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A DECISION SUPPORT SYSTEM FOR OPTIMAL SELECTION OF ROADWAY ALIGNMENT USING SUSTAINABILITY AND MX ROAD SOFTWARE

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Abstract - *Transportation and the Environment are strongly interlinked and dependent. Sustainability Transportation projects such as more efficient rural roads rehabilitation and clean urban transport system not only provide economic development but important social benefit. However, transport projects can have significant effect on the environmental and local communities.*

Roadway alignments are usually designed based on cost minimization such as Earthwork cost minimization (cutting and filling). However. To design a good roadway alignment and sustainable one there is some factors incorporates the design process such as road accident and roadway lifetime these would lead to designing a roadway alignment based on sustainability.

The present research study mostly attempts to address the roadway footprints on the environment and achieve a sustainable roadway design model that can evaluate and reduce the roadway environmental impacts according to the alignment geometries such as vertical alignment and horizontal alignment. To achieve a sustainable roadway alignment evaluation models for the flowing factors are developed: Sight distance, Terrain disturbance, environment and economic. There are six different alignments and each alignment will be checked social safety, environmental impacts on natural terrain shape and the least costs. The formulation for all these models is implemented in MXROAD software package to automatically evaluate any given alignment based on these metrics.

The developed model provides the tools for designers and planners to quantitively compare and rate various alternatives and select the optimal alignment.

Key Words: Optimization Roadway Alignment, Using Mx road Software.

1. Introduction

Sustainability economic growth in low -and middle -income countries is a key poverty reduction and shared prosperity, which in part dependent on reliable and safe transportation system. Road and highway systems provide a critical function in creating and maintaining a desirable quality of life. Many transportation planners, Engineers, and Environmental Scientists Worldwide recognize that roadway systems need to be more sustainable in light of finite natural resources, sensitive Environmental conditions, and limited Economic resources. Sustainability is not just about the environmental considerations associated with energy conservation and alternative energy generation. It is the inseparable integration of the environmental, community and society, and economic attributes that need to be managed at the project level to be effective and successful. While the traditional roadway design process wats mainly focused on economic minimization, achieving a green or sustainable roadway is not possible without accounting for the environmental impacts such as air quality, energy consumption, and terrain disturbance.

Roadway alignments are usually designed based on short -term cost minimization such as earthwork cost minimization. However, adopting a long-term perspective in the design method that incorporates other important influences such as overall amount of fuel consumption, time and accident costs in the roadway lifetime would make possible to designing the roadway alignment based on sustainability [1].

The present research study mostly attempts to address the roadway safety on the social, environment, cost minimization, and achieve a sustainable roadway design model that can evaluate and reduce the roadway environmental impacts according to the alignment geometries. To achieve a sustainable roadway alignment, evaluation models for the following factors are developed Economic, Sight distance, and terrain disturbance. [2], the main critical of roadway design can be classified into these parts:

1. **Social safety:** Safety issues are the main social concerns affecting the roadway design in different stages and different method. Safety can directly affect the roadway design, according the vertical and horizontal alignment during designing.
2. **Economic:** the second parameter for road design is economic which governing the cost of roadway design. Earthwork costs such as cutting and filling are main critical parameters.
3. **Environmental:** the third one is environmental impact such as terrain disturbance or its original shape and fair quality after constructed the road project

To analyse and these parameters mentioned above we will use Mx road design software package to determine how much required sight distance and cut and fill balance.

Model that compares alternative alignments in terms of sight distance required.

Earthwork models are set up to minimize the total earthwork volume by cutting and filling volume. The amount of fill and cut volume is balanced by an equal volume each result. The proposed alignment is acceptable in terms of earthwork costs but environmental impacts according the natural shape of the terrain are being ignored. This paper, anew method is defined to minimize the disturbance of terrain caused by hauling. This method minimizes volume by following the natural terrain shape instead of only making balancing cut and fill volume.

2. Objective

Designing roadway alignment is quite complex. But, to design a sustainable roadway alignment and friendly environment, social safety and minimum economic the following objectives are pursued in this research paper:

- To evaluate the required sight distance model and compares the alternative alignments safety based on available and required sight distance each profile.
- To make balance the cut and fill and minimize the costs of the roadway alignment.
- Improvement of a terrain disturbance evaluation and compares each alignment and to minimize the total volume of hauling to prevent environmental impact on natural terrain shape.

3. Methodology

3.1 Sight distance required for vertical curves

Habitually, the equation for required sight distance, was used for calculating required sight distance on vertical curves as a shown (equation 1).

Recent studies on crest curve's sight distance [3] suggest a more precise method which has improved the braking istance accuracy by calculating the mean grade on each point of the crest curves. A detailed a mathematical model is proposed to determine the mean grade on each point of the curve and later apply the mean grade to the [4] stopping sight distance model. This research paper is used a concept applying calculating the required sight distance for the vertical curve to ensure that safety of roadway alignment. This model will use a software programme (Mx road design software), no need to for determining mean grade by mathematical calculation.

Equation 1

$RSDT = 0.278V.T + V^2/ 254((a/9.8) + G_m)$

Where:

RSDT: Required sight distance on tangent

T: brake reaction time, 2.5 s (AASHTO, 2001)

V:design speed, km/h

a: deceleration rate, m/s²

G_m*: percentage of grade divided by %*

3.2 Sight distance Evaluation Factor

The main critical parameter in roadway safety is sight distance deficiency. A safe road alignment should provide enough sight distance through the roadway length corresponding to the design speed on roadway available and geometry [5]. Each point and section of the roadway alignment, the achieved sight distance (ASD) should be greater than or equal to the required sight distance (RSD) (Equation 2 and equation 3). Roadway alignment safety is affected by the number of points with sight distance deficiency. So, to design the sight distance achieved and sight distance required in each sections of the road alignments

Equation 2

d_{def} *=sight distance deficiency; SSD-ASD*

Equation 3

d_{ex} *=Sight distance excess =ASD-SSD*

Figure 1 through Figure 6 show the achieved sight distance (ASD) and sight distance required (SDR).

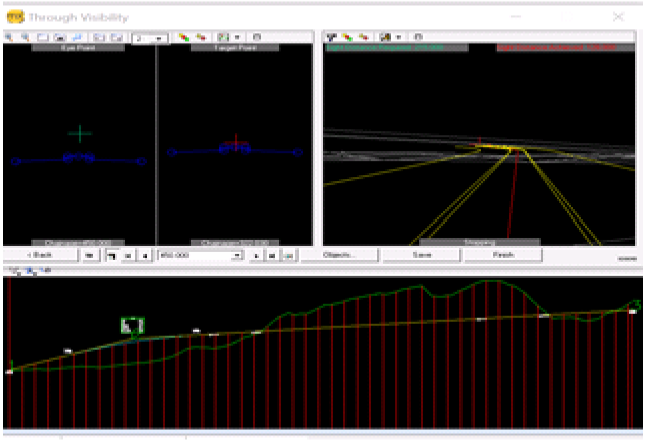

Fig- 1: Sight distance profile alternative 1

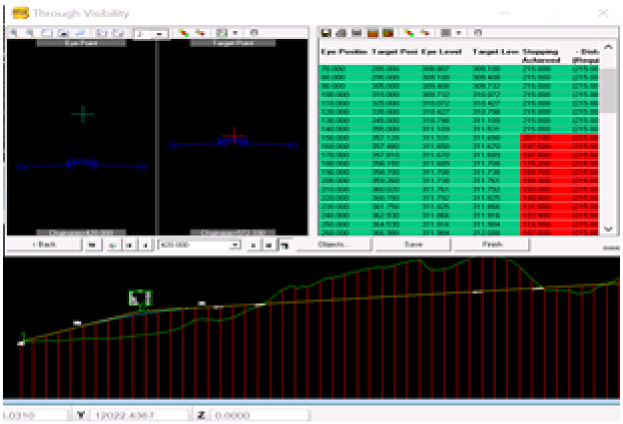

Fig- 2: Sight distance profile alternative 2

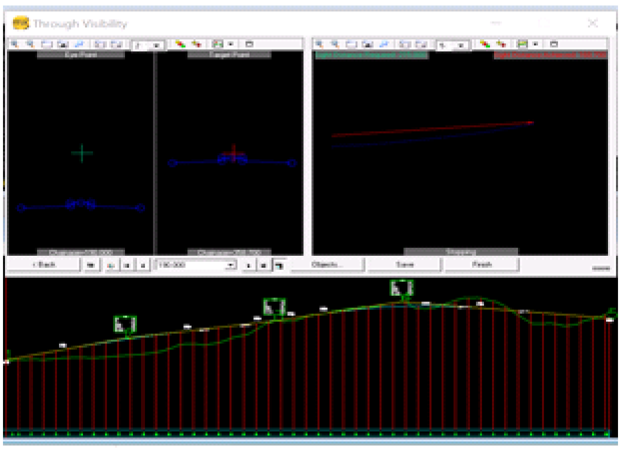

Fig- 3: Sight distance profile alternative 3

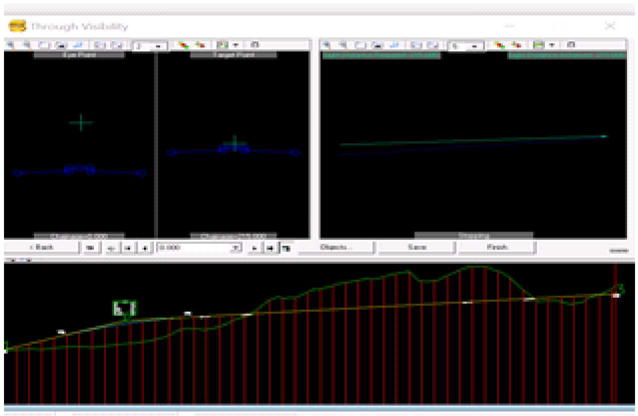

Fig- 4: Sight distance profile alternative 4

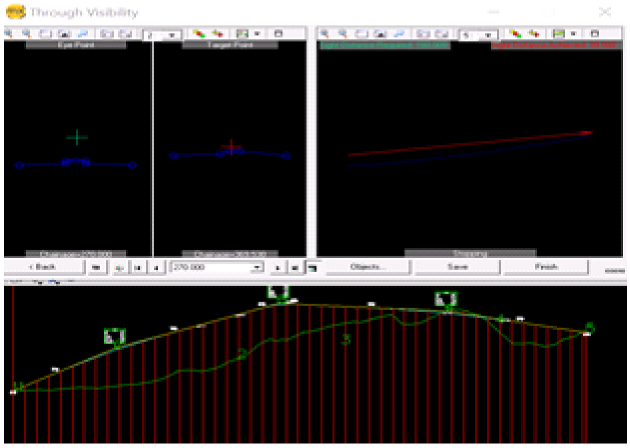

Fig- 5: Sight distance profile alternative 5

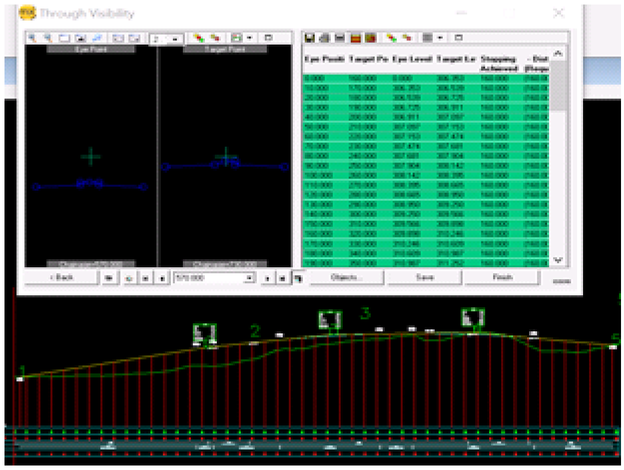

Fig- 6: Sight distance profile alternative 6

3.4 Earth work Evaluation Model

Minimizing Earthwork volume is one of the major objectives of roadway alignment. Minimization is the mass haul cost i.e. cut and fill balance volume along the alignment. Moreover, the quantity of soil hauling cost varies by different factors such as moving distance, soil density, strength, and shrinkage factor [8]. There are different methods for calculation of Earthwork volume (e.g. Prismoidal and average) For Earthwork calculation are implemented roadway software such as Mx road software [9]. It is a comprehensive optimization algorithm covering many of the roadway costs HAO model implemented the average end area method as part of its earthwork evaluation function The model is set up to minimize the earthwork only by balancing the cut and fill volumes and therefore the actual quantities of cuts and fills volumes are not taken into consideration. As a result, in the case that a significant amount of fill volume is balanced by an equal amount of cut volume; the results are considered satisfactory [10]. It is self-evident that although the proposed alignment is acceptable in terms of earthwork cost, significant environmental impacts on the natural shape of the terrain are being ignored. Figure 6 through Figure 10 is the alternative of Earthwork, after each alteration the optimum Earthwork selected according to the cost of hauling and terrain disturbance.

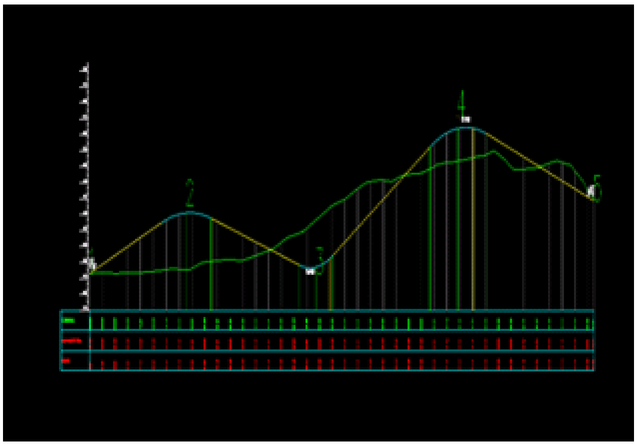

Fig- 7: Mass haul profile 1

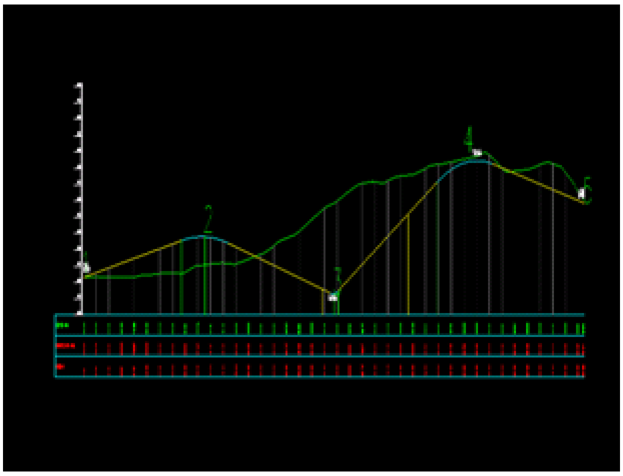

Fig- 8: Mass haul profile 2

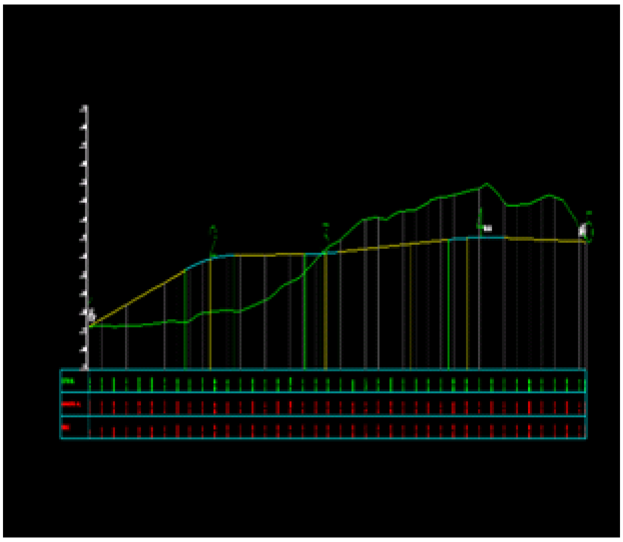

Fig- 11: Mass haul profile 3

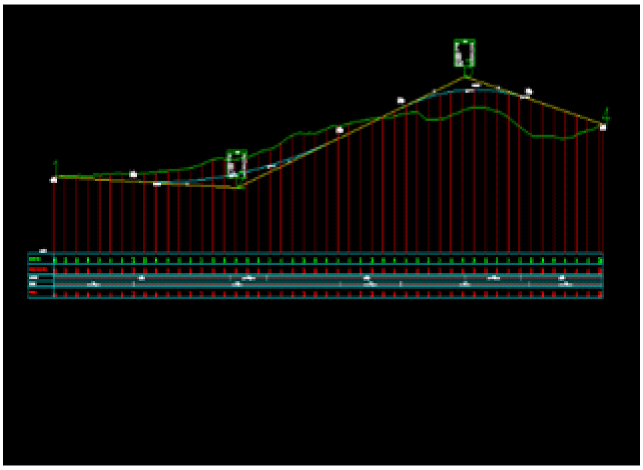

Fig- 12: Mass haul profile 4

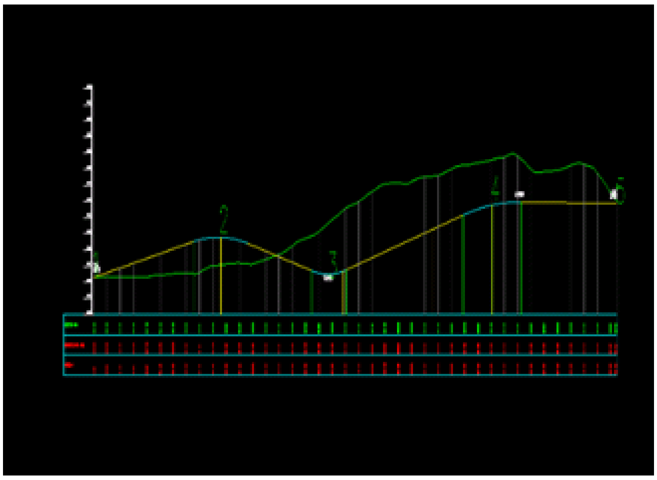

Fig- 12: Mass haul profile 5

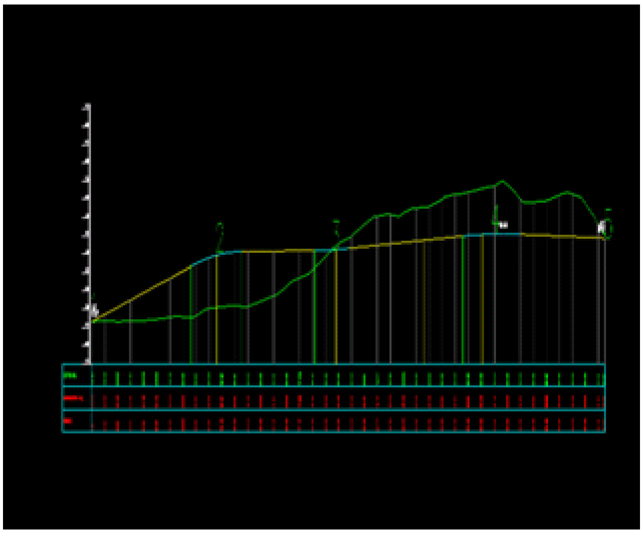

Fig- 12: Mass haul profile 6

Alternatives	Cut	Fill	Total
1	7750	-1324	6426
2	6845	-1324	5521
3	1549	-5659	-4110
4	10094	-1638	8456
5	3400	-225	3175
6	1485	-1903	-418

Table 1: Summary of cut and fill Earthwork

5. Results and discussions

Evaluation functions were explained in methodology. The sight distance model evaluates the social aspects of the alternative based on their safety impact, environmental aspects of the alternatives and Earthwork model evaluates the economic aspects of the alternative by comparing by their Earthwork volume. In order to find the most sustainable alternative among all possible solutions, the results of the developed models should be presented in similar metrics. At this point the results are expressed from Sight Distance model are expressed meter, and Earthwork results are expressed in cubic meter of soil. One way to develop comparable units for these three aspects (Environmental, Social and Economic) is to define them based on dollar costs.

Therefore, each of the alternative alignments will be compared for their sustainability indices in similar comparison scale of 0 to 1. So, when social factor index close to one shows the worst alternative and close to 0 shows the best alternative alignment according social factor. Equation 6 shows the formula for cumulative normal distribution function with mean value of μ and standard deviation of σ. Statistical software packages such as SPSS and Excel can be used to calculated normal values.

Equation 6

$$f(x,\mu,\delta) = \int_{\infty}^{x} \frac{1}{\delta\sqrt{2\pi}}\, e^{-\left(\frac{(x-\mu)2}{2\sigma 2}\right)}$$

Table 2 and Table 3 shows the normalized values (Indices) for each of the Economic and social impact. The basic assumption used for estimating the associated cost in each Table. It should be noted that the normalized values are only depend on the ratio of the impact caused by each alternative. Table 2 shows the social factors and each alternative based on their sight distance evaluation. The second and third columns show the calculated sight distance required and achieved. the fourth column shows the estimated Danger Factor and the last column shows the normalized value associated with the Social Impacts for each alternative based on the associated dangerousness and discomfort factors.

Table 2: Social Factor for 6 alternative alignment

Alternative alignments	**Sight distance required(m)**	**Sight distance achieved (m)**	**Danger factor**	**Social impact index (normalized value)**
1	215	215	0	0.32
2	168.7	215	7.84	0.99
3	128	215	5.95	0.98
4	50	160	3.19	0.78
5	99.5	160	4.65	0.82
6	160	160	0	0.21

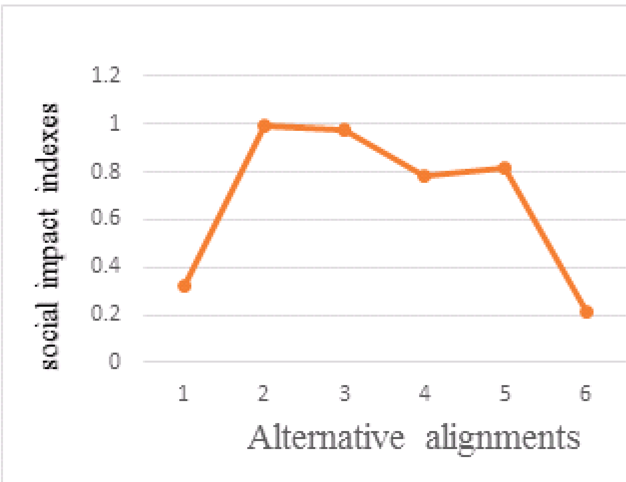

Table 13: Social Impact Index for 6 alternative alignment

Figure 13 illustrates the social impact index for each alternative alignment. Alternative 6 and 1 is the safest alignment with the social impact index o.21, 0.32, and alternative 2 is the least favourable with the social impact of 0.99. Table lists the Economic factors for each alternative based on their earthwork evaluation. The second and third column the estimated amount of cutting and filling based on the (prismoidal) method of earthwork calculation. The fourth column is the total mass haul, which is the sum of cumulative cut and fill volumes. The fifth column shows the associated cost of earthwork. The associated cost is calculated based on the following assumed unit costs: cutting ($20/m3), filling ($25/m3), and hauling ($45/m3). Finally, the last column lists the normalized value for Economic Impact for each alternative.

Table 3: Economic Factor for 6 alternatives

Alternative alignments	Cut (m3)	Fill (m3)	Total Earth work	Associated Earthwork cost	Economic impact index (Normalised value)
1	7750	-1324	6426	564310	0.61
2	6845	-1324	5521	541836	0.58
3	1549	-5659	-4110	403830	0.41
4	10094	-1638	8426	870355	0.97
5	3400	-225	3175	24690	0.21
6	1485	-1903	-418	80826	0.05

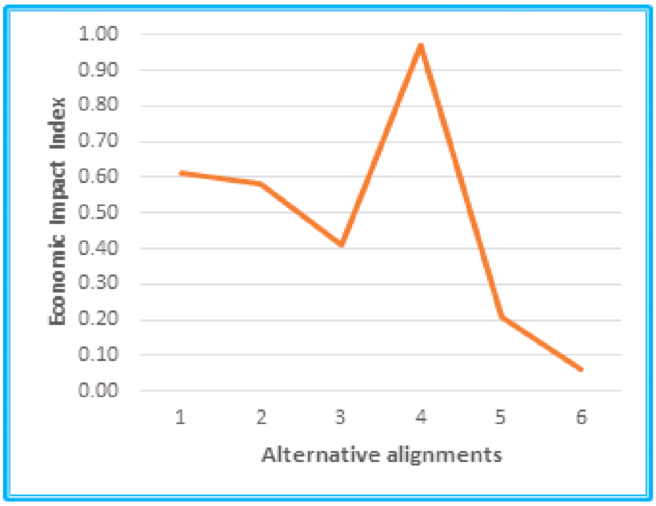

Table 14: Social Economic Impact Index for 6 alternative alignment

Fig- 14: illustrates Economic Impact Index for each alternative alignment. Here, alternative 6 is the most economic alignment with the Economic Impact Index of 0.050, and alternative 5 is the most expensive one with the Economic Impact Index of 0.980. The most sustainable alternative is the one with the minimum environmental, social, and economic impacts. Figure 15 illustrates all three impact indices for each alternative. It can be observed that, alternative 1 is a good environmental and social impact but relatively high economic impact. On the ther hand, Alternative 6 has good in economic aspect and environmental and social impact

Table 4: Sustainability impact index for 6 alternatives

Alternative alignments	Social impact index	Economic impact index	Sum of Sustainability index	Sustainability impact index
1	0.32	0.42	0.74	0.312
2	0.99	0.73	1.72	0.948
3	0.98	0.34	1.32	0.688
4	0.78	0.54	1.32	0.68
5	0.82	0.98	1.8	1
6	0.21	0.05	0.21	0

The normalized value of the sum of all three indices is defined as the sustainability Impact Index and is used to fine the most sustainable alternative. Table 4 has summarized the parameters: Economic, Environmental and social impact indices, sum of these values and the sustainable Impact Index for each alternative. Figure 16 illustrates the sustainability Impact Index for each alternative.

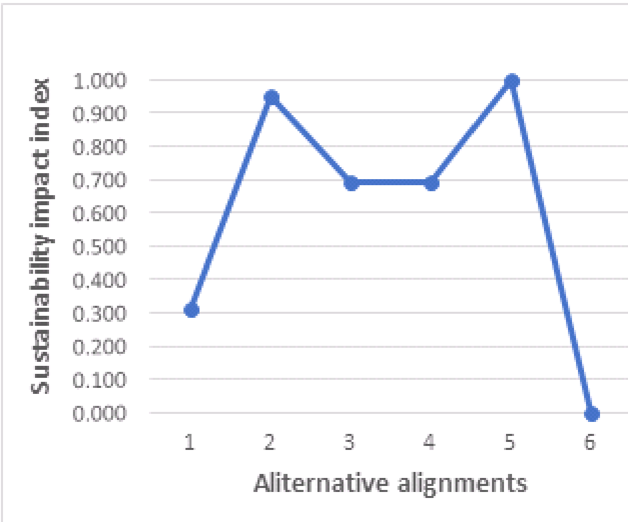

Table 15: Sustainability Index for 6 alternatives

Same as before a sustainability Impact Index close to one shows the most non-sustainability alignment and sustainability Impact Index close to zero shows the most sustainable alignment .As shown in figure , alternative 6 is the most sustainable alignment with the sustainability impact index of 0 and alternative 5 is the most none-sustainable alignment with sustainability impact index of 1.

6. Conclusions

The current study has developed a mathematical basis for decision support system for evaluation, comparison, and rating of roadway project on sustainability factors. Sustainability has been defined based on its application withing the roadway project and models have been developed to evaluate alternative alignments based on their environmental, social and economic impacts considered.

The formulation for all models is implemented in Mx road software to automatically evaluate any given alignment. Evaluation and comparison of six arbitrary alignments is conducted here to demonstrate the capability of the developed models.

The developed model provides the tools for designers and planners to quantitatively compare and rate various alternatives, and select the optimal alignment. This model is advantageous over existing rating systems that predominantly use qualitative evaluation metrics. Various organizations and companies can use this decision support system to determine sustainable solution for roadway alignment selection.

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