EAST WEST RAIL

BUSINESS REPORT

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EXECUTIVE SUMMARY

East West Rail is nationally important rail project with a target to provide necessary railway link between communities living between Oxford and Cambridge. The project is divided in three stages namely stage 1 for implementing railway line between Oxford to Bletchley/Milton Keynes, stage 2 for railway line Bletchley to Bedford and stage 3 for rail link from Bedford to Cambridge. The stage 3 of the project has raised many concerns for the company and the members of the public affected by the project. The project also has caught national attention due to positives and negative effects on communities affected by the East West Rail link between Bedford and Cambridge. Hence, a careful consideration of all the possible advantages and disadvantages of all the possible routes between Bedford and Cambridge is required.

Besides a need to involve members of the public, businesses, and local authorities for consultation about the best possible route, a GIS based study with an application of structured methodology which will not only assist in determining the best route option given the availability of information, but also offer an opportunity to weigh in positives and negatives of all the route options during the decision-making process. Specifically, in the case of East West Rail, the multicriteria analysis-based decision-making technique is appropriately suitable as there are more than one possible route with similar attributes posing a decision-making challenge.

As part of this study, an applied multicriteria analysis technique has been used along with spatial analysis performed using ArcGIS software tool to achieve the following:

- Selection of appropriate multicriteria analysis technique.
- Problem statement identification for goal definition.
- Identification of decision-making bodies involved.
- Finalisation of decision alternatives available.
- Definition of criteria and sub-criteria deemed important for decision making.
- Quantification, calculation, and valuation of various criteria/sub-criteria.
- Determination of decision framework.
- Application of specific multicriteria analysis process.
  - Standardisation, Weight determination, Scoring of criteria/sub-criteria & Ranking of alternatives.
- Determining the most suitable alternative.
- Concluding with comparison between highly ranked alternatives to analyse positives and negatives amongst them.

INTRODUCTION

Purpose

East West Railway Company Ltd (EWR Co) under establishment of Department for Transport (DfT) has initiated an effort to provide direct rail link between Oxford and Cambridge and in the process join other key towns within the region (Technical Report, 2019). The company intends to realise the government's plan for the Oxford-Cambridge Arc by delivering a new railway link between the two cities (Technical Report, 2019). The company also intends to achieve strategic objectives set forwards by DfT for the east west rail project as mentioned below.

The company plans to achieve following list of objectives (Technical Report, 2019):

- Provide east-west transport connectivity through rail links between the key towns in the Oxford-Cambridge Arc.
- Encourage economic growth, housing and jobs through reliable passenger transport services in the Oxford - Cambridge Arc.
- Project future demand and make provision wherever possible.
- Improve journey times and regional passenger connectivity by linking with other routes beyond the two cities.
- Make provision to support freight and facilitate future demand.
- Provide a sustainable and value for money solution.

Background

East West Rail project to connect Oxford and Cambridge via a railway link which was started in three different stages. In stage 1, the rail services will commence between Oxford and Bletchley/Milton Keynes. In stage 2, the rail service extends further to run up till Bedford. In stage 3 which is the focus of this report, the East West Rail services will extend from Bedford and connect with Cambridge via one of the several proposed routes (East West Rail, 2022).

Initial Analysis

Initial analysis of Beford to Cambridge section for East West Rail requires a detailed study of the area to consider how the construction for the new railway line between Bedford and Cambridge will be implemented. This includes identification and shortlisting of a preferred corridor and route options. Further, identification of towns where new stations will be built (East West Rail, 2022). Additionally, providing connectivity with existing main lines to provide better interconnectivity with other regions. And finally, consider environmental factors, cost, and economic growth to finalise the route option to connect Bedford and Cambridge.

1: Information Gathering

The primary source of information for this report has been the East West Rail website and documentations available on the website (East West Rail, 2022). Specifically, documents were referenced for analysis of proposed routes between Bedford and Cambridge. Documents such as technical report (Technical Report, 2019), available maps, and other documents were referenced for this report (Key Documents & Assets, 2022). Additional data from publicly available sources were also used for the report.

2: Literature Review and Data Analysis

During analysis, reasons for initiating the East West Rail project and establishing East West Railway Company Ltd (EWR Co) by Department for Transportation (DfT) was studied (Technical Report, 2019). Initiatives from EWR Co such as consultation about route options within preferred corridor, public consultation, engagement with local authorities and other stakeholders were understood (Technical Report, 2019). Further, necessity of a new railway line to create global knowledge intensive cluster between Oxford and Cambridge as per the consideration of National Infrastructure commission (NIC) was also reviewed (Technical Report, 2019). Additionally, not only strategic objectives of EWR Consortium were reviewed, but also strategic objectives set by DfT for EWR Co were also analysed (Technical Report, 2019).

Further, a high-level review of all five route corridors was performed to understand the reason why corridor via Sandy (Corridor C) was finalised. Additionally, important factors such as transport user benefits, economic growth, capital and operating costs, environmental impacts, rail passenger connectivity with the main lines, and journey times between Bedford and Cambridge were analysed from the perspective of EWR Co and the DfT to finalise the baseline criteria in this report (Technical Report, 2019). Finally, all the route options along with their maps (including the ones ruled out) were also reviewed to gather and derive important quantitative data to support the baseline criteria defined. Further, all the approaches such as Northern Approach, Tunnelled Approach, and Southern Approach were also considered to understand the reasons behind EWR Co's preferred approach to Cambridge (Technical Report, 2019). Finally, housing potential and environmental issues identified for each route were understood from the technical report (Technical Report, 2019).

Additionally, digital elevation model of south-east England was downloaded from the NASA Earth Data website (ASTER Global Digital Elevation Model, 2013) was downloaded to analyse the topography of the area between Bedford and Cambridge. Further, carbon emission data was also referenced to calculate train emissions (Rail Emissions, 2022). Also, GIS tools such as ArcGIS Pro and feature layers for Network Rail (Network Rail, 2022) and SSSIs (Sites of Special Scientific Interest, 2023) were used for analysis.

3: Methodology

Several multicriteria analysis techniques were considered for evaluation of best possible route between Bedford and Cambridge including Boolean Overlay, Weighted Linear Combination, Analytical Hierarchical Process (AHP) and other available techniques. However, AHP was understood to be the best suitable for this project as it offers pairwise comparison between criteria for determination of appropriate weights to be applied amongst different criteria for each alternative (Dean, 2022).

Following the multicriteria analysis (MCA) process, important aspects such as goal, decision makers, decision alternatives, criteria, sub-criteria, and decision framework considering AHP process were defined as detailed below.

Goal: To find optimal route between Bedford and Cambridge for east west rail.

Decision Makers: East West Rail Co. with public consultation.

Decision Alternatives: Routes alternatives between Bedford and Cambridge (Technical Report, 2019).

Route A: Bedford South – Sandy (re-located south) – Cambridge (via Bassingbourn)
Route B: Bedford South – Sandy (re-located north) / Tempsford area / south of St Neots – Cambourne – Cambridge.
Route C: Bedford South – Tempsford area – Sandy – Cambridge (via Bassingbourn)
Route D: Bedford Midland – Tempsford area – Sandy – Cambridge (via Bassingbourn)
Route E: Bedford Midland – Tempsford area / south of St Neots – Cambourne – Cambridge
Alternate route: A new route detailed in Appendix 1 considered for comparison.

Criteria: The strategic objectives set forward by DfT (Technical Report, 2019) were used to derive below mentioned criteria.

- Journey times between Oxford and Cambridge to be 60 minutes. Journey time from Bedford to Cambridge should be as fast as possible.
- Better connectivity to be provided between existing rail links such as Midland Main Line, East Coast Main Line, and West Anglia Main Line.
- The route should be sustainable and offer value for money with low development cost and better transport user benefits.
- Low environmental impact with low emissions, limited impact on topography, impact to nature.
- Economic growth to be considered as more the intermediate stops on route from Bedford to Cambridge, more the opportunities for housing, businesses, and jobs around the train stations. Additionally, housing potential to be considered along the major area of intersections between Bedford and Cambridge.

Criteria/Sub-Criteria Quantification: All the qualitative and quantitative criteria/sub-criteria to be quantified for multi criteria analysis as detailed below (Refer Appendix 1 for alternate route).

Journey Times: This criterion is represented in minutes as shown in table 1.

	Route A	Route B	Route C	Route D	Route E	Alternate
Journey Times	23 mins	27 mins	27 mins	25 mins	24 mins	25 mins

Table 1. Journey Times referenced from technical report (Technical Report, 2019).

Environmental Impact: This criterion is sub-categorised as impact to nature, rail emissions, and topographic complexity.

Impact to Nature: This sub-criterion is calculated as a count for the number of environmental sites affected by the route. Each route to be assigned a value of 1 or 0 based on the below identified set of environmental sites considered to be affected between Bedford and Cambridge as shown in table 2 (Technical Report, 2019). Refer Appendix 1 for alternate route.

- Environmental sites (Technical Report, 2019): Watercourses (W), Flood zones (F), Sandy Warren SSSI (S), Biggleswade Common and the RSPB Nature Reserve (B), Wimpole Hall Avenue (WH), Listed buildings (LB), scheduled monuments (SM), Ickwell Bury Registered Park and Garden (I), nature reserves (NR), Eversden and Wimpole SAC (EW), SSSIs and ancient woodland (SA), Moggerhanger Park Registered Park and Garden (M).

Env. Impact / Alternative	W	F	S	B	WH	LB	SM	I	NR	EW	SA	M	Total Score
Route A	1	1	1	1	1	1	1	1	1	1	1	0	11
Route B	1	1	0	0	0	1	1	0	1	1	1	1	8
Route C	1	1	1	1	1	1	1	0	1	1	1	1	11
Route D	1	1	1	1	1	1	1	0	1	1	1	0	10
Route E	1	1	0	0	0	1	1	0	1	1	1	0	7
Alternate	1	1	0	0	0	1	1	0	1	0	1	0	6

Table 2. Environmental Impact score across categories for each alternative.

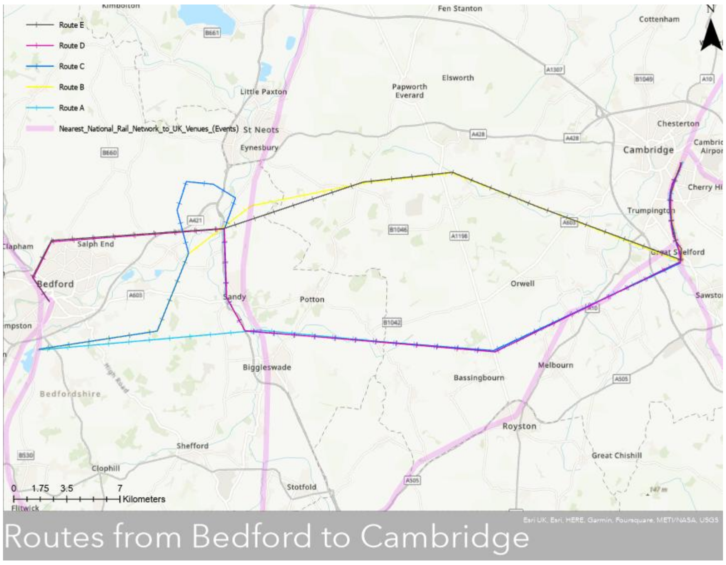

Fig. 1. Distance calculated for each route.

Emissions / Alternative	Distance in km	Total Emissions in g/CO_2e/Passanger/Km/yr
Route A	50.75	2,410.63
Route B	55.38	2,630.55
Route C	68.05	3,232.38
Route D	60.01	2,850.48
Route E	54.47	2,587.33
Alternate	56.65	2,690.88

Table 3. Emissions per alternative in Co2 / Passenger / Km / year

Rail Emissions: This sub-criterion required calculation of total emissions as shown in table 3 based on the route distance measured using ArcGIS by creating line features (shape files) for each route as shown in fig. 1, and by collecting yearly carbon emissions by trains from the Office of Rail and Road (Rail Emissions, 2022).

The latest normalised CO_2 emissions are 47.5g CO_2e per passenger per kilometre in 2022. Details for alternate route are in Appendix 1.

Topographical Complexity: This sub-criterion accounts for unavoidable topographical complexities expected for the railway construction. Using digital elevation model as shown in fig. 2, the difference in elevation was considered to count the number of times topography changes from lower elevation to considerably higher elevation and vice-versa for each route as depicted in table 4. Details for alternate route are in Appendix 1.

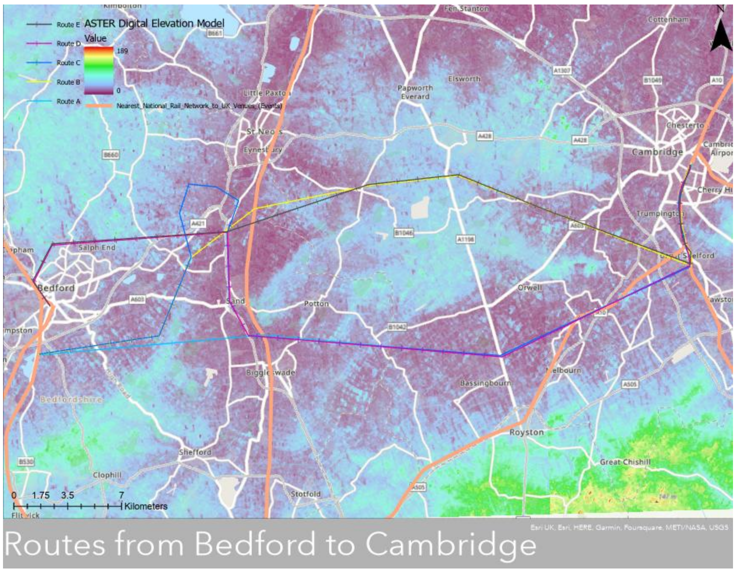

Fig. 2. Topographic complexity across routes.

Topographic Complexity / Alternative	Topography elevation changes (low to high)	Topography elevation changes (high to low)	Total
Route A	1	1	2
Route B	1	1	2
Route C	1	1	2
Route D	2	2	4
Route E	3	3	6
Alternate	3	3	6

Table 4. Topographic Complexity per route identified as number of times elevation. changes.

Economic Growth: This criterion defines sub-criteria as number of stops and housing potential.

- Number of stops: More stops are considered better for economic growth. Number of stops per route are as shown in Table 5 and details for alternate route are covered in Appendix 1.

Stops / Alternative	Possible Stops	Count
Route A	Bedford, Sandy, Arrington/Bassingbourn, Great Shelford, Cambridge	5
Route B	Bedford, Sandy/St. Neots, Cambourne, Little Eversden, Great Shelford, Cambridge	6
Route C	Bedford, Tempsford, Sandy, Arrington/Bassingbourn, Great Shelford, Cambridge	6
Route D	Bedford, Tempsford, Sandy, Arrington/Bassingbourn, Great Shelford, Cambridge	6
Route E	Bedford, Tempsford/South St. Neots, Cambourne, Little Eversden, Great Shelford, Cambridge	6
Alternate	Bedford, Tempsford/South St. Neots, Cambourne, Northstowe, Cambridge North	6

Table 5. Possible number of stops across each route for economic development.

Housing Potential: This sub-criterion is a sum of the values assigned between Less Significant (1), Constrained (2), and Significant (3) based on the housing potential assessed in different sections along the route (Technical Report, 2019) as shown in Table 6 below. Refer Appendix 1 for details on alternate route.

Housing Potential / Alternative	Bedford	East Coast Main Line	Northstowe/ South Cambridgeshire	Total
Route A	Significant (3)	Constrained (2)	Significant (3)	8
Route B	Significant (3)	Significant (3)	Constrained (2)	8
Route C	Significant (3)	Constrained (2)	Significant (3)	8
Route D	Less Significant (1)	Constrained (2)	Significant (3)	6
Route E	Less Significant (1)	Significant (3)	Constrained (2)	6
Alternate	Less Significant (1)	Significant (3)	Significant (3)	7

Table 6. Housing potential in different sections along the route (Technical Report, 2019)

Decision Framework: The decision framework shown in fig. 3 outlines the relationship between the goal, criteria, sub-criteria, and the alternatives. Note that the criterion requiring rail link connectivity between the main lines is no longer considered for decision making as all the alternatives satisfy the criteria.

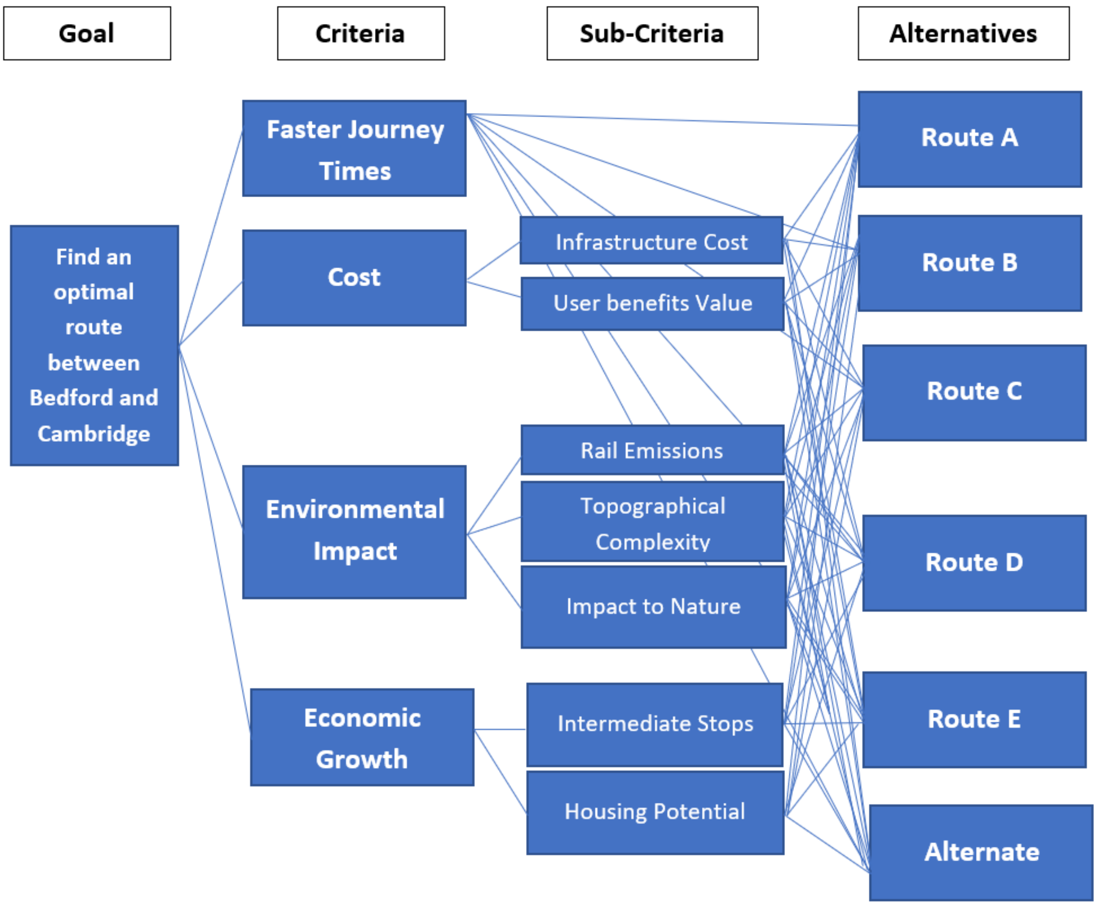

Fig. 3. Decision Framework using MCA.

AHP Process Application: In the AHP process application, all the criteria are quantified (as shown in table 7), standardised, pairwise comparison is performed, scored and ranked for all the alternatives.

Quantified Criteria for Decision Framework:

Alternatives /Criteria	Travel Time in Mins.	Cost		Environmental Impact			Economic Growth	
		Infra. Cost in billions	User Benefits in billions	Nature Impact Score	Emissions (g/CO2e/ passenger / km / yr)	Topographic Complexity	# of stops	Hsg. / Bus.
Route A	23	1.7	0.7	11	2,410.63	2	5	8
Route B	27	2.2	0.6	8	2,630.55	2	6	8
Route C	27	2.1	0.5	11	3,232.38	2	6	8
Route D	25	2.2	0.7	10	2,850.48	4	6	6
Route E	24	2.8	0.7	7	2,587.33	6	6	6
Alternate	25	2.8	0.7	6	2,690.88	6	6	7

Table 7. Quantified criteria/sub-criteria per route

Standardisation: In this stage standardisation of all the values assigned to all the criteria/sub-criteria is performed using below mentioned equation (Carver, 1991).

Standardisation Score = raw score – min raw score / max raw score – min raw score

Alternatives / Criteria	Travel Time Std. Score (Rev)	Cost		Environmental Impact			Economic Growth	
		Infra. Cost Std. Score (Rev.)	User Benefits Std. Score	Nature Impact Std. Score (Rev.)	Emissions Std. Score (Reversed)	Topographic Complexity Std. Score (Reversed)	# of stops Std. Score	Hsg. Std. Score
Route A	1-0=1	1-0=1	1	1-1=0	1-0=1	1-0=1	0	1
Route B	1-1=0	1-0.45= 0.55	0.5	1-0.4= 0.6	1-0.27= 0.73	1-0=1	1	1
Route C	1-1=0	1-0.36 =0.64	0	1-1=0	1-1=0	1-0=1	1	1
Route D	1-0.5= 0.5	1-0.45 =0.55	1	1-0.8= 0.2	1-0.54= 0.46	1-0.5=0.5	1	0
Route E	1-0.25 =0.75	1-1=0	1	1-0.2=0.8	1-0.21= 0.79	1-1=0	1	0
Alternate	1-0.5=0.5	1-1=0	1	1-0=1	1-0.34=0.66	1-1=0	1	0.5

Table 8. Standardised Score for each criterion/sub-criterion per route.

The table 8 shows the calculated values for all the criteria/sub-criteria for each route using the standardisation equation. It is important to note that standardisation output for sub-criteria such as Journey/Travel Time, Infrastructure Cost, Nature Impact, Emissions, and Topographic Complexity are reversed as lower value for these sub-criteria should be considered better. For instance, lower carbon emission should be valued more and hence, it must have higher standardised value.

Pairwise Comparison Matrix: Pairwise comparison matrix of AHP provides a mechanism to calculate weights for each criteria/sub-criteria based on their importance over other criteria as shown in table 9.

	Travel Time Std. Score	Environmental Impact			Cost		Economic Growth	
		Nature Impact Std. Score	Emissions Std. Score	Topography changes. Std. Score	User Benefits Std. Score.	Infra. Cost Std. Score	Hsg. Std. Score	# of stops Std. Score
Travel Time Std. Score	1	2	3	4	5	6	7	8
Nature Impact Std. Score	½	1	2	3	4	5	6	7
Emissions Std. Score	1/3	½	1	2	3	4	5	6
Topography changes. Std. Score	¼	1/3	½	1	2	3	4	5
User Benefits Std. Score	1/5	¼	1/3	½	1	2	3	4
Infra. Cost Std. Score	1/6	1/5	¼	1/3	½	1	2	3
Hsg. Std. Score	1/7	1/6	1/5	¼	1/3	½	1	2
# of stops Std. Score	1/8	1/7	1/6	1/5	¼	1/3	½	1
Weights= 1/(Σcolumns)	**0.37**	**0.22**	**0.13**	**0.09**	**0.06**	**0.05**	**0.04**	**0.03**

Table 9. Pairwise comparison matrix for weight determination per criteria.

Scoring: In this stage, each alternative is valued using below equation with calculation outcome as shown in table 10.

$$V(a) = \sum_{j=0}^{n} \mathbf{w\,j} \times \mathbf{x\,j}\,(\mathbf{a})$$

wj is weights for j-th criteria calculated as per Table 9 and xj is the standardised score for j-th criteria for an alternative (a) (Dean, 2022).

w j * x j (a) Weight x Std. Score per alternative route	Travel Time Std. Score	Environmental Impact			Cost		Economic Growth		V(a)
		Nature Impact Std. Score	Emissions Std. Score	Topographic Complexity. Std. Score	User Benefits Std. Score.	Infra. Cost Std. Score	Hsg. Std. Score	# of stops Std. Score	
Route A	0.37	0	0.13	0.09	0.06	0.05	0.04	0	**0.74**
Route B	0	0.132	0.09	0.09	0.03	0.0275	0.04	0.03	**0.44**
Route C	0	0	0	0.09	0	0.032	0.04	0.03	**0.19**
Route D	0.185	0.044	0.06	0.045	0.06	0.0275	0	0.03	**0.45**
Route E	0.278	0.176	0.10	0	0.06	0	0	0.03	**0.65**
Alternate	0.185	0.22	0.08	0	0.06	0	0.04	0.015	**0.61**

Table 10. Valuation score using weights and standardised score.

Ranking: Finally, based on the valuation score of each alternative, rank is derived to determine which alternative compares better than other as shown in table 11 below. As per the table Route A is preferable for establishing rail link between Bedford and Cambridge considering the calculations performed for all the list of criteria/sub-criteria detailed earlier in the report.

Route Alternatives	V(a)	Rank
Route A	**0.74**	**1**
Route B	**0.44**	**4**
Route C	**0.19**	**6**
Route D	**0.45**	**5**
Route E	**0.65**	**2**
Alternate	**0.61**	**3**

Table 11. Final ranking based on the valuation of alternatives.

CONCLUSION

The ambitious project of EWR Co to connect Oxford and Cambridge to create a single knowledge intensive cluster was initiated to compete on a global stage, protects environment, and secures homes and provides jobs in the area (Technical Report, 2019). The project involves careful consideration of strategic objectives proposed by DfT for the EWR Co to improve transport connectivity, stimulate economic growth through housing and employment, faster journey times, sustainable as well as value for money transport to meet current and future demand for passengers as well as possible freight transport. Keeping the strategic objectives in mind, EWR Co has shortlisted five possible route options from several routes, however the project lacked the application of structured methodology to finalise the best suitable route option for the project.

A structured approach with multicriteria analysis (MCA) was found to be applicable for the EWR project by reviewing the strategic objectives, route options and other details made available by EWR Co on their website (East West Rail, 2022) and other documentations (Technical Report, 2019). Further, a goal, criteria, sub-criteria, and alternatives could also be defined along with the application of Analytical Hierarchical Process (AHP) for identifying suitable route to implement as described in Methods section earlier. Further, the defined set of criteria were also quantified individually and standardised on a single scale applicable for all the criteria. Subsequently, specific wrights applicable for each criterion were derived with pairwise comparison matrix and each alternative was scored with a unique value calculated based on weights and standardised score derived for all the criteria as detailed earlier in the Results & Discussion section. Finally, the ranking was performed to identify the best suitable route to be the 'Route A' between Bedford and Cambridge.

The reason why 'Route A' was found to be best suitable because the priority assigned to each criterion determined the applicable weightage applicable to the standardised value derived for that criterion. In other words, the journey time received higher weight and was considered most important criterion followed by the environmental impact, cost and economic growth. Specifically, the 'Route A' performed better on journey time, emissions, transport user benefits and infrastructure cost compared to other routes confirming the best rank for route A. However, 'Route E' which ranked second was also close in comparison for journey time to 'Route A', but it comparatively scored lower on emissions, topographic complexity, and infrastructure cost. Although, it is understood that the 'Route E' has been chosen as the preferred route (Preferred Route Option Report, 2020) by EWR Co for further detailed route alignment process. However, it is unclear what set of criteria, weight preferences, methods of scoring and ranking were applied if any to determine the Route E as a preferred choice for implementation. As per the EWR Co, the Route E was a chosen based on the outcome of public consultation (Preferred Route Option Report, 2020).

Finally, the alternate northern approach route considered for comparison was a close third in rank compared to 'Route A' and 'Route E'. As the route was just having a different approach to Cambridge, it was found to be very similar to 'Route E'. But despite it having better housing potential in Northstowe area, it scored slightly lower in journey time due to additional distance and lower score in emissions which resulted in ranking it as close third alternative among the routes.

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APPENDIX I

Alternate Route:

A new alternate route following northern approach to Cambridge was considered for comparison along with the other routes proposed by EWR Co as shown in fig. 4. The route was created as a line feature class (shape file) using ArcGIS based on the review of information available for northern approach into Cambridge (Technical Report, 2019). The route was found to be comparable to 'Route E' with only difference being that the new route traverses through north of Cambridge as opposed to South Cambridgeshire.

Being a new route journey time data was not directly available from EWR documents, so the journey time was calculated using the distance measured with measure tool of ArcGIS Pro and using the approximate speed calculated considering other route's distances and journey times. For 'Impact to nature' criteria, it was found that the northern approach route passes by fewer environmental sites compared to the other routes. The environmental sites along the new route were confirmed by accessing SSSI feature class available online (Sites of Special Scientific Interest, 2023). Further, the emissions were also calculated using the distance measured earlier and per passenger kilometre CO2 emissions for railways (Rail Emissions, 2022). Topographic Complexity was also evaluated to determine number of elevation changes encountered along the northern route as shown in fig. 5.

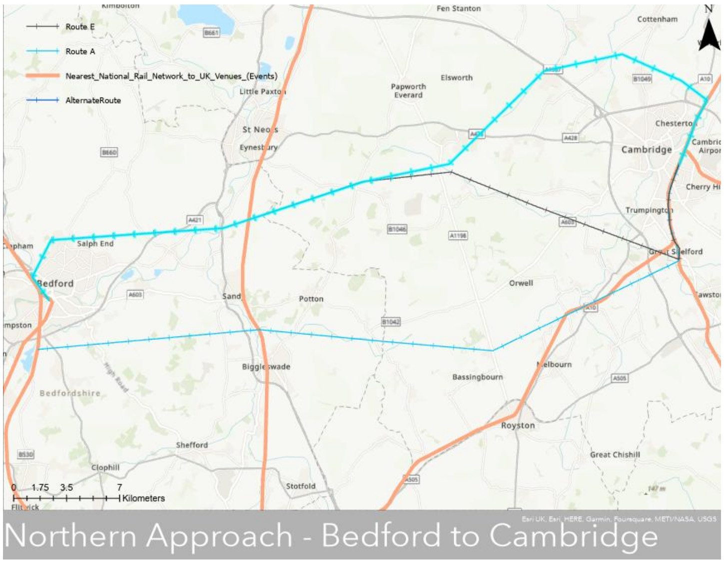

Fig. 4. Northern Approach for Bedford to Cambridge route

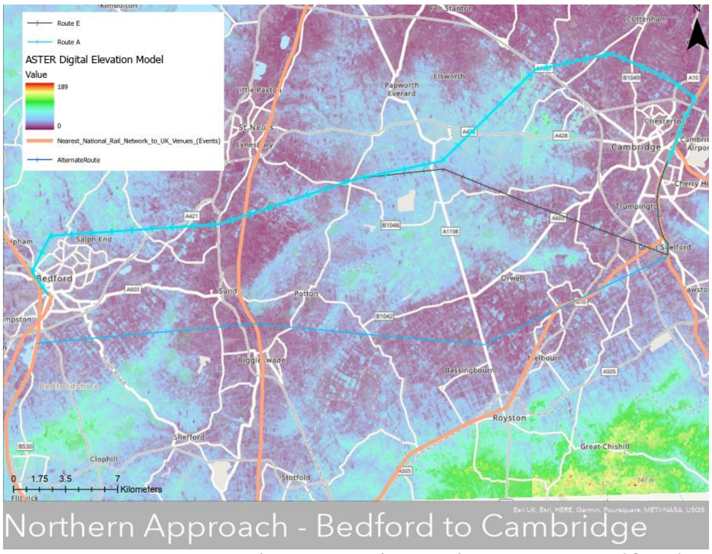

Fig. 5. Topographic Complexity between Bedford and Cambridge for Northern Approach for route.

Further, economic growth along the northern approach is expected to be in Northstowe where new station could have been located. Furthermore, Northstowe is already expected to have 10,000 new homes and population of 26,000 people (Northstowe, 2023), hence housing potential is considered significant in the area.

Once all the criteria for the alternate route were evaluated, the route was also considered for application of AHP processing as detailed earlier in Results & Discussion section.