to the arch bridge alternative.		○
	Constructability, Construction period	• Cantilever erection method is suitable for construction of superstructure. • Use of slip form for RC towers enables reduction of construction period. • Approximately 40 months.		○
	Impact on navigation	•Satisfy the navigation width 80m and minimum space for construction 30m.		◎
	Overall evaluation	•Tentative AHP result 0.347 (2nd rank)		◎
Plan B. Suspension bridge	Overview	• Since the soil is soft, the bridge is self-anchored and does not employ anchorages. • Single steel box girders with a polarized hexagonal cross-section are employed to counteract the axial force on the stiffening girders.		
	Construction cost	Main bridge superstructure (girders, cables, towers): 7.34 billion Main bridge substructure (piers, foundation): 2.39 billion Approach bridge 96m: 0.51 billion	10.24 billion(JPY) (1.41)	△
	Maintenance	• The stiffening girders and cable anchorages are made of steel and thus require periodic re-painting. • Special technique for inspection and additional monitoring equipment is required.		○
	Design innovation	• The suspension bridge with the longest span in Southeast Asia employs this design. • Self-anchored suspension bridge would be the first of its type in Vietnam.		◎
	Aesthetics	• The bridge has an attractive design since the curved cables make it look wide in the horizontal direction. • The bridge towers can be designed so that the bridge stands out as a landmark.		◎
	Widening at south side approach	• It is not easy to widenen at south side approach.		△
	Constructability, Construction period	• The navigation channel has to be closed for a long time due to the girder support for all length of suspension bridge needed between construction phases. • Approximately 40 months.		×
	Impact on navigation	•Satisfy the navigation width 80m and minimum space for construction 30m.		◎
	Overall evaluation	•Tentative AHP result 0.240 (3rd rank)		△
Plan C. Arch bridge	Overview	•As a measure for soft soil, balanced arch type bridge which reduced the horizontal force to foundation is selected. •In order to reduce the cost of construction, PC slab and large block erection can be applied.		
	Construction cost	Main bridge superstructure (girders, cables): 6.17 billion Main bridge substructure (piers, foundation): 1.47 billion Approach bridge 133m: 0.69 billion	8.33 billion(JPY) (1.15)	○
	Maintenance	• The stiffening girders and arch members are made of steel and thus require periodic inspection and re-painting. • Area of steel surface is larger than other type. Re-paint cost is higher.		○
	Design innovation	• Would be the longest-span arch bridge in Southeast Asia. • Would be the first balanced arch bridge in Vietnam.		◎
	Aesthetics	• The elegant arch structure makes the bridge stand out as a landmark. • Has symbolic value as the shape is very different from other bridges over Cam River.		◎
	Widening at south side approach	• Since it is possible to widen the side spans, this type is easiest to deal with.		◎
	Constructability, Construction period	• The navigational channel only has to be closed once since batch erection with jacks can be used. • Arch members are pre-fabricated so the substructure can be constructed simultaneously with superstructure fabrication. • The construction period is approximately 34 months.		◎
	Impact on navigation	•Satisfy the navigation width 80m and minimum space for construction 30m. •The height limit is little lower than other plan at North pier.		○
	Overall evaluation	•Tentative AHP result 0.413 (1st rank)		◎

Evaluation ◎ : Best, ○ : Second-best, △ : Possible if no other, × : Unsuitable

(2) Evaluation by AHP method

The alternatives were evaluated using the AHP (Analytic Hierarchy Process) method.

1) Attributes for Bridge Type Selection

The following attributes were selected for bridge type evaluation by AHP. This selection of bridge type is comparison of bridge with same center span length and same foundation type, and there are no superiority or inferiority about environmental and social impact. For this reason, bridge type is mainly compared about characteristic of structure.

a) Construction Cost
b) Maintenance
c) Design Innovation
d) Aesthetics
e) Widening at south side approach
f) Construction Period
g) Impact on Navigation

Evaluation for each attributes is commented in Table 5.4-3

2) Scale of Relative Importance

The scale of relative importance used in the AHP is shown in Table 5.4-4 .

Table 5.4-4 Scale of Relative Importance

1	A is equal to B
3	A is moderately more important or favorable than B
5	A is strongly more important or favorable than B
7	A is very strongly more important or favorable than B
9	A is extremely strongly more important or favorable than B
2,4,6,8	Intermediate intensities between the above values

3) Weight of Attributes

The weights of the attributes were determined as follows.

Table 5.4-5 Weights of Attributes

Attribute	Construction Cost	Maintenance	Innovative Design	Aesthetic	Widening at south side approach	Construction Period	Impact on navigation	Eigen Vector	Weight
Construction Cost	1.000	7.000	3.000	3.000	5.000	3.000	5.000	1.830	0.249
Maintenance	0.143	1.000	0.500	0.500	0.500	0.500	0.500	0.679	0.092
Innovative Design	0.333	2.000	1.000	1.000	3.000	1.000	3.000	1.137	0.154
Aesthetic	0.333	2.000	1.000	1.000	3.000	1.000	3.000	1.137	0.154
Widening at south side approach	0.200	2.000	0.333	0.333	1.000	1.000	3.000	0.866	0.118
Construction Period	0.333	2.000	1.000	1.000	1.000	1.000	1.000	0.971	0.132
Impact on navigation	0.200	2.000	0.333	0.333	0.333	1.000	1.000	0.740	0.101
								7.360	1.000

4) Pairwise Matrix between Bridge Type and Attributes

Construction Cost

As an estimate for construction costs, an absolute measurement method based on band of cost was used. As shown in Table 5.4-6, it is divided into 7 ranges normalized by the lowest construction cost, that of a cable-stayed bridge.

Table 5.4-6 Band of Cost

	From	To
1	1.00	1.07
2	1.07	1.14
3	1.14	1.21
4	1.21	1.29
5	1.29	1.36
6	1.36	1.43
7	1.43	1.50

Note: These values are normalized by the cost of a cable-stayed bridge.

The pairwise matrix for Construction Cost based on the above estimate is as follows.

Table 5.4-7 Pairwise Matrix for Construction Cost

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	6.000	3.000	2.621	0.655
Suspension Br.	0.167	1.000	0.333	0.382	0.095
Arch	0.333	3.000	1.000	1.000	0.250
				4.002	1.000

Maintenance

The pairwise matrix for Maintenance is as follows.

Table 5.4-8 Pairwise Matrix for Maintenance

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	2.000	1.260	0.400
Suspension Br.	1.000	1.000	2.000	1.260	0.400
Arch	0.500	0.500	1.000	0.630	0.200
				3.150	1.000

Design Innovation

The pairwise matrix for Design Innovation is as follows.

Table 5.4-9 Pairwise Matrix for Design Innovation

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	0.200	0.200	0.342	0.091
Suspension Br.	5.000	1.000	1.000	1.710	0.455
Arch	5.000	1.000	1.000	1.710	0.455
				3.762	1.000

Aesthetics

The pairwise matrix for Aesthetics is as follows.

Table 5.4-10 Pairwise Matrix for Aesthetics

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	0.333	0.693	0.200
Suspension Br.	1.000	1.000	0.333	0.693	0.200
Arch	3.000	3.000	1.000	2.080	0.600
				3.466	1.000

Widening at South Side Approach

The pairwise matrix for Widening at South Side Approach is as follows.

Table 5.4-11 Pairwise Matrix for Widening at South Side Approach

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	5.000	0.333	1.186	0.279
Suspension Br.	0.200	1.000	0.143	0.306	0.072
Arch	3.000	7.000	1.000	2.759	0.649
				4.250	1.000

Construction Period

The pairwise matrix for Construction Period is as follows.

Table 5.4-12 Pairwise Matrix for Construction Period

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	0.333	0.693	0.200
Suspension Br.	1.000	1.000	0.333	0.693	0.200
Arch	3.000	3.000	1.000	2.080	0.600
				3.467	1.000

Impact on Navigation

The pairwise matrix for Impact on Navigation is as follows.

Table 5.4-13 Pairwise Matrix for Impact on Navigation

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	3.000	1.442	0.429
Suspension Br.	1.000	1.000	3.000	1.442	0.429
Arch	0.333	0.333	1.000	0.481	0.143
				3.365	1.000

5) Conclusions of AHP

Table 5.4-14 shows the conclusions of the AHP. The arch bridge and cable-stayed bridge alternatives have the highest priority. Based on the results and focusing on these 2 bridge types, the Study Team will confirm the opinions of the Vietnamese side regarding aesthetics, innovative design features, etc. As a result of hearing, arch bridge is preferred by Hai Phong side (1126/SGTVT-TDXD by Hai Phong DOT, 1210/SXD-QLQH by Hai Phong DOC).

Table 5.4-14 Estimation of Priority

Structure Type	Attribute for Evaluation							Priority	Rank
	Construction Cost	Maintenance	Innovative Design	Aesthetic	Widening at south side approach	Construction Period	Impact on navigation		
	0.249	0.092	0.154	0.154	0.118	0.132	0.101		
Cable Stay Br.	0.655	0.400	0.091	0.200	0.279	0.200	0.429	0.347	2
Suspension Br.	0.095	0.400	0.455	0.200	0.072	0.200	0.429	0.240	3
Arch	0.250	0.200	0.455	0.600	0.649	0.600	0.143	0.413	1

5.4.2 Bridge Type for Vu Yen Bridge

(1) Selection of Main Bridge Type

A comparison study of the following three bridge types for Vu Yen Bridge is shown in bellow.

Case 1: Cable-Stayed Bridge

Case 2: Arch Bridge

Case 3: Self-Anchored Suspension Bridge

Table 5.4-15 Comparison Study of Vu Yen Bridge (1/2)

Study of Bridge Type of Vu Yen Bridge (1/2)

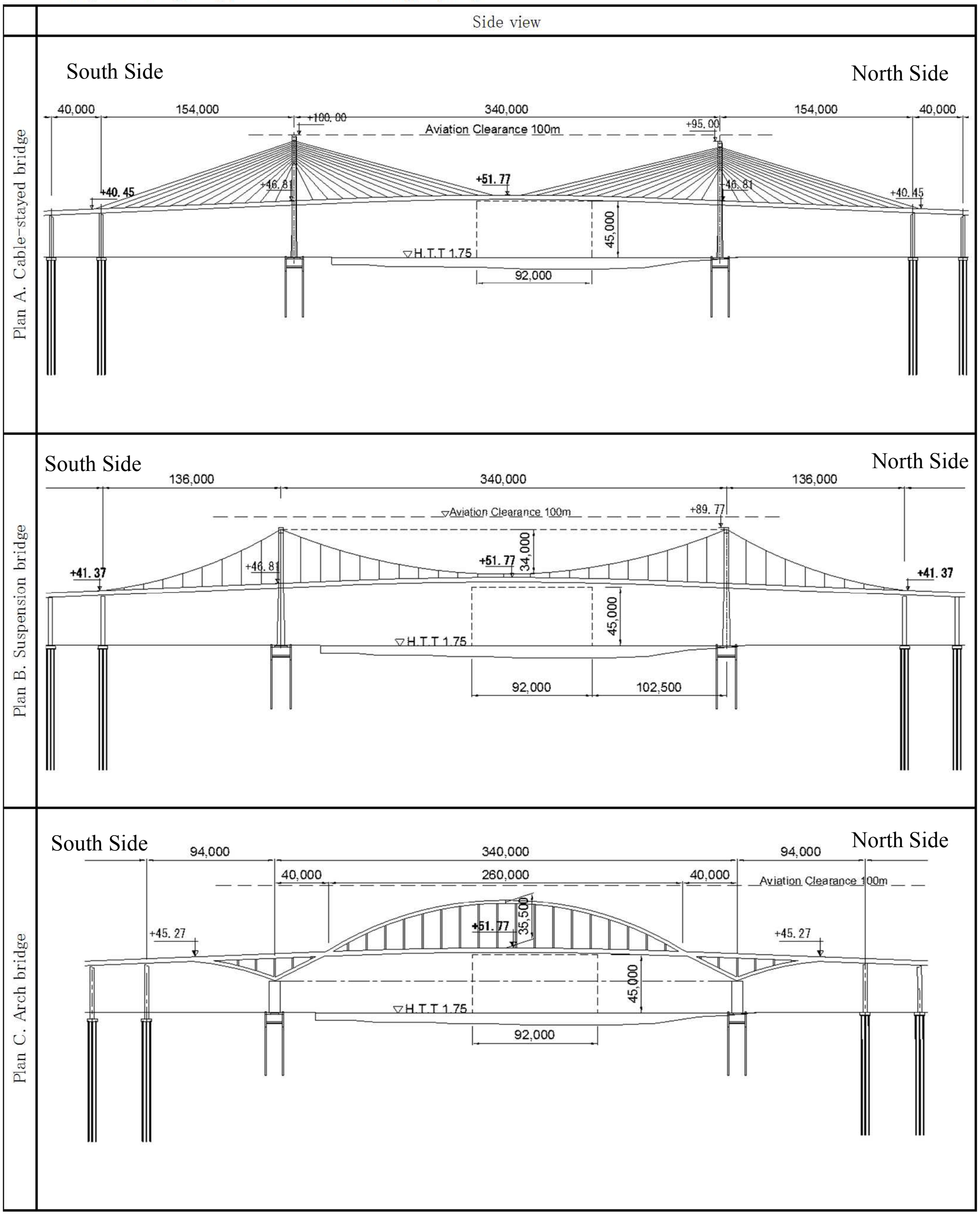


Table 5.4-16 Comparison Study of Vu Yen Bridge (2/2)

Study of Bridge Type of Vu Yen Bridge (2/2)

	Evaluation		
Plan A. Cable-stayed bridge	Overview	• Employs concrete towers and PC girders. Same type as Binh Bridge and Kien Bridge. • Single-plane cable arrangement. Different variations such as composite girders are possible.	
	Construction cost	Main bridge superstructure (girders, cables, towers): 5.63 billion Main bridge substructure (piers, foundation): 2.28 billion Approach bridge 0m: 0.00 billion 7.91 billion(JPY) (1.00)	◎
	Maintenance	• The steel girders and cable anchorages require periodic re-painting. • Special technique for inspection and additional monitoring equipment is required.	○
	Design innovation	• Not very innovative since there are already many bridges of the same type over the Cam River and elsewhere in Vietnam.	△
	Aesthetics	• The high bridge towers can be designed so that the bridge stands out as a landmark.	◎
	Aviation clearance	•It is possible to design the bridge securing aviation clearance. Pylon height is low compared with similar Cable stayed bridge. •Pylon height is 100m	○
	Constructability, Construction period	• Cantilever erection method is suitable for construction of superstructure. • Use of slip form for RC towers enables reduction of construction period. • Construction period is approximately 42 months.	◎
	Impact on navigation	•Satisfy the navigation width 80m and minimum space for construction 30m. •Foundation is located at riverbank for safety to 50,000DWT vessel.	◎
	Overall evaluation	•Tentative AHP result 0.403 (1st rank)	◎
Plan B. Suspension bridge	Overview	• Since the soil is soft, the bridge is self-anchored and does not employ anchorages. • Single steel box girders with a polarized hexagonal cross-section are employed to counteract the axial force on the stiffening girders.	
	Construction cost	Main bridge superstructure (girders, cables, towers): 9.17 billion Main bridge substructure (piers, foundation): 2.41 billion Approach bridge 116m: 0.71 billion 12.29 billion(JPY) (1.55)	△
	Maintenance	• The stiffening girders and cable anchorages are made of steel and thus require periodic re-painting. • Special technique for inspection and additional monitoring equipment is required.	○
	Design innovation	• The suspension bridge with the longest span in Southeast Asia employs this design. • Self-anchored suspension bridge would be the first of its type in Vietnam.	◎
	Aesthetics	• The stiffening girders and cable anchorages are made of steel and thus require periodic re-painting. • Special technique for inspection and additional monitoring equipment is required.	◎
	Aviation clearance	•Structure height is low and it is possible to secure aviation clearance easily.	◎
	Constructability, Construction period	• The navigation channel has to be closed for a long time due to the girder support for all length of suspension bridge needed between construction phases. • Construction period is approximately 42 months.	×
	Impact on navigation	•Satisfy the navigation width 80m and minimum space for construction 30m. •Foundation is located at riverbank for safety to 50,000DWT vessel.	◎
	Overall evaluation	•Tentative AHP result 0.304 (2rd rank)	△
Plan C. Arch bridge	Overview	•As a measure for soft soil, balanced arch type bridge which reduced the horizontal force to foundation is selected. •In order to reduce the cost of construction, PC slab and large block erection can be applied.	
	Construction cost	Main bridge superstructure (girders, cables, towers): 8.29 billion Main bridge substructure (piers, foundation): 2.01 billion Approach bridge 198m: 1.22 billion 11.52 billion(JPY) (1.46)	△
	Maintenance	• The stiffening girders and arch members are made of steel and thus require periodic inspection and re-painting. • Area of steel surface is larger than other type. Re-paint cost is higher.	○
	Design innovation	• Would be the longest-span arch bridge in Southeast Asia. However, the length is over experience in Japan also. • Would be the first balanced arch bridge in Vietnam.	○
	Aesthetics	• The elegant arch structure makes the bridge stand out as a landmark. • Has symbolic value as the shape is very different from other bridges over Cam River.	◎
	Aviation clearance	•Structure height is low and it is possible to secure aviation clearance easily.	◎
	Constructability, Construction period	•Difficulty of construction is high •There are no construction experience applying large block erection for this span length. Construction period will be long.	×
	Impact on navigation	•Satisfy the navigation width 80m and minimum space for construction 30m. •Foundation is located at riverbank for safety to 50,000DWT vessel. •The height limit is little lower than other plan at pier.	○
	Overall evaluation	•Tentative AHP result 0.293 (3nd rank)	△

Evaluation ◎ : Best, ○ : Second-best, △ : Possible if no other, × : Unsuitable

(2) Evaluation by AHP method

The alternatives were evaluated using the AHP (Analytic Hierarchy Process) method.

(Refer to Appendix 5: Priority Ordering Method for Bridge Type Selection)

1) Attributes for Bride Type Selection

The following attributes were selected for bridge type evaluation by AHP. This selection of bridge type is comparison of bridge with same center span length and same foundation type, and there are no superiority or inferiority about environmental and social impact. For this reason, bridge type is mainly compared about characteristic of structure.

a) Construction Cost
b) Maintenance
c) Design Innovation
d) Aesthetics
e) Aviation Clearance
f) Construction Period
g) Impact on Navigation

Evaluation for each attributes is commented in Table 5.4-16.

2) Scale of Relative Importance

The scale of relative importance used in the AHP is shown in Table 5.4-17.

Table 5.4-17 Scale of Relative Importance

1	A is equal to B
3	A is moderately more important or favorable than B
5	A is strongly more important or favorable than B
7	A is very strongly more important or favorable than B
9	A is extremely strongly more important or favorable than B
2,4,6,8	Intermediate intensities between the above values

3) Weight of Attributes

The weights of the attributes were determined as follows.

Table 5.4-18 Weights of Attributes

Attribute	Construction Cost	Maintenance	Innovative Design	Aesthetic	Aviation clearance	Construction Period	Impact on navigation	Eigen Vector	Weight
Construction Cost	1.000	7.000	5.000	3.000	5.000	3.000	5.000	1.898	0.257
Maintenance	0.143	1.000	0.500	0.500	0.500	0.500	0.500	0.679	0.092
Innovative Design	0.200	2.000	1.000	0.500	1.000	0.500	1.000	0.848	0.115
Aesthetic	0.333	2.000	2.000	1.000	3.000	1.000	3.000	1.194	0.162
Aviation clearance	0.200	2.000	1.000	0.333	1.000	1.000	3.000	0.937	0.127
Construction Period	0.333	2.000	2.000	1.000	1.000	1.000	1.000	1.021	0.138
Impact on navigation	0.200	2.000	1.000	0.333	0.333	1.000	1.000	0.801	0.109
								7.378	1.000

4) Pairwise Matrix between Bridge Type and Attributes

Construction Cost

As an estimate for construction costs, an absolute measurement method based on band of cost was used. As shown in Table 5.4-19, it is divided into 7 ranges normalized by lowest construction cost, that of a cable-stayed bridge.

Table 5.4-19 Band of Cost

	From	To
1	1.00	1.08
2	1.08	1.16
3	1.16	1.24
4	1.24	1.31
5	1.31	1.39
6	1.39	1.47
7	1.47	1.55

Note: These values are normalized by the cost of a cable-stayed bridge.

The pairwise matrix for Construction Cost based on the above estimate is as follows.

Table 5.4-20 Pairwise Matrix for Construction Cost

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	7.000	6.000	3.476	0.764
Suspension Br.	0.143	1.000	1.000	0.523	0.115
Arch	0.167	1.000	1.000	0.550	0.121
				4.549	1.000

Maintenance

The pairwise matrix for Maintenance is as follows.

Table 5.4-21 Pairwise Matrix for Maintenance

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	2.000	1.260	0.400
Suspension Br.	1.000	1.000	2.000	1.260	0.400
Arch	0.500	0.500	1.000	0.630	0.200
				3.150	1.000

Design Innovation

The pairwise matrix for Design Innovation is as follows.

Table 5.4-22 Pairwise Matrix for Design Innovation

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	0.200	0.200	0.342	0.091
Suspension Br.	5.000	1.000	1.000	1.710	0.455
Arch	5.000	1.000	1.000	1.710	0.455
				3.762	1.000

Aesthetics

The pairwise matrix for Aesthetics is as follows.

Table 5.4-23 Pairwise Matrix for Aesthetics

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	0.333	0.693	0.200
Suspension Br.	1.000	1.000	0.333	0.693	0.200
Arch	3.003	3.003	1.000	2.081	0.600
				3.468	1.000

Aviation Clearance

The pairwise matrix for Aviation Clearance is as follows.

Table 5.4-24 Pairwise Matrix for Aviation Clearance

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	0.500	0.500	0.630	0.200
Suspension Br.	2.000	1.000	1.000	1.260	0.400
Arch	2.000	1.000	1.000	1.260	0.400
				3.150	1.000

Construction Period

The pairwise matrix for Construction Period is as follows.

Table 5.4-25 Pairwise Matrix for Construction Period

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	2.000	1.260	0.400
Suspension Br.	1.000	1.000	2.000	1.260	0.400
Arch	0.500	0.500	1.000	0.630	0.200
				3.150	1.000

Impact on Navigation

The pairwise matrix for Impact on Navigation is as follows.

Table 5.4-26 Pairwise Matrix for Impact on Navigation

Structure Type	Cable Stay	Susp.	Arch	Eigen Vector	Weight
Cable Stay Br.	1.000	1.000	3.000	1.442	0.429
Suspension Br.	1.000	1.000	3.000	1.442	0.429
Arch	0.333	0.333	1.000	0.481	0.143
				3.365	1.000

5) Conclusions of AHP

Table 5.4-27 shows the conclusions of the AHP. The cable-stayed bridge alternative has the highest priority. The Study Team confirmed the opinions of the Vietnamese side regarding aesthetics, innovative design features, etc. As a result of hearing, cable-stayed bridge is preferred by Hai Phong side (1126/SGTVT-TDXD by Hai Phong DOT, 1210/SXD-QLQH by Hai Phong DOC).

Table 5.4-27 Estimation of Priority

Structure Type	Attribute for Evaluation							Priority	Rank
	Construction Cost	Maintenance	Innovative Design	Aesthetic	Aviation Clearance	Constructio n Period	Impact on navigation		
	0.257	0.092	0.115	0.162	0.127	0.138	0.109		
Cable Stay Br.	0.764	0.400	0.091	0.200	0.200	0.400	0.429	0.403	1
Suspension Br.	0.115	0.400	0.455	0.200	0.400	0.400	0.429	0.304	3
Arch	0.121	0.200	0.455	0.600	0.400	0.200	0.143	0.293	2

5.5 Comparison of Approach Bridge Types

5.5.1 Selection of Superstructure Type

The type of Super-T girder proposed as the superstructure for the approach bridges is the most popular and economical structural solution for this type of viaduct in Vietnam.The assumed span arrangement is based on a 40m span length which is the maximum span length of this girder type.

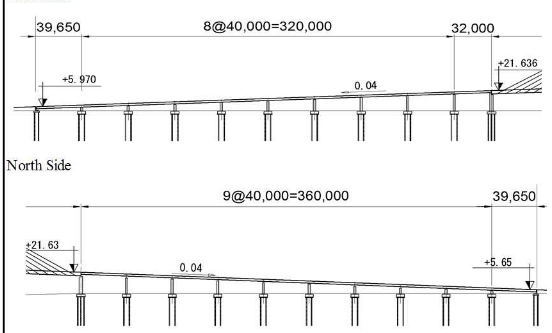
(1) Comparison of Approach Bridge Types

In order to demonstrate the economical superiority of precast Super-T girders, the cost of cast-in-place PC box girders (which use fewer piers and foundations due to their greater 60m span length) is compared to that of Super-T girders.

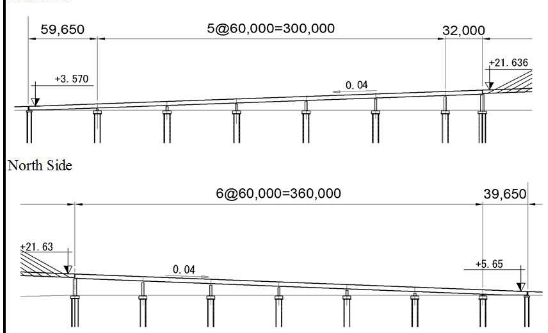
Table 5.5-1 shows the comparison table for Nguyen Trai Bridge (similar results can be obtained also for Vu Yen Bridge).

Table 5.5-1 Comparison Table for Approach Bridge

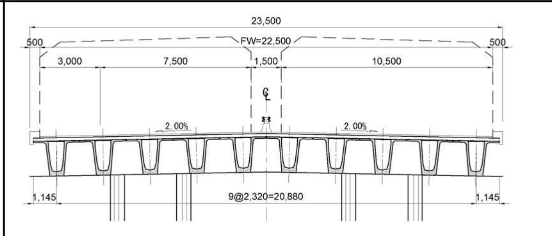
Side View – Super-Tee



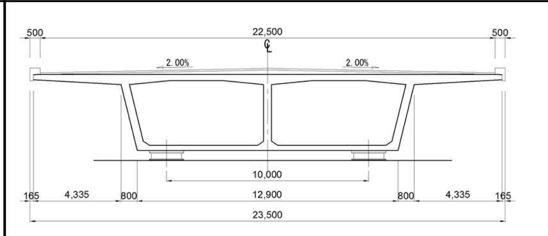
Side View – PC-Box



Crossection – Super-Tee



Crossection – PC-Box



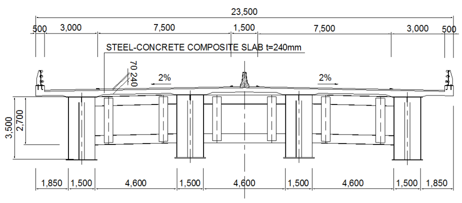
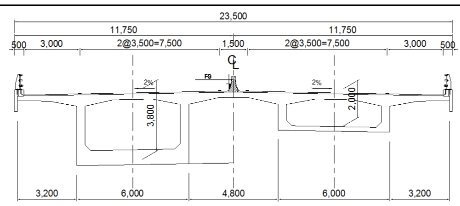
Structural comparison	Super-Tee		PC-Box		
Overview	Super-Tee Girder Light precast concrete superstructure enables less loading on substructure. Very popular structure in Vietnam.	◎	Overview	PC-Box girder Typical cast-in-place cocrete structure is applicable for the span length of 30 - 40m. Very popular structure in the world.	○
Construction Cost	Approach Bridge Superstructure 2 billion JPY Approach Bridge Substructure (Pier&Foundation) 2 billion JPY Total 4 billion JPY (1.00)	◎	Construction Cost	Approach Bridge Superstructure 4 billion JPY Approach Bridge Substructure (Pier&Foundation) 3 billion JPY Total 7 billion JPY (1.67)	○
Appearance	Shorter span length makes the space under the suprstructure less open.	○	Appearance	Longer span length makes the space under the superstructure more open than the Super-Tee girder.	◎
Constructablity	The superstructure girders are produced on the fabrication yard and erected on the bridge site by crane. Only the slab is cast-in-place structure. Prestressing at the bridge site is not necessary. Labour-saving construction.	◎	Constructablity	The superstructure girders are produced by cast-in-place method on the falsework at the bridge site.	○
Construction Period	Precast girder enables short construction period.	◎	Construction Period	Longer construction period than the precast girder.	○
Maintenance	No special maintenance is necessary.	◎	Maintenance	No special maintenance is necessary.	◎
Overall evaluation	Preferable	◎	Overall evaluation	Not preferable	○

Evaluation ◎ : Best, ○ : Second-best, △ : Possible if no other, × : Unsuitable

(2) Comparison of Approach Bridge Types over Railway Station

By the discussion with railway administrator and PMU, it is requested to minimize affect to the railway station as much as possible. 80m span bridge is planed based on the condition that a pier is not installed in the site of a railway station. As a result of comparison of steel box girder type and PC-box girder type for 80m bridge, Steel box girder bridge shall be applied for overpass from the viewpoint of influence to railway operation during construction.

Table 5.5-2 Comparison of Structure Type for Overpass Bridge

	Case 1 (Steel girder)		Case 2 (PC-Box girder)	
Structure	 Steel box girder with composite slab Span = 40m:SuperT + 80m + 40m:Super-T, Single span is applicable		 Concrete box girder Span = 50m + 70m + 40m, 3-span continuous girder is applied for cantilever construction method	
Cost	Superstructure = 678 Substructure = 319 Total = 997 *million JPY, only direct cost (1.02)	△	Superstructure = 525 Substructure = 451 Total = 977 *million JPY, only direct cost (1.00)	◎
Construction	- Launching erection method which will not affect to railway use can be applied. - Construction period over railway is short. - There are many adoption in Japan for the bridge over railway from the view of public responsibility and importance of railway.	◎	- Cantilever construction method which will not affect to railway operation can be applied. - Construction use above railway during construction and the period over railway is long. Careful management to safety of railway operation is required.	○
Technology transfer	- Composite slab is the first application in Vietnam. Composite slab can reduce construction period and has durability equivalent to PC slab. - 80-m is the longest as box-girder bridge in Vietnam.	◎	- It is a common bridge type in Vietnam.	○
Appearance	- Structure has a smooth shape, in case reducing bolt connection and using composite slab.	◎	- Structure has a smooth shape.	◎
Maintenance	- Steel structures require periodical inspection and re-painting.	○	- Concrete members require periodical inspection.	○
Evaluation	- No influence to operation of railway during construction using Launching erection method. - Construction cost is almost same with Case-2.	◎	- Construction period over railway is long. - Construction cost is almost same with Case-1	○

Evaluation ◎ : Best, ○ : Second-best, △ : Possible if no other, × : Unsuitable

5.6 Selection of Substructure and Foundation Type

5.6.1 Foundation Structural Type of Main Bridge

The structural type for the foundations is selected by taking into account geological conditions, procurement (experience) conditions, work conditions, etc. Comparative studies are conducted for using in-river and on-land towers, respectively.

(1) Applicable Foundation Types

The bearing layer for the main bridge towers should be the basement rock layer located around EL-45.0m considering the capability of the bearing layer to absorb a magnitude of reaction forces.

Applicable foundation types which satisfy the depth and procurement requirements and which have been used in Vietnam in the past include Cast-In-Place (CIP) pile and Steel Pipe Sheet Pile (SPSP) foundations. There are two major construction methods for CIP piles, namely the earth drill method and the reverse circulation drilling method. The reverse circulation drilling method is more suitable than the earth drill method from the point of view of working efficiency and costs. SPSP foundations are getting more common in Vietnam since being used on the Nhat Tan Bridge project, Lach Huyen Project, etc.

Table 5.6-1 Foundation Types and Conditions

Conditions \ Foundation Type			Spread Footing Foundation	Driven Pile Foundation: PHC Pile & SC Pile	Driven Pile Foundation: Steel Pipe Pile – Percussion Method	Driven Pile Foundation: Steel Pipe Pile – Vibro-hammer method	Inner Excavation Pile Foundation, PHC・SC Pile: Final driving method	Inner Excavation Pile Foundation, PHC・SC Pile: Pile tip grouting method	Inner Excavation Pile Foundation, PHC・SC Pile: Pile tip concrete casting method	Inner Excavation Pile Foundation, Steel Pipe Pile: Final driving method	Inner Excavation Pile Foundation, Steel Pipe Pile: Pile tip grouting method	Inner Excavation Pile Foundation, Steel Pipe Pile: Pile tip concrete casting method	Steel pipe & soil cement Hybrid pile Foundation	Pre-boring Pile Foundation	Cast-In-Place Pile Foundation: All casing	Cast-In-Place Pile Foundation: Reverse circulation	Cast-In-Place Pile Foundation: Earth drill method	Steel Screw Pipe Pile Foundation	Caisson Foundation: Pneumatic caisson method	Caisson Foundation: Open caisson method	Steel Sheet Pipe Pile Foundation	CIP diaphragm Wall Foundation
Soil Conditions	Intermediate layer	Existence of extremely weak layer	/	○	○	○	○	○	○	○	○	○	○	○	×	○	○	○	○	△	○	○
		Existence of extremely hard layer	/	△	△	△	○	○	○	○	○	○	○	○	△	○	×	○	○	△	△	○
	Existence of gravel	Dia. ≦ 5cm	/	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		5cm ＜Dia≦10cm	/	△	△	○	△	△	△	△	△	△	○	○	△	×	○	○	○	○	△	△
		10cm ＜Dia≦50cm	/	×	×	×	×	×	×	×	×	×	×	×	△	×	×	×	○	△	×	△
		Existence of liquefaction layer	/	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Bearing Stratum – Depth of Bearing Stratum	5m ＜	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
		5～15m	△	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	△	△
		15～25m	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		25～40m	×	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	○
		40～60m	×	△	○	○	△	△	△	○	○	○	○	○	△	○	×	○	△	○	○	○
		≦ 60m	×	×	△	△	×	×	×	×	×	×	△	△	×	△	×	○	×	△	△	△
	Bearing Stratum – Soil Type	Sand/Sand gravel (30≦N)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		Cohesive soil (20≦N)	○	○	○	○	○	△	×	○	△	×	△	△	○	○	○	△	△	△	○	○
		Soft rock	○	×	○	△	○	△	×	○	△	×	△	△	○	○	○	△	○	○	○	○
		Hard rock	○	×	×	×	×	×	×	×	×	×	×	×	△	△	△	×	△	×	×	△
	Bearing Stratum	Inclined, uneveness, depth changes	△	△	△	△	△	△	△	△	△	△	△	△	○	○	○	○	△	×	○	○
	groundwater condition	Ground water level close to ground level	△	○	○	○	○	○	○	○	○	○	○	○	△	△	△	○	○	○	○	△
		Large amount of spring water	△	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	○	△
		Confined ground water pressure ≧2m	×	○	○	○	×	×	×	×	×	×	×	×	×	×	×	○	△	△	○	×
		Flow rate more than 3m/min	×	○	○	○	○	×	×	○	×	×	×	×	×	×	×	○	○	△	○	×
Bearing Type		Bearing Pile	/	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	/	/	/	/
		Friction Pile	/	○	○	○	×	×	×	×	×	×	○	×	○	○	○	×	/	/	/	/
Construction Conditions	On water construction	Water depth is less than 5m	○	○	○	○	△	△	△	△	△	△	×	×	×	×	×	○	△	△	○	×
		Water depth is 5m or deeper	×	△	○	○	△	△	△	△	△	△	×	×	×	×	×	○	△	△	○	×
		Narrow working space	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	×	△
		Use of batter piles	/	○	○	○	×	×	×	×	×	×	×	×	×	×	×	○	/	/	/	/
		Possibility of noxious fume	/	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	○	○	○
	impact to neighbor	Low vibration and noise	○	×	×	△	△	○	○	△	○	○	○	○	○	○	○	○	△	△	△	○
		Low impact to adjacent structures	○	×	△	△	△	○	○	△	○	○	○	○	○	○	○	○	△	△	△	○

○:High applicability △:Applicable ×:Low applicability

Reference: SPECIFICATIONS FOR HIGHWAY BRIDGES / Part Ⅳ (Japan Road Association)

1) Comparison Study Results (Foundation Type for Towers)

Based on the above considerations, the options for the comparison study are as follows:

- In-river pier / On-land pier (tower)

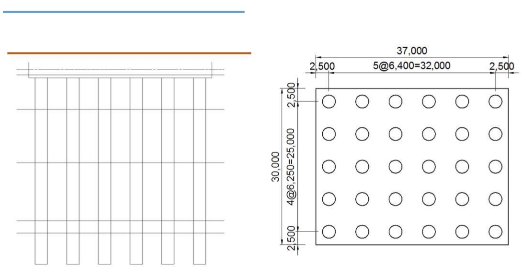
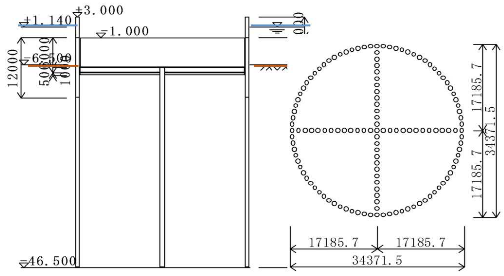
  Option 1: CIP (2.5m diameter) with SPSP cofferdam

  Option 2: SPSP foundation (1.0m diameter) cum cofferdam

Water depth is one of the key issues affecting working conditions, and temporary cofferdams should be considered for both the in-river and on-land towers. The water is relatively deep and reaches a depth of approximately 10m.

In-river Pier (Tower) at Nguyen Trai

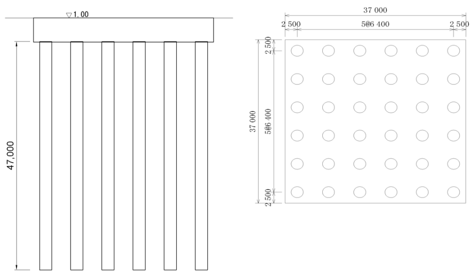
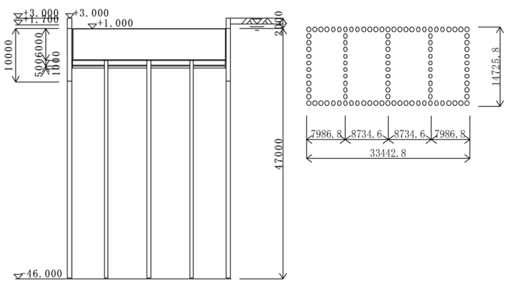
Table 5.6-2 Comparison Study of In-river Tower of Main Bridge

	Cast in Place Pile	**Steel Pipe Sheet Pile**
	Φ 2.5m	**Steel Pile Φ 1.0m**
Structural Drawing		
Structural feature	・An elastic foundation of which vertical and horizontal stabilities are secured by a vertical bearing resistance (sum of pile tip resistance and skin friction) and a stiffness of piles. ・A steel pipe sheet pile (SPSP), as a temporary cofferdam, is demanded for a dry construction of pile cap in river because of a relatively higher water pressure (water head difference).	・An elastic foundation of which vertical and horizontal stabilities are secured by a vertical bearing resistance and stiffness of piles although the foundation looks like a caisson foundation type. ・A steel pipe piles use in the SPSP-foundation can be extended to upward and be used as cofferdam. A steel pipe sheet pile (SPSP), as a temporary cofferdam, is demanded for a dry construction of pile cap in river because of a relatively higher water pressure (water head difference). ・Foundation is located in the rivers, but considering the economic efficiency and workability, a round planar shape foundation occupies water surface.
Construction period	・SPSP-cofferdam, of which construction procedure is same as SPSP-foundation, shall be established in advance of the construction of CIP pile and its pile cap. Accordingly, the total construction period become longer than the other alternative.	・Construction period is shorter because the SPSP-foundation enables to omit a construction of temporary cofferdam which required in the case of CIP foundation on left.
Constructability	・A specialized foundation company shall be hired for construction of the SPSP cofferdam, and quality and construction schedule of SPSP is maintained. ・Construction experience of large diameter (d=2.5m) bored pile is uncommon, and it may increase an already-difficult quality control of bored pile. As a result, a risk for delay of the construction is concerned.	・A specialized foundation company shall be hired for construction of SPSP foundation, and quality and constrution schedule of SPSP is maintained. ・Whole of work from coffering to construction of SPSP is carried out by an experienced contractor as one sequence. As a result, a risk for delay of the construction is concerned.
Quality Control	・QC item is too many such as controls of materials, a borehole excavation, a slim treatment, a concrete mixing, casting, etc. and a difference in quality is vary widely depending on a contractor's skill. ・A confirmation of a bearing layer can be assumed from an excavated material only.	・QC is relatively easy thanks to use of prefabricated steel pile. ・A confirmation of a bearing layer can done through a hammering of each steel pipe piles.
Environmental	・Treatment facilities of bentonite fluid is necessary, and amount of excavated soil to be treatment as industrial waste is large.	・Bentonite fluid is not used. Amount of excavated soil to be treatment as industrial waste is small.

Social Impact	・Level of noise and vibration due to construction of SPSP-cofferdam are same degree to the other option.	・Level of noise and vibration due to construction of SPSP-foundation are same degree to the other option.
Construction Cost(ratio)	1.15	1.00
Evaluation	・QC of this option is more complicated that the other option. ・Risk on the construction delay is higher than SPSP. ・Environmental protection is required. ・Slightly expensive than the other option.	・QC of this option is easier than the other option. ・Risk on the construction delay is smaller the CIP pile. ・Environmental protection is not required in general. ・A slight advantage in cost is confirmed.
	△	◎

On-land Pier (Tower) at Nguyen Trai

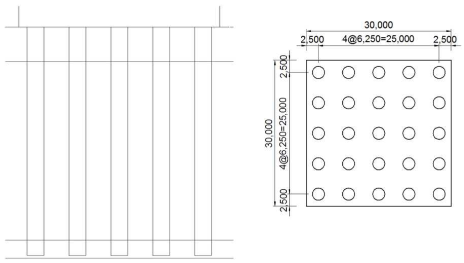
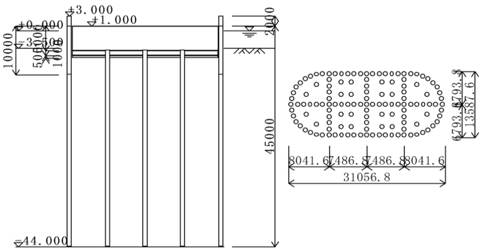
Table 5.6-3 Comparison Study of On-land Tower of Main Bridge

	Cast in Place Pile	**Steel Pipe Sheet Pile**
	ɸ 2.5m	**Steel Pile ɸ 1.0m**
Structural Drawing		
Construction Cost(ratio)	1.03	1.00
Evaluation	・QC of this option is more complicated that the other option. ・Risk on the construction delay is higher than SPSP. ・Environmental protection is required. ・Slightly expensive than the other option.	・QC of this option is easier than the other option. ・Risk on the construction delay is smaller the CIP pile. ・Environmental protection is not required in general. ・A slight advantage in cost is confirmed.
	△	◎

Evaluation ◎ : Best, ○ : Second-best, △ : Possible if no other, × : Unsuitable

On-land Pier (Tower) at Vu Yen

Table 5.6-4 Comparison Study of On-land Tower of Main Bridge

	Cast in Place Pile	**Steel Pipe Sheet Pile**
	Φ 2.5m	**Steel Pile Φ 1.0m**
Structural Drawing		
Construction Cost(ratio)	1.06	1.00
Evaluation	・QC of this option is more complicated that the other option. ・Risk on the construction delay is higher than SPSP. ・Environmental protection is required. ・Slightly expensive than the other option.	・QC of this option is easier than the other option. ・Risk on the construction delay is smaller the CIP pile. ・Environmental protection is not required in general. ・A slight advantage in cost is confirmed.
	△	◎

Evaluation ◎ : Best, ○ : Second-best, △ : Possible if no other, × : Unsuitable

(2) Foundation Structural Type of Approach Bridge

The structural type for the foundations is selected by taking into account geological conditions, procurement (experience) conditions, work conditions, etc.

1) Applicable Foundation Types

The bearing layer for the approach bridges should be the basement rock layer located around EL-45.0m as a typical case and for comparative study of foundation type of approach bridge.

Applicable foundation types which satisfy the depth and procurement requirements and which have been used in Vietnam in the past include Cast-In-Place (CIP) piles. There are two major construction methods for CIP piles, namely the earth drill method and the reverse circulation drilling method. The reverse circulation drilling method is more suitable than the earth drill method from the point of view of working efficiency and costs.

Considering the scale of the approach bridges, Steel Pipe Sheet Pile (SPSP) foundations which are getting more common in Vietnam since being used on the Nhat Tan Bridge project and Lach Huyen Project, cannot be economical although the basic technique of steel pipe pile driving is useful. Steel pipe pile foundations have therefore been included in the comparison study of foundation types.

Based on the above considerations, the options for the comparison study are as follows:

Comparison study 1: Approach bridge foundation type

Option 1: Cast-In-Place pile (Dia. 1.2m, 1.5m)

Option 2: Steel pipe pile (Dia. 0.8m, 0.9m, 1.1m)

Regarding the construction period, construction of one steel pipe pile takes 0.6 days whereas a construction of one CIP pile takes 1.6 days.

With respect to quality control of the construction, CIP pile requires bunch of on-site inspections to which very skilled QC manager is required such as a borehole excavation including a bentonite fluid treatment, a concrete quality test before and after casting, etc. On the other hand, less efforts are required for the quality control of steel pipe pile foundation construction thanks to a prefabrication of steel pipe piles.

Moreover, an advantage of steel pipe pile foundation in terms of cost aspect is confirmed through the comparison study. Quantities and unit price of cost elements (concrete, foundation piles, lean concrete, excavation and cofferdam) are displayed in Appendix A5 for reference.

As above, it has been confirmed through the comparison study 1 that the most appropriate foundation type for the approach bridge is the steel pipe pile with Dia. 0.9m in all aspects such as cost, quality control, and construction period.

The Study Team also performed the comparison study 2. In this study an influence of negative skin friction (a down drag) is studied using the most economical pile type of the approach bridge as selected foregoing, namely a steel pipe pile (Dia. 0.9m). Pile options shown below were applied for the comparison.

C**omparison study 2**: Approach bridge foundation type with Down Drag load

Option 1-DD: Steel pipe pile (Dia. 0.9m)

Option 2-DD: Steel pipe pile (Dia. 0.9m) with slip layer *(called "SL pile")*

*Note: The purpose of the slip layer applied to the steel pipe surface is to reduce a down drag load to be act on the steel pipe piles.

- Objected piers:

Based on the investigation of the JICA Study Team, Piers of P8 through P12 in Nguyen Trai Bridge and Piers P57 through P63 and A2 Abutment of Vu Yen Bridge will be a target for examination of negative friction influence because of the change of Ground elevation in future.

Table 5.6-5 Change of Ground Elevation

Bridge Name	Structure No.	Nos	Current GL	Future GL
Nguyen Trai	A1 - P7	8	EL+2.30m	EL+2.30m
	P8 - P12	5	EL-1.50 ~ EL 0.00m	EL +2.30m
	2P	1	In-river	No-change
	3P- A2	14	EL+2.30m	EL +2.30m
Vu Yen	A1 - P31	32	EL+0.5～EL+1.00m	EL+0.5～EL+1.00m
	2P	1	In-river	No-change
	3P	1	In-river	No-change
	P32 - P55	24	EL+2.50	EL+2.50
	P56	1	In-channel	No-change
	P57 - 63, A2	8	EL+0.4m	EL+2.50m
Total number of structure		95	-	-

- Objected soil layer:

The objected soil layer is the alluvial cohesive soil layer (Ac) and the thickness of the layer from which negative skin friction is assumed to be occur is around 14.0m according to a consolidation settlement analysis performed by the Study Team.

In case of use of SL pile, the number of piles for one pier can be reduced up to around a half of the one employs normal steel pipe piles according to the study. Although a unit price of SL pile is higher than that of normal steel pile, total construction cost of a foundation become small if the SL pile is employed. Above all, use of the Steel Pipe Pile (Dia. 0.9m) with Slip Layer (SL Pile) is recommended where negative skin friction is expected. Comparison result is shown in Appendix A5.

Table 5.6-6 Foundation Types and Conditions

Conditions		Foundation Type	Spread Footing Foundation	Driven Pile Foundation: PHC Pile & SC Pile	Driven Pile Foundation: Steel Pipe Pile: Percussion Method	Driven Pile Foundation: Steel Pipe Pile: Vibro-hammer method	Inner Excavation Pile Foundation: PHC・SC Pile: Final driving method	Inner Excavation Pile Foundation: PHC・SC Pile: Pile tip grouting method	Inner Excavation Pile Foundation: PHC・SC Pile: Pile tip concrete casting method	Inner Excavation Pile Foundation: Steel Pipe Pile: Final driving method	Inner Excavation Pile Foundation: Steel Pipe Pile: Pile tip grouting method	Inner Excavation Pile Foundation: Steel Pipe Pile: Pile tip concrete casting method	Steel pipe & soil cement Hybrid pile Foundation	Pre-boring Pile Foundation	Cast-In-Place Pile Foundation: All casing	Cast-In-Place Pile Foundation: Reverse circulation	Cast-In-Place Pile Foundation: Earth drill method	Steel Screw Pipe Pile Foundation	Caisson Foundation: Pneumatic caisson method	Caisson Foundation: Open caisson method	Steel Sheet Pipe Pile Foundation	CIP diaphragm Wall Foundation
Soil Conditions	Intermediate layer	Existence of extremely weak layer		○	○	○	○	○	○	○	○	○	○	○	×	○	○	○	○	△	○	○
Soil Conditions	Intermediate layer	Existence of extremely hard layer		△	△	△	○	○	○	○	○	○	○	○	△	○	×	○	○	△	△	○
Soil Conditions	Intermediate layer: Existence of gravel	Dia. ≦ 5cm		△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Soil Conditions	Intermediate layer: Existence of gravel	5cm ＜Dia≦10cm		△	△	○	△	△	△	△	△	△	○	○	△	×	○	○	○	○	△	△
Soil Conditions	Intermediate layer: Existence of gravel	10cm ＜Dia≦50cm		×	×	×	×	×	×	×	×	×	×	×	△	×	×	×	○	△	×	△
Soil Conditions	Intermediate layer	Existence of liquefaction layer		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Soil Conditions	Bearing Stratum: Depth of Bearing Stratum	5m ＜	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Soil Conditions	Bearing Stratum: Depth of Bearing Stratum	5～15m	△	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	△	△
Soil Conditions	Bearing Stratum: Depth of Bearing Stratum	15～25m	×	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Soil Conditions	Bearing Stratum: Depth of Bearing Stratum	25～40m	×	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	○
Soil Conditions	Bearing Stratum: Depth of Bearing Stratum	40～60m	×	△	○	○	△	△	△	○	○	○	○	○	△	○	×	○	△	○	○	○
Soil Conditions	Bearing Stratum: Depth of Bearing Stratum	≦ 60m	×	×	△	△	×	×	×	×	×	×	△	△	×	△	×	○	×	△	△	△
Soil Conditions	Bearing Stratum: Soil Type	Sand/Sand gravel (30≦N)	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Soil Conditions	Bearing Stratum: Soil Type	Cohesive soil (20≦N)	○	○	○	○	○	△	×	○	△	×	△	△	○	○	○	△	△	△	○	○
Soil Conditions	Bearing Stratum: Soil Type	Soft rock	○	×	○	△	○	△	×	○	△	×	△	△	○	○	○	△	○	○	○	○
Soil Conditions	Bearing Stratum: Soil Type	Hard rock	○	×	×	×	×	×	×	×	×	×	×	×	△	△	△	×	△	×	×	△
Soil Conditions	Bearing Stratum	Inclined, uneveness, depth changes	△	△	△	△	△	△	△	△	△	△	△	△	○	○	○	○	△	×	○	○
Soil Conditions	groundwater condition	Ground w ater level close to ground level	△	○	○	○	○	○	○	○	○	○	○	○	△	△	△	○	○	○	○	△
Soil Conditions	groundwater condition	Large amount of spring water	△	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○	○	○	△
Soil Conditions	groundwater condition	Confined ground water pressure ≧2m	×	○	○	○	×	×	×	×	×	×	×	×	×	×	×	○	△	△	○	×
Soil Conditions	groundwater condition	Flow rate more than 3m/min	×	○	○	○	○	×	×	○	×	×	×	×	×	×	×	○	○	△	○	×
Bearing Type		Bearing Pile		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○				
Bearing Type		Friction Pile		○	○	○	×	×	×	×	×	×	○	×	○	○	○	×				
Construction Conditions	On water construction	Water depth is less than 5m	○	○	○	○	△	△	△	△	△	△	×	×	×	×	×	○	△	△	○	×
Construction Conditions	On water construction	Water depth is 5m or deeper	×	△	○	○	△	△	△	△	△	△	×	×	×	×	×	○	△	△	○	×
Construction Conditions		Narrow working space	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	×	△
Construction Conditions		Use of batter piles		○	○	○	×	×	×	×	×	×	×	×	×	×	×	○				
Construction Conditions		Possibility of noxious fume		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	○	○	○
Construction Conditions	impact to neighbor	Low vibration and noise	○	×	×	△	△	○	○	△	○	○	○	○	○	○	○	○	△	△	△	○
Construction Conditions	impact to neighbor	Low impact to adjacent structures	○	×	△	△	△	○	○	△	○	○	○	○	○	○	○	○	△	△	△	○

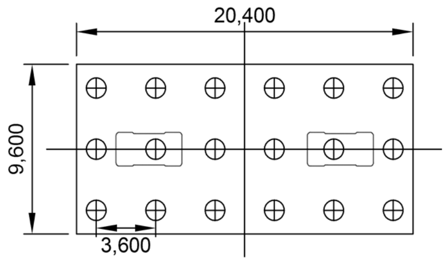
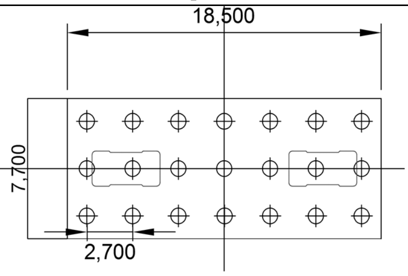
○: High applicability △: Applicable ×: Low applicability

Reference: SPECIFICATIONS FOR HIGHWAY BRIDGES / Part IV (Japan Road Association)

2) Comparison Study Results (Foundation Type for Approach Bridges)

Comparison study result of foundation type of Approach Bridge is shown in Table 5.6-7. Comparison of cost estimation of each foundation type is shown in Appendix A5-2.

Table 5.6-7 Summary of General feature of Steel Pipe Pile and CIP pile

	Cast in Place Pile	**Steel Pipe Pile**
	ϕ 1.2m	**ϕ =0.9m**
Structural Drawing		
Structural feature	・An elastic foundation of which vertical and horizontal stabilities are secured by a vertical bearing resisntance (sum of pile tip resistance and skin friction) and a stiffness of piles. ・A steel sheet pile, as a temporary cofferdam, can be hired for a dry construction of pile cap in town area and swamp land.	・An elastic foundation of which vertical and horizontal stabilities are secured by a vertical bearing resisntance (sum of pile tip resistance and skin friction) and a stiffness of piles. ・A steel sheet pile, as a temporary cofferdam, can be hired for a dry construction of pile cap in twon area and swamp land.
Construction period	・The construction period is long comparatively. ・About 4.0 day/pile.	・Construction period is short comparatively. ・About 1.3 day/pile.
Constructability	・Construction experience of ordinal diameter (d=1.2m) bored pile is many. However, a certain degree of number of piles are found defective and needed to be remededed due to difficulty of QC in general. As a result, a risk for delay of the construction is concerned.	・Construction experience of steel pipe piles is not many in Vietnam. But Lach Huyen port construction project employed a steel pipe pile foundation.
Quality Control	・QC item is too many such as controls of materials, a borehole excavation, a slim treatment, a concrete mixing, casting, etc. and a difference in quality is vary widely depending on a contractor's skill. ・A comfirmation of a bearing layer can be assumed from an excavated material only.	・QC is relatively easy thanks to use of prefabricated steel pile. ・A confirmation of a bearing layer can done through a hammering of each steel pipe piles.
Environmental	・Treatment facilities of bentnite fluid is necessary, and amount of excavated soil to be treatment as industrial waste is large.	・Bentnite fluid is not used. Amount of excavated soil to be treatment as industrial waste is small.
Social Impact	・Level of noise and vibration due to construction of the piles are lesser than that of the other option. But 24 hours construction is normally required until completing of concrete casting.	・Level of noise and vibration due to pile driving is relatively larger than that of the other option. But night time construction is not required.
Evaluation	・QC of this option is more complicated that the other option. ・Risk on the construction delay is higher than steel pipe pile foundation. ・Environmental protection is required. ・Slighty expensive than the other option.	・QC of this option is easier than the other option. ・Risk on the construction delay is smaller tha CIP pile. ・Environmental protection is not required in general. ・A slight advantage in cost is confirmed.
	△	◎

Evaluation ◎：Best, ○：Second-best, △：Possible if no other, ×：Unsuitable

Preliminary Design for Tunnel Crossing

Immersed tube tunnel and Shield tunnel are examined as alternatives for a tunnel crossing under the Cam River. Detailed study result is attached in Appendix A5.

5.6.2 Criteria for the Preliminary Design of Tunnel Planning

(1) Geological and Hydrological Conditions

River width and depth at each site are shown in Figure 5.6-1.

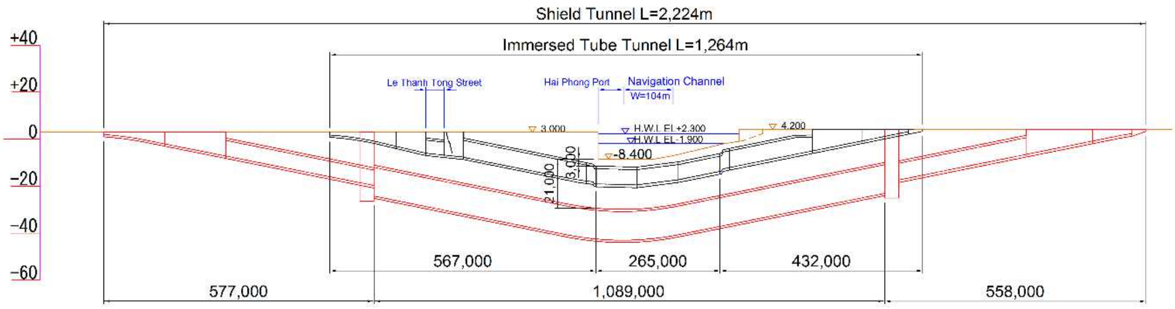
(2) Geological Conditions

According to the soil investigation results, the subsoil consists of soft alluvial layers and marine clay deposit layers with a thickness of about 30m in both the Nguyen Trai and Vu Yen area. Some of the upper layers where the proposed tunnel is planned to be located consist of softer ground with an SPT value of less than 5 and the total thickness of the softer clay layer is about 20m.

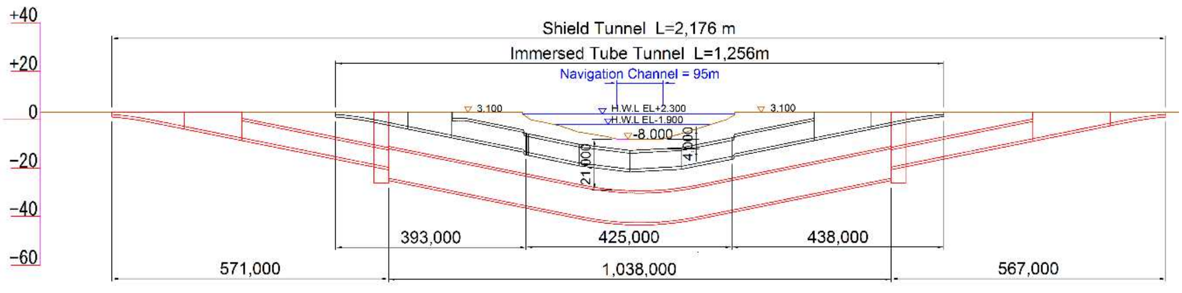
(3) Navigational Conditions

According to information from Maritime Safety North, the conditions of the navigation channel are as follows.

- Navigation channel: One way navigation for vessels accessing the port of Hai Phong and Vat Cach. The navigation channel of the Cam River has a design width of 80m.
- Tonnage allowed on channel: Song Cam channel is designed for vessels up to 20,000GWT entering Chua Ve Port and 10,000GWT entering Hai Phong Port. However, 50,000GWT vessels of suitable draft, in other words 50,000GWT vessels which are not fully loaded, can enter Hai Phong Port.



a) Nguyen Trai Tunnel



b) Vu Yen Tunnel

Figure 5.6-1 Comparison of Immersed Tube Tunnel and Shield Tunnel

5.6.3 Selection of Tunnel Type for Cam River Crossing

(1) Selection of Tunneling Method

Table 5.6-8 shows a comparison between the immersed tube tunneling method and the shield tunneling method.

Table 5.6-8 Comparison of Immersed Tube Tunneling and Shield Tunneling Methods

Item		Immersed Tube Tunneling	Comparison	Shield Tunneling
Width	Under river	31.3m	= 1)	42.3m
	On land	31.7m		42.3m
Length	Nguyen Trai	**1,262m**	> 2)	2,224m
	Vu Yen	**1,256m**	>	2,176m
Impact on Navigation		Some works impact navigation but can be controlled	< 3)	**No impact**
Social impact		**small**	>	Large (Because the length of tunnels longer)
Impact on natural environment		Necessary countermeasure	<	**No large-scale excavation inside the river**
Construction Period		**Shorter (50 to 55 month)**	>	60 to 65 months
Construction Cost		**Cheaper**	>	Around 1.5 times of immersed tube tunnel
Experience in Vietnam		**Saigon River Tunnel (opened in Nov. 2011)**	>	No experience in Vietnam
Construction Yard		Dry dock for fabrication of tunnel elements is required as an additional yard.	<	**Not required**
Maintenance		**Cheaper**	>	Tunnel length is longer

Notes: 1) = Both methods equal or equivalent.
2) > Immersed tube tunneling method is superior to shield tunneling method.
3) < Immersed tube tunneling method is inferior to shield tunneling method.

According to our analysis on Table 5.6-8 , the immersed tube tunneling method is superior to the shield tunneling method in regard to construction cost and construction period. It is also advantageous as there is past experience in Vietnam of using the method for the Saigon River Tunnel in Ho Chi Minh City which was opened to traffic in 2011.

5.6.4 Preliminary Design for Immersed Tunnel

The overall tunnel structure therefore consists of the following parts:

a) Immersed tube tunnel

b) End section constructed with the bottom-up method which connects the immersed tunnel and the cut and cover tunnel constructed with the top-down method

c) Cut and cover tunnel constructed with the top-down method

d) U-shaped structure with diaphragm wall

e) U-shaped retaining wall

A summary of the preliminary design of the tunnel structure for both Nguyen Trai Tunnel and Vu Yen Tunnel are shown below.

Table 5.6-9 Outline of Preliminary Design for Nguyen Trai Tunnel

Item	Structure Type, Dimensions and Length
Immersed tunnel	- Cross section: 8.8m(H)x31.3m(W) - Length L=87+89+89=265m (3 elements)
End Section	- Between the immersed tube tunnel and the cut and cover tunnel - Constructed with the bottom-up method with steel pipe pile cofferdams - Each length L=20mx2=40m
Cut and Cover Tunnel	- Old city side L=262m, VSIP side L=177m (total L=460m) - RC diaphragm wall: t=1.2m, L=40m - Top-down method
U-shaped Structure with Diaphragm Wall	- Old city side L=41m, VSIP side L=105m (total L=125m) - RC diaphragm wall: t=1.0m, L=40m - Top-down method
Box Culvert	- To pass under Le Thanh Tong Street - RC box culvert (L=40m)
U-shaped Retaining Wall	- Old city side L=162m, VSIP side L=100m (total L=282m) - Nguyen Trai Street in VSIP area

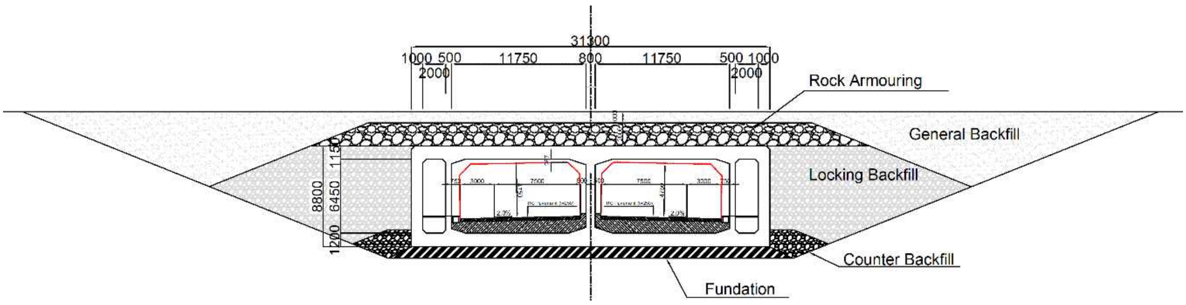


Figure 5.6-1 Cross Section of Nguyen Trai Tunnel

Table 5.6-10 Outline of Preliminary Design for Vu Yen Tunnel

Item	Structure Type, Dimensions and Length
Immersed tunnel	- Cross section: 8.9m(H)x31.3m(W) - Length L=110+105x3=425m (4 elements)
End Section	- Between the immersed tube tunnel and the cut and cover tunnel. - Constructed with the bottom-up method with steel pipe pile cofferdams - Each length L=30mx2=60m
Cut and Cover Tunnel	- Hai Phong side L=123m, VY Island side L=140m (total L=263m) - RC diaphragm wall: t=1.2m, L=40m - Top-down method

U-shaped Structure with Diaphragm Wall	- Hai Phong side L=91m, VY Island side L=118m (total L=209m) - RC diaphragm wall: t=1.0m, L=40m - Top-down method
U-shaped Retaining Wall	- Hai Phong side L=149m, VY Island side L=110m (total L=220m) - Nguyen Trai Street in VSIP area

5.6.5 Construction / Maintenance Cost

The Construction cost and maintenance is estimated as shown below.

Table 5.6-11 Cost for Construction of Nguyen Trai Tunnel (1 JPY=202.84VND)

Item	Description/Quantity	Equivalent JPY	Equivalent VND (Million VND)
General	7% of Total	1,030,000,000	208,925
Immersed tunnel (RC structure)	8.8m(H)x31.3(W)x3 units L=87+89+89=265m	5,468,000,000	1,109,129
Approach Tunnel	Old city side L=567m VSIP side L=432m	6,459,000,000	1,310,144
Finishing work	L=1,234m	236,000,000	47,870
E&M	L=744m	2,552,000,000	517,648
Total		**15,745,000,000**	**3,193,716**

Table 5.6-12 Cost for Construction of Vu Yen Tunnel (1 JPY=202.84VND)

Item	Description/Quantity	Equivalent JPY	Equivalent VND (Million VND)
General	7% of Total	1,182,000,000	239,757
Immersed tunnel (RC structure)	8.9m(H)x31.3(W)x4units L=110+105x3=425m	7,933,000,000	1,609,130
Approach Tunnel	HP side L=393m VY island side L=438m	6,171,000,000	1,251,726
Finishing work	L=1,256m	244,000,000	49,493
E&M	L=748m (Tunnel Section)	2,536,000,000	514,402
Highway	W=35.5m, L=924m	492,000,000	99,797
Total	Total length L=2,180m	**18,558,000,000**	**3,764,305**

Table 5.6-13 Cost for Tunnel Operation and Maintenance

Item	Cost (million VND)	Equivalent JPY (1 JPY=202.84VND)
Operation include electricity cost	10,750	53,000,000
Cost for replacement of E&M facility or its parts	11,562	57,000,000 *1)
Maintenance of Tunnel include cleaning	8,114	40,000,000
Total	30,426	150,000,000

Note 1): Cost for replacement of E&M facility or its parts depending on the condition of the tunnel, such as traffic volume, temperature, humidity, operation of facility etc. and the total annual cost is different every year. Therefore the cost indicated in this table is the annual average of expenditure for the replacement of E&M facility or its parts.