Application of green value engineering in MRT geotechnical engineering

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ABSTRACT

Due to the worsening global warming, the issue of energy conservation and carbon reduction continues being attached great importance. Except that, the main goal of public construction is humanism, high quality, and sustainability nowadays; therefore, there is an underground MRT station in Taiwan which combined value engineering techniques with concept of carbon footprint tracking in design stage to figure out the design alternative plans to decrease the construction cost and reduce carbon emissions. All the design alternative plans described in this article could totally save about 1.3 billion NTD, and 31,482 tons carbon emissions could be reduced.

Keywords: Green value engineering, Energy conservation, Carbon reduction, Cost model, CO_2 model

1 INTRODUCTION

Although Taiwan is not a member of Intergovernmental Panel on Climate Change (IPCC), we still make every effort to mitigate climate changes.

Public Construction Commission in Taiwan promotes the concept of energy conservation and carbon reduction in public constructions all the time. In whole life cycle of the project, including planning, design, construction, and operation stage, energy-saving and carbon-reduction methods should be used as much as possible. Besides, the application of green energy equipments should also be increased.

In this article, take an underground MRT station in Taiwan for example which combined value engineering techniques with concept of carbon footprint tracking in design stage, and figure out the alternative plans in order to decrease the construction cost and reduce carbon emissions.

2 ANALYSIS METHOD OF GREEN VALUE ENGINEERING

Green value engineering is the combination of economic evaluation (by value engineering techniques), application of green energy, and carbon reduction estimates, as Fig. 1 shows. The detail implement contents of green value engineering are shown in Table 1. The carbon emissions estimate is added in the original process of value engineering, and the research range of MRT geotechnical engineering is searched and defined in design stage. The design alternative plans satisfying key functions are figured out to reduce construction cost greatly and decrease amount of carbon emissions. Through selecting process, the design alternative plans with greater benefits would be chosen to carry out to reach the goal of maximizing efficiency and sustainable energy conservation.

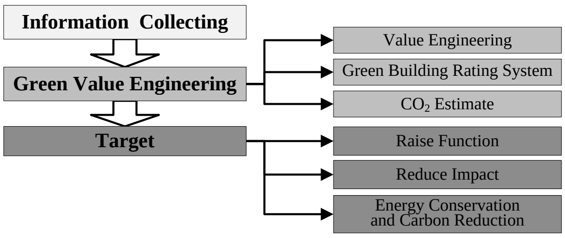

Fig. 1. Concept and target of green value engineering

Table 1. Implement contents of green value engineering

Stage	Contents
Stage 1 Information Collecting Stage	Collect and review information, set up cost model and CO_2 model, search and define research range, evaluate and analyze functions, etc.
Stage 2 Creative Stage	Propose design alternative plans which satisfy key functions and reduce carbon emissions greatly.
Stage 3 Judgment Stage	Determine the pros and cons of each idea. Ask each professional (carbon emission estimation engineer and BIM engineer to assist in checking carbon emission estimation) to rate and select from each idea.
Stage 4 Development Stage	Collect more detail information about the selected alternative plans. Estimate the potential savings and carbon emission reductions.
Stage 5 Suggestion Stage	Prepare analysis report about the alternative plans. (including potential savings and carbon emission reductions)
Stage 6 Tracking Stage	Track the accepted alternative plans to make sure that the concept is used in the design actually.

3 RESEARCH RESULTS OF GREEN VALUE ENGINEERING

Take the experience of design an underground MRT station with green value engineering method for example. Through selecting process, there are five design alterative plans are chosen, as Table 2 shows. The details of each plan are described as following sections.

Table 2. Design alternative plans

NO.	Design Alternative Plans
1	Straighten the route of shield tunnel in order to shorten the line and improve passenger service.
2	Adjust alignment to prevent the conflict between dike foundations and shield tunnels, and make sure the height of overburden soil is enough.
3	Adjust the position of station and turnout to reduce the length of cut and cover tunnel.
4	The platform of underground station changes from double layers to center to reduce the excavation depth.
5	Review the type of ventilation shaft to decrease excavation depth and construction risk.

3.1 Straighten the route between LG04 and LG05 stations

In original plan, there were three plane curves set up in the route, and the route passed under the traditional market, expressway and dikes on both sides of Xindian river, as Fig. 2 shows.

After collecting design drawings of traditional market, expressway and dikes adjacent to the route, the horizontal alignment is straightened, and two plane curves are canceled to improve passenger comfort in alternative plan, as Fig. 3 shows. Besides that, there are more benefits accompanying with the design in alternative plan, as Table 3 shows.

Table 3. Benefits of cancel plane curve and straighten the route

Item	Benefit
Route length	Shorten 20m
Construction period	Shorten 0.1months
Carbon emission	Reduce 98tons
Cost	Save 9.27 million NTD

Fig. 2. The route design in original plan (three curves)

Fig. 3. The route design in alterative plan (only one curve)

3.2 Adjust vertical alignment between LG04 and LG05 stations

In original plan, there were two major safety risks for shield tunnels between LG04 and LG05 stations during passing under Xindian river:

(1) There existed the conflict between dike foundations and shield tunnels, as Fig. 4 shows.

(2) River bed might be eroded continuously in extreme climate. The overburden depth of shield tunnel was only 12m. If there was no river bed protector, the safety of shield tunnel structures might be affected (uplift failure), as Fig. 6 shows.

After analyzing river bed eroding trend and shield tunnel safety, the vertical alignment is adjusted within the operational tolerance, as Fig. 5 and Fig. 7 show. The shield tunnels pass underneath pile tips of dike to avoid conflict. Besides that, the overburden depth of tunnels increase to 24m; therefore, in extreme climate, the overburden depth is at least 12m without any river bed protector, and the safety of shield tunnel structure is improved.

The other benefits accompanying with the design in alternative plan are listed in Table 4.

Table 4. Benefits of adjusting alignment in alternative plan

Item	Benefit
Construction period	Shorten 6months
Carbon emission	Reduce 7,785tons
Cost	Save 5.6 hundred million NTD

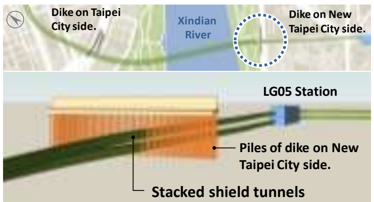

Fig. 4. The position of stacked shield tunnels conflict with dike piles in original plan

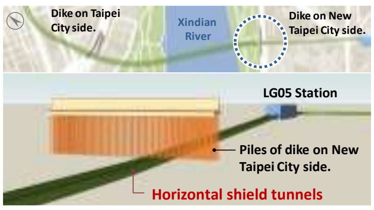

Fig. 5. Horizontal shield tunnels pass underneath dike pile tips to avoid conflict in alternative plan

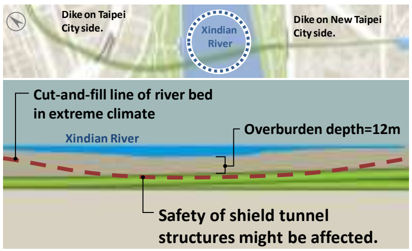

Fig. 6. River bed eroding might influent shield tunnels safety in original plan

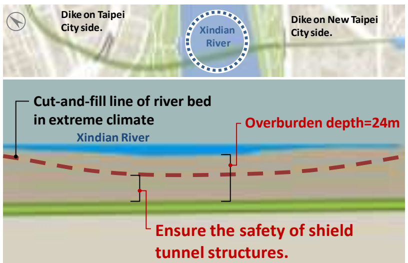

Fig. 7. Adjust vertical alignment to keep shield tunnels safe in alternative plan

3.3 Adjust position of LG04 station to shorten the length of cut and cover tunnels

In original plan, according to the position of LG04 station and the current road conditions, the turnout is located at turning section, and the other disadvantages in the original plan are listed in Table 5, and as Fig. 8 shows.

In alternative plan, the station is shifted slightly, and the turnout is also adjusted the position to lower the construction risk. The benefits accompanying with the design in alternative plan is listed in Table 5, and as Fig. 9 shows.

Table 5. Compare of original plan and alternative plan

Item	Original Plan	Alternative Plan
Cut&cover tunnel length	455m	400m (shorten 55m)
Construction period	-	Shorten 3months
Carbon emission	Great environmental impact	Reduce 4,241tons
Cost	-	Save 1.68 hundred million NTD

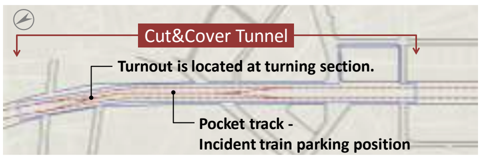

Fig. 8. Turnout is located at turning section in original plan

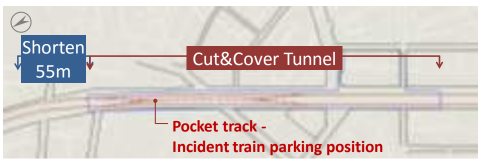

Fig. 9. Position of station is shifted in alternative plan

3.4 Change the platform type of LG05 station from double layers to center

In original plan, LG05 station was an underground double layers station. The excavation depth was 36m, and the type of shield tunnels linking to the station was stacked. The advantage of original plan was to keep the ample clearance from the shield tunnels to the adjacent buildings, but the passenger service of double layers platform is worse, as Fig. 10 shows.

LG05 station is shifted slightly in the alternative plan, and the shield tunnels linking to the station change into horizontal type by adjusting alignment. In alternative plan, LG05 station is an underground center station. The excavation depth could decrease to 23m, and the other benefits accompanying with the alternative design are listed in Table 6. In addition, the construction risk is also decrease, and the station functions and passenger service are improved, as Fig. 11 shows.

Table 6. Benefits of adjusting station in alternative plan

Item	Benefit
Excavation depth	Decrease 13m
Construction period	Shorten 7months
Carbon emission	Reduce 14,925tons
Cost	Save 4.8 hundred million NTD

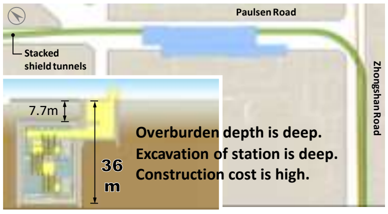

Fig. 10. Design of double layers station in original plan

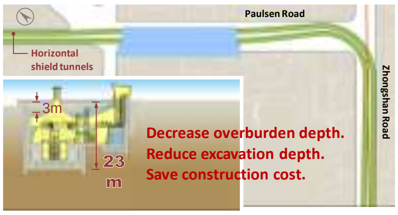

Fig. 11. Design of center station in alternative plan

3.5 Review the type of ventilation shaft

In original plan, the ventilation shaft (vent shaft) was installed next to Wa-Yao ditch, as Fig. 12 shows. In addition, the cross passage between tunnels and vent shaft should be excavated by NATM method. However, the depth of ground improvement area was 30m, so the precision and quality were difficult to control. The segment structure of tunnel should also be broken for NATM method. The construction risk was high.

In alternative plan, because of the alignment adjusting and LG05 station shifting, the stacked shield tunnels change into horizontal. Besides, the vent shaft is shifted to another place; therefore, the excavation depth of vent shaft decreases 8.5m, and the amount of dewatering in Jingmei layer could also reduce. In addition, the shield tunnels could arrive at vent shaft directly with mirror-face breaking method to avoid the usage of NATM method, and the segment of tunnels could not be disassembled, as Fig. 13 shows. The construction risk could lower greatly in alternative plan. The benefits accompanying with the alternative design are listed in Table 7.

Table 7. Benefits of review the type of ventilation shaft

Item	Benefit
Excavation depth	Decrease 8.5m
Construction period	Shorten 5months
Carbon emission	Reduce 4,433tons
Cost	Save 76 million NTD

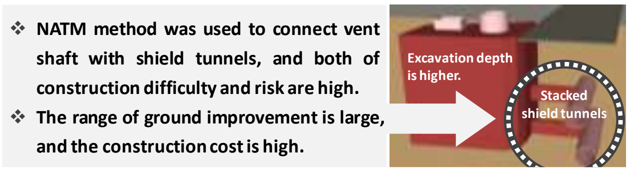

Fig. 12. Vent shaft design in original plan

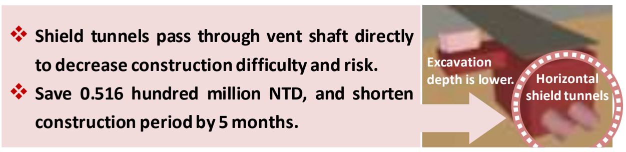

Fig. 13. Vent shaft design in alternative plan

4 INTRODUCTION OF ENERGY CONSERVATION AND CARBON REDUCTION ESTIMATE TECHNIQUES

Carbon footprint tracking is not only suitable for the case which we can see the smoke exhausting directly, but also for all the activities in whole life cycle of construction project which exhaust carbon directly or indirectly. Emission factor method is usually used to estimate the amount of greenhouse gas emission. The equation is shown as Eq. (1).

$$\text{Greenhouse Gas Emissions } (CO_2 \text{ equivalent}) = \Sigma \text{ Emission Intensity} \times \text{Carbon Emission Factor} \quad (1)$$

where Emission Intensity is activity data, like the usage of oil, electricity, water and other materials, etc.; Carbon Emission Factor is the amount of greenhouse gas emission per unit activity, expressed in terms of CO_2 equivalent.

We need to clarify and collect the information about emission intensity and carbon emission factor at first. In planning and basic design stage, there is not enough information for estimate Emission Intensity (activity data); so that the experiences and data of similar detail design projects should be the auxiliary information.

In principle, the activity data are the quantity of construction items, and the amount of construction materials and energy consumption equipments are analyzed from the items. Besides, the carbon emission factor could be identified by the collected information from previous project experiences, bureau of energy, institute of transportation, etc. The carbon reduction estimate results for all five alternative plans described above are shown in Table 8.

Table 8. Amount of carbon reduction in design stage

NO.	Design Alternative Plans	Carbon Reduction (tons)
1	Cancel curved route and straighten the route of shield tunnel. (shorten 20m)	98
2	Adjust alignment to prevent the conflict between dike piles and shield tunnels, and keep the tunnel structure safe in extreme climate.	7,785
3	Adjust the position of station and turnout to reduce the construction length of cut and cover tunnel. (shorten 55m)	4,241
4	The platform of underground station changes from double layers to center to reduce the excavation depth. (lower 13m)	14,925
5	Review the type of ventilation shaft and decrease excavation depth. (lower 8.5m)	4,433
	Total	31,482

5. CONCLUSION

Although the underground MRT system is a green transport in urban life circle, but the large amount of excavation and shielding would occur high carbon emissions in the city; therefore, how to combine construction with green value engineering and carbon reduction is important.

In this project, the concept of footprint tracking is used to estimate the possible amount of greenhouse gas emissions. In addition, the value engineering technique is also used to search and define the alternative plans which could lower construction cost and reduce carbon emission. Finally, total construction cost could be lowered substantially, CO_2 emission could be reduced, and the construction period could be shortened accompanying with the alternative design.

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