# Analyzing the Alignments of Roads by Giving Weightages to Various Factors - a Case Study

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ABSTRACT

There is an increasing demand of Infrastructure roads due to increase in road traffic and related issues in safety. Roads are the dominant mode of transportation in India. Roads carry almost 85 percent of the country's passenger traffic and more than 62 percent of its freight traffic Due to improvement in transportation network, reduction in transportation costs, such as reduction in travel time, decrease in vehicle operations cost, increased safety and reduction in the level of air and noise pollution. In addition to reduction is transportation cost, it also increases comfort to passenger and enhancing land value. Widening of road is mostly the case followed for the increasing demand. However, nowadays, for catering the needs of increasing traffic demand, Greenfield alignment is also as an option. Hence, there are advantages and disadvantages in both the alignments. This study involves for comparing and analyzing a NH 160A highway section between Ghoti to Trimbakeshwar for a length of 14.3 km. This paper compares the pros and cons of both alignments, costing of both the alignments, Geometry of both alignments; problems/issues like encroachment, forest area, Utilities in both alignments. In this study, the optimal alignment has been arrived by bringing all the issues to a common platform with a grading system. Further, different scenarios considered based on the requirement of a Client by doing Sensitivity analysis for various cases.



## 1. Introduction

Before starting of any project, road alignment needs to be determined this are an optimal alignment and a basic requirement for implementation of a Highway project. There are two approaches in planning stage. Either widening of existing roads are done or a new alignment is planned which is a Greenfield alignment. Hence, it is necessary to consider both the alternatives in designing stage based on the benefit it will render to the highway user as well as the agency constructing it. The benefits can be in term of savings in travel-time and construction cost, safety improvements, and reduction in environmental impact. The aim of this research is to develop a grading system to compare all the factors on a common platform and hence design the optimized highway alignment between two given points. Hence, this study needs to be authentic, accurate and thorough as investment option depends on this basis.

## 2. Study Area Location

The highway section between Ghoti-Trimbakeshwar section of NH 160A in the state of Maharashtra is considered for the study. The length of stretch considered for study is between Ch. 53/500 and Ch. 67/800 i.e. for a length of 14.3 km. The Brownfield alignment is passing through route Ghoti-Khambale-Waki-Kurnoli-Korapgaon-Bhavli Bk-Sutarli, This alignment follows the existing road where widening of road is considered. The Greenfield alignment route is passing through Ghoti-Khambale-Waki-Biturli-Awali Dumla-Sutarli. Greenfield alignment plotted in Google map after observing the terrain. The horizontal alignment then finalized in AutoCAD for meeting horizontal curves requirements as per Specification. Subsequently, after picking the ground levels in Google map, the vertical curves finalized to meet the specifications as per manual of specification and standards for two laning of highway with paved shoulder IRC SP 73 [1]. The Greenfield alignment finalized after doing trial and error method Fig 1 shows the map view of both alignments.

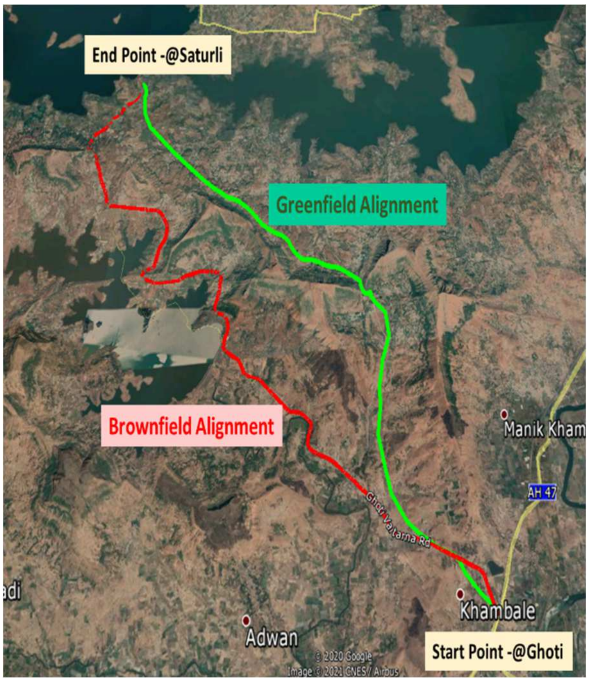


**Fig. 1** Map view of both alignments

## 3. Data Collection

### 3.1 Advantages and Disadvantages

Factors considered for advantages and dis-advantages are as follows:

1) Alignment- Green field alignment will follow the curves matching with IRC standards.
2) Land acquisition-People staying in built up areas object to give the land and hence delay in land acquisitions in Brownfield project.
3) Built-up areas- Interference from local public and land acquisition delays in the project
4) Encroachments- Public anger and Law and order situation while removing the encroachments delays the widening projects.
5) Utility shifting- Many utilities adjacent to existing roads add to cost of shifting the same and delays the project of widening.
6) Speed of Construction- Above factors reduces the speed of widening project.
7) Safety during Construction- Existing moving traffic in Brownfield alignment project is prime importance. Restrictions from traffic Police for getting permissions to work in phased manner.
8) Accidents-Non-standard curves in present existing alignment might result in extra injuries due to accidents in Brownfield.

9) Environment- Old trees adjacent to existing roads needs cutting in case of brownfield alignments. Tree cutting permission consumes a lot of time. Substandard curves in current alignment make heavy trucks to transport in lower gears, which end up in smoke pollutants and noise pollutants.
10) Toll fees- If Brownfield road is toll road; people do not have the choice to take another road.
11) Forest areas-The alignment of road in Forest areas is by-passed in Greenfield alignments as it takes lot of time for work permission from Forest Department.
12) Construction cost- Greenfield alignment length might be generally lesser in length; it could have trouble in terrains and subsequently may be costly.
13) Land acquisition cost- Land cost near existing roads will be more costly then land away from Built up area.
14) Construction issues- Differential settlements issues will be there in Brownfield project.
15) Geometric design-Green field alignments can meet speed requirements as per design throughout the project length as vertical and horizontal alignment is as per the specifications.
16) Time value- Traffic jams due to sub-standard curves can be a concern for achieving time value in Brownfield alignments.

### 3.2 Project Features

Project features for both the alignments are as shown in Table I.

**Table 1.** Project Features

| Sr. No. | Description | Option-1 Widening of existing alignment | Option-2 Greenfield alignment |
|---|---|---|---|
| 1 | Design Chainage | | |
| | Start chainage | 53.5 | 53.5 |
| | End Chainage | 67.8 | 67.8 |
| 2 | Total Design Length | 14.3 | 11.934 |
| 3 | Route | Ghoti-Khambale-Waki-Kurnoli-Korapgaon-Bhavli Bk-Saturli | Ghoti-Khambale-Waki-Biturli-Awali-Dumla-Saturli |
| 4 | Land-use Pattern | | |
| | Open Country | 12.74 | 7.864 |
| | Built-up | 0.2 | 0.00 |
| | Mountainous | 0.00 | 4.07 |
| | Forest Sections | 1.36 | 0.00 |
| 5 | Existing ROW (m) | 12 m | 0m |
| | Proposed ROW (m) | 30 m | 30m/45m |

### 3.3 Traffic details for both alignments

The existing traffic detail from traffic survey was used for deciding the lane configuration of the project road [2] as shown in Table II.

**Table 2.** Traffic data

| Sr. No. | Category | PCU Factor | @Khambale | |
|---|---|---|---|---|
| | | | ADT | PCU |
| 1 | Two-Wheeler | 0.5 | 2560 | 1280 |
| 2 | Auto Rickshaw | 1 | 41 | 41 |
| 3 | LMV | 1 | 1327 | 1327 |
| 4 | Mini LCV | 1.5 | 310 | 465 |
| 5 | Mini Bus | 1.5 | 20 | 30 |
| 6 | LCV | 1.5 | 38 | 57 |
| 7 | Pvt. Bus | 3 | 9 | 27 |
| 8 | Govt. Bus | 3 | 34 | 102 |
| 9 | School Bus | 3 | 2 | 6 |

| Sr. No. | Category | PCU Factor | @Khambale | |
|---|---|---|---|---|
| | | | ADT | PCU |
| 10 | 2-Axle | 3 | 18 | 54 |
| 11 | 3-Axle | 3 | 4 | 12 |
| 12 | 4 to 6 Axles | 4.5 | 0 | 0 |
| 13 | 7 or more Axle | 4.5 | 0 | 0 |
| 14 | Tractor | 1.5 | 5 | 7.5 |
| 15 | Tractor with Trailer | 4.5 | 16 | 72 |
| 16 | Cycle | 0.5 | 22 | 11 |
| 17 | Cycle Rickshaw | 1 | 0 | 0 |
| 18 | Road Roller | 4.5 | 2 | 9 |
| 19 | **Total** | | **4408** | **3501** |

A. Cross-Section considered for both alignments:

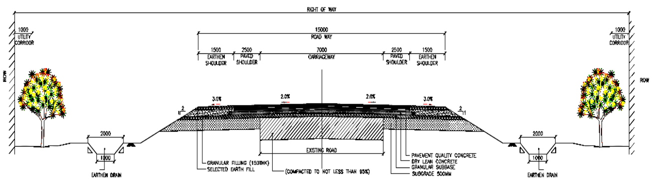

**Fig. 2** Brown Field Cross section

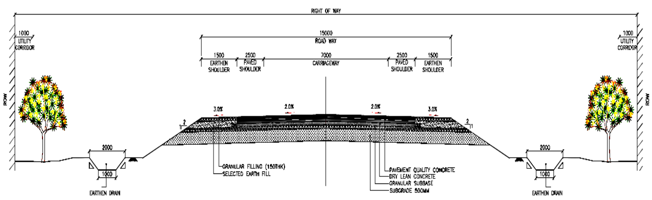

**Fig. 3 Green Field Cross section**

## 4. Data Analysis

### 4.1 Project Costing

1) Cost Computation for Brownfield Alignment as per Figure 2 shown in table III.

**Table 3.** Cost Computation for Brownfield Alignment

| S. No. | Item Description | Amount in Crores |
|---|---|---|
| (I) | CIVIL WORKS | |
| 1 | Site Clearance and Dismantling | 0.48 |
| 2 | Excavation & Earthwork | 21.98 |
| 3 | Sub-bases, bases (GSB, WMM) | 3.71 |
| 4 | Cement Concrete Pavement | 40.59 |
| 5 | Bituminous work (Forest section) | 1.60 |
| 6 | Road Furniture | 0.90 |
| 7 | Junctions | 0.46 |
| 8 | Gutters & Footpath | 0.95 |
| 9 | Utility Ducts Across The Highway | 0.15 |
| 10 | Bus Bays with Bus Shelters | 1.24 |
| 11 | Electrification | 0.05 |
| 12 | Gantry | 0.02 |

| S. No. | Item Description | | Amount in Crores |
|---|---|---|---|
| 13 | Protective works | | |
| | a) Toe wall | | 4.36 |
| | b) Retaining wall | | 9.30 |
| 14 | Structures | | |
| | a) Box Culverts | | 3.69 |
| | b) Pipe Culverts | | 3.44 |
| 15 | Other Facilities | | |
| | Miscellaneous items (crash barriers, Guard rail,) | | 5.17 |
| | TOTAL | | 98.09 |
| | GST (12%) | 12% | 11.77 |
| | Royalty Charges | | 5.88 |
| (A) | Total Civil Construction Cost (A) | | 115.74 |
| II | Contingency 2.8% | 2.80% | 3.24 |
| (B) | Total Civil Construction cost B | | 118.98 |

Land acquisition cost: 259136325/- (Rs 25.91 cr)

2) Cost Computation for Greenfield alignment as per Figure 3 as shown in Table IV

**Table 4.** Cost Computation for Greenfield Alignment

| S. No. | Item Description | | Amount in Crores |
|---|---|---|---|
| (I) | CIVIL WORKS | | |
| 1 | Site Clearance and Dismantling | | 0.30 |
| 2 | Excavation & Earthwork | | 53.58 |
| 3 | Sub-bases, bases (GSB, WMM) | | 7.00 |
| 4 | Cement Concrete Pavement | | 27.75 |
| 5 | Bituminous work (Forest section) | | 3.68 |
| 6 | Road Furniture | | 0.77 |
| 7 | Junctions | | 0.58 |
| 8 | Gutters & Footpath | | 0.29 |
| 9 | Utility Ducts Across The Highway | | 0.13 |
| 10 | Bus Bays with Bus Shelters | | 0.74 |
| 11 | Electrification | | 0.00 |
| 12 | Gantry | | 0.02 |
| 13 | Protective works | | |
| | a) Toe wall | | 0.26 |
| | b) Retaining wall | | 1.44 |
| 14 | Structures | | |
| | a) Box Culverts | | 0.38 |
| | b) Pipe Culverts | | 0.21 |
| 15 | Other Facilities | | |
| | Miscellaneous items (crash barriers, Guard rail,) | | 3.39 |
| | TOTAL | | 100.53 |
| | GST (12%) | 12% | 12.06 |
| | Royalty Charges | | 4.58 |
| (I) | Total Civil Construction Cost (I) | | 117.18 |
| II | Contingency 2.8% | 2.80% | 3.28 |
| (I) | Total Civil Construction cost I | | 120.46 |

Land acquisition cost: 270457003 /- (Rs 27.04 cr)

### 4.2 Comparison considering Geometry

**Table 5.** Comparison Considering Geometry of Greenfield Alignment and Brownfield Alignment

| Sr No | Items | Brownfield alignment | Greenfield alignment | Remarks |
|---|---|---|---|---|
| 1 | No. of locations where minimum 80 kmph could not be achieved due to curves | 19 locations | 8 locations | In Brownfield 11 locations speed is 20 |
| 2 | Average speed achieved for whole length | 64 kmph | 84kmph | Saving in Vehicle operation cost |
| 3 | Time required for complete length if free flow | 13.46 min | 8.49 min | Saving of 5 minutes |
| 4 | Land required for acquisition | 37.63 Ha | 12.21a | |

### 4.3 Comparison considering Geometry

**Table 6.** Cost Comparison for Greenfield Alignment and Brownfield Alignment

| Sr. | Item | Brownfield Alignment | Greenfield Alignment | Remarks |
|---|---|---|---|---|
| 1 | Construction Cost | 118.98 | 120.46 | |
| 2 | Escalation cost for delays | 0.78 | 0 | 1.36 km forest 0.2 km built-up area |
| 3 | Land Cost | 25.91 | 27.01 | |
| 4 | Utility Shifting Cost | 3.97 | 0 | |
| | Total cost | 149.64 Crs. | 147.47rs. | |

### 4.4 Comparison considering environmental and social factors

In Greenfield alignment, tree cutting involved is very less as compared to Brownfield alignment. Further, the Brownfield alignment is passing through a forest stretch for a length of about 1.35 km length.

## 5. Sensitivity

### 5.1 Sensitivity calculations

To compare the Green field and Brownfield alignment, a grading system is adopted in this paper to bring it to common platform all the factors like Geometry, Costing and other issues/hurdles like Built up areas, Forest areas etc.

1) Geometry of Road

In this, sub-factors considered are like number of curves and lengths, speed achieved, time of travel for the proposed stretch and length of road in both cases i.e. Brownfield and Greenfield alignments.

1.1. Curves

In Brownfield alignment, the numbers of locations of curves are 19 with a cumulative length of 1673m. Whereas, in Greenfield alignment the number of curve locations are eight with a cumulative length of 1176m. In the ideal case, the curves shall be zero. The ideal case of zero curves is absent in both the alignments. The percentage achieved in brownfield alignment is =100-(1673/14300*100) i.e. 88.3%. The percentage achieved in Greenfield alignment is =100-(1176/11934*100) i.e. 90.15%. Hence grading of 8.8 and 9 are for Brownfield alignment and Greenfield alignment respectively.

1.2. Speed

The average speed achieved in Brownfield alignment and Greenfield alignment is 64 Kmph and 84 Kmph respectively. Hence grading of 6.4 and 8.4 are for Brownfield alignment and Green field alignment respectively.

1.3. Time

The time of journey for the stretch is 13.46 minutes and 8.49 minutes in Brownfield alignment and Greenfield alignment respectively. In ideal case with a speed of 100 Kmph, the stretch shall require 6.45 minutes. Percentage of speed achieved in case of Brownfield alignment in comparison with ideal case is 6.45/13.46x100=47.92%. Similarly, the percentage achieved in case of Greenfield alignment is 6.45/8.49x100=75.97%. Hence, the grading of 4.8 and 7.6 are for Brownfield alignment and Greenfield alignment respectively.

1.4. Length

The length of stretch from origin to destination is 14.3 km for Brownfield alignment, whereas for Greenfield alignment it is 11.934 km. In ideal case, the straight shortest length from origin to destination is 10.75 km. Hence, the achievement for Brownfield alignment is 100-((14.3-10.750/10.75x100)=66.98% and for Greenfield alignment is 88.99%. Hence, the grading are for Brownfield alignment and Greenfield alignment 6.7 and 8.9 respectively.

The total rating considering the factor Geometry, are in Table VII in the form of grading.

**Table 7.** Grading for Both Alignments Considering Sub Factors in Geometry

| **Sr. No.** | **Sub-Factors** | **Brownfield alignment** | **Greenfield alignment** | **Out of** |
|---|---|---|---|---|
| 1 | Curves | 8.8 | 9.0 | 10 |
| 2 | Speed | 6.4 | 8.4 | 10 |
| 3 | Time | 4.8 | 7.6 | 10 |
| | Length | 6.7 | 8.9 | 10 |
| | | **26.7** | **33.9** | **40** |

2) Costing

From Table VI, we can see the total costing of Brownfield alignment and Greenfield alignment are 149.64 crs and 147.47 crs respectively. If the costing of Greenfield alignment is 100%, then the percentage with respect to this will be 98.68% for Brownfield alignment. Hence, the grading for both alignments considering the Costing of Project is in table VIII given below.

**Table 8.** Grading for Both Alignments Considering Sub Factors in Geometry

| **Sr. No.** | **Sub-Factors** | **Brownfield alignment** | **Greenfield alignment** | **Out of** |
|---|---|---|---|---|
| 1 | Construction Cost | | | |
| 2 | Escalation cost for delays | | | |
| 3 | Land Cost | | | |
| 4 | Utility Shifting Cost | | | |
| | Total Cost | **10.00** | **9.6** | **10** |

3) Other issues

The sub-factors under this are Built-up area, Speed of Construction and Forest area. In this case as per the practical experience, the construction will delay by one year due to forest clearances for 1.36 km length and Built-up area of 0.2 Km length. On pro-rata basis, the delay due to forest area and built –up area will be 315 days and 45 days. However, in ideal case, the time required for completing

Built up area length of 0.2 km is 10 days and forest area of 1.36 km is 69 days. Based on this the grading achieved for these cases are as shown in table IX.

**Table 9.** Grading for Both Alignments Considering Other Issues/Hurdles Factor

| Sr. No. | Sub-Factors | Brownfield alignment | Greenfield alignment | Out of |
|---|---|---|---|---|
| 1 | Built up area (0.2 Km) | 2.2 | 10 | 10 |
| 2 | Speed of Construction | 6.7 | 10 | 10 |
| 3 | Forest area (1.36 km) | 2.2 | 10 | 10 |
| | | **11.1** | **30** | **30** |

## 5.2 Sensitivity analysis

The grading system adopted for arriving at the optimal alignment as observed in the above Calculations. There can be different weightages given to above factors. We have to do sensitivity analysis by giving different weightages to different factors. Some Clients may give more weightage to Costing and some may give to Geometry. Here we will do analysis by giving no weightage, by giving 25:50:25 weightages to Geometry, Costing and other factors in alignment. Similarly, the analysis in the form 5:90:5 and 0:100:0 done as follows. Both the alignments are checked to verify which alignment is optimal.

**Table 10** Sensitivity Analysis Considering No Weightages

| Sr. No. | Field | Percentage weightage | Brown field alignment | Green field alignment | Out of |
|---|---|---|---|---|---|
| 1 | Geometry of road | No weightage given | 26.7 | 33.9 | 40 |
| 2 | Costing of road | | 10.0 | 9.6 | 10 |
| 3 | Hurdles in alignment | | 11.1 | 30 | 30 |
| | | Total | 47.8 | 73.5 | 80 |
| | | Convert to 10 marks | 5.97 | 9.19 | 10 |

**Table 11.** Sensitivity Analysis Considering 25:50:25 Weightages

| Sr. No. | Field | Percentage weightage | Brown field alignment | Green field alignment | Out of |
|---|---|---|---|---|---|
| 1 | Geometry of road | 25 | 6.675 | 8.47 | 10 |
| 2 | Costing of road | 50 | 5 | 4.8 | 5 |
| 3 | Hurdles in alignment | 25 | 2.775 | 7.5 | 7.5 |
| | | Total | 14.45 | 20.77 | 22.5 |
| | | Convert to 10 marks | 6.42 | 9.23 | 10 |

**Table 12.** Sensitivity Analysis Considering 05:90:05 Weightages

| Sr. No. | Field | Percentage weightage | Brown field alignment | Green field alignment | Out of |
|---|---|---|---|---|---|
| 1 | Geometry of road | 5 | 1.33 | 1.69 | 2 |
| 2 | Costing of road | 90 | 9 | 8.64 | 9 |
| 3 | Hurdles in alignment | 5 | 0.55 | 1.5 | 1.5 |
| | | Total | 10.89 | 11.83 | 12.5 |
| | | Convert to 10 marks | 8.71 | 9.47 | 10 |

**Table 13.** Sensitivity Analysis Considering 0:100:0 Weightages

| Sr. No. | Field | Percentage Weightage | Brownfield alignment | Greenfield alignment | Out of |
|---|---|---|---|---|---|
| 1 | Geometry of road | 0 | 0 | 0 | 0 |
| 2 | Costing of road | 100 | 10 | 9.6 | 10 |
| 3 | Hurdles in alignment | 0 | 0 | 0 | 0 |
| | | Total | 10 | 9.6 | 10 |
| | | Convert to 10 marks | 10.00 | 9.60 | 10 |

**Table 14.** Sensitivity Analysis

| Sr. No. | Field | Base case | Weightage 25-50-25 | Weightage 5-90-5 | Weightage 0-100-0 |
|---|---|---|---|---|---|
| 1 | Brownfield alignment | 5.95 | 6.38 | 8.57 | 9.8 |
| **2** | Greenfield | 9.24 | 9.32 | 9.76 | 10 |
| 3 | Out of | 10.00 | 10.00 | 10.00 | 10 |
| | **Result** | **Green field is ok** | **Green field is ok** | **Greenfield is ok** | **Green field is ok** |

## 6. Conclusion

We observed that the average speed achieved in Greenfield alignment is 84 kmph in comparison to 64 kmph in Brownfield alignment, which leads to saving of time of 5 minutes for considered length of 14.3 km. We observed that the total cost of Greenfield alignment including construction cost, escalation due to delays, land cost, Utility Shifting cost is Rs 147.47 Cr in comparison with Brownfield alignment cost of Rs 149.64 cr. Greenfield has less pollution due to smooth horizontal curves as per specifications and less tree cutting is involved. Brownfield alignment passes through 1.35km Forest area affecting to some extent the natural environment. Hence, Greenfield alignment has less impact on Environment compared to Brownfield alignment. Brownfield alignment passes through 0.2 km Built up area and Greenfield alignment does not pass through Built-up area. Hence, in case of Greenfield alignment there is nil effect on rehabilitation and saving in project time as compared to Brownfield alignment.

From the above study, we observed that Greenfield alignment has more advantages considering geometry, time cost, environment and Social criteria. From the Sensitivity analysis, the weightage of 25 percent-50percent-25percent on Geometry, Costing, and hurdles gives a mark 6.38 to Brownfield alignment and 9.32 to Greenfield alignment. Further, considering variation in weightages to all factors, Greenfield alignment gets higher grading in all cases.

From the above, it is concluded that, Greenfield alignment has more advantages as compared to Brownfield alignment. Hence, optimal alignment for the construction of two-lane section of Ghoti to Trimbakeshwar is Greenfield alignment and is proposed for the development of the project road.

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