

A Novel Approach for Identifying the Locations of Potential Transit Rail Stations Using a GIS Based Model



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Outline

- ❑ Motivation
- ❑ Background & Aim
- ❑ Methodology Framework
- ❑ Model Framework
- ❑ Case Study
- ❑ Sensitivity Analysis
- ❑ Conclusion



Motivation

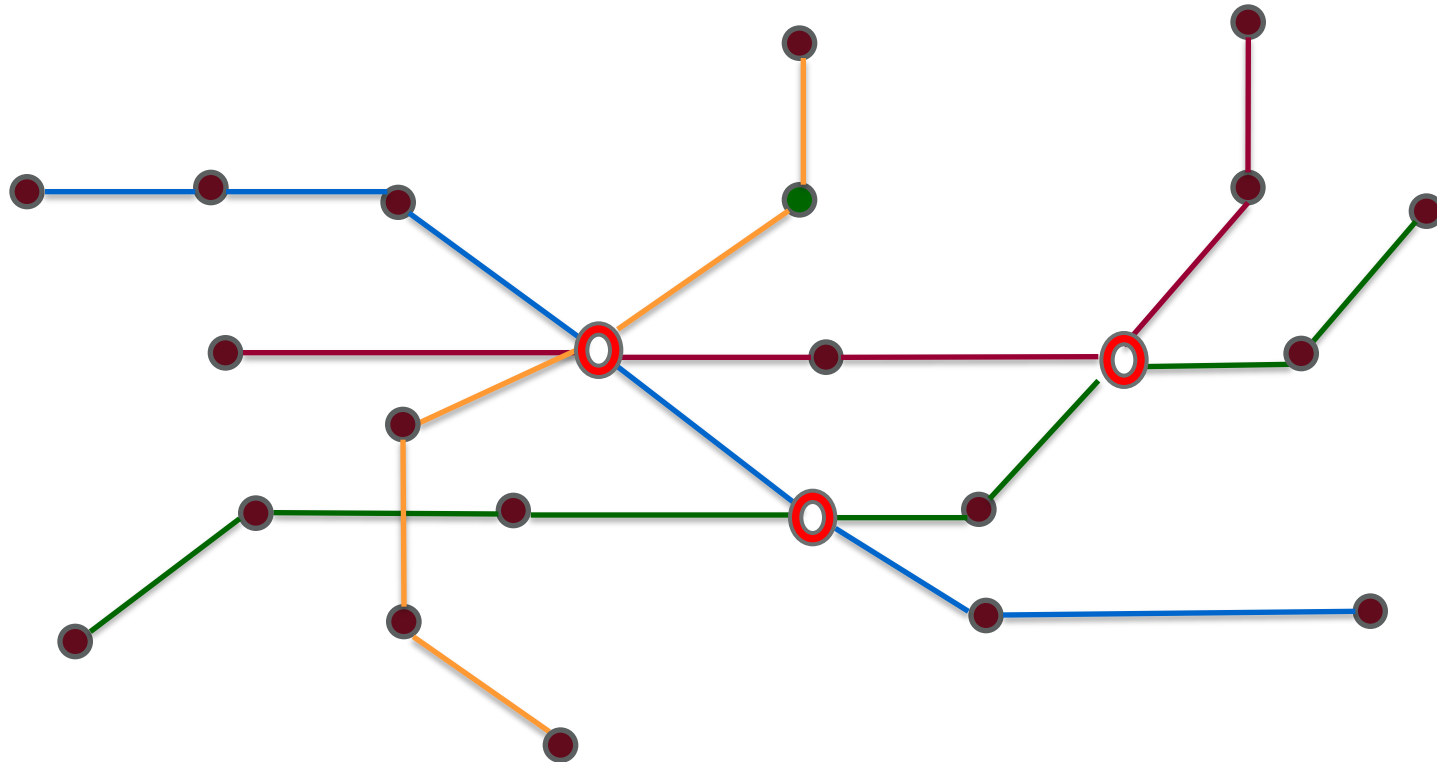
- Continuous growth of urban areas
 - increased need for mobility
 - traffic congestion on roads

- Transit rail network systems can :
 - relieve highway congestion,
 - decrease commute time,
 - reduce transport related air pollution,
 - provide quick and convenient services
 - improve economic activities



Transit Rail System Planning Aspects

- 1- Determination of station locations
- 2- Determination of line network linking the stations

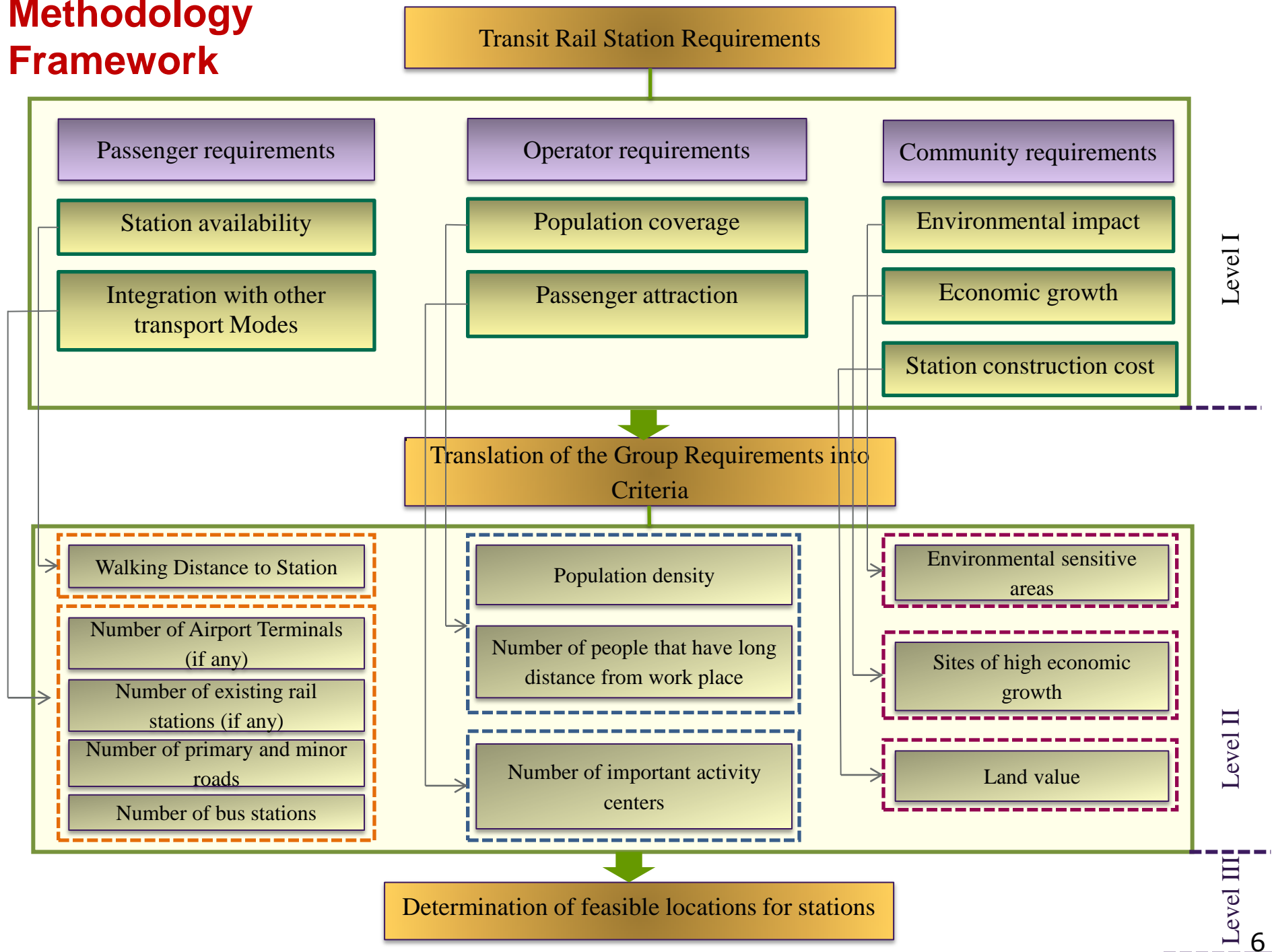


Research Background and Aim

- Limitations of the current models for station location determination
 - Mainly consider a single objective for rail station planning
 - Rail line alignment determined before station location determination
 - Consider a single rail line with predetermined terminal stations

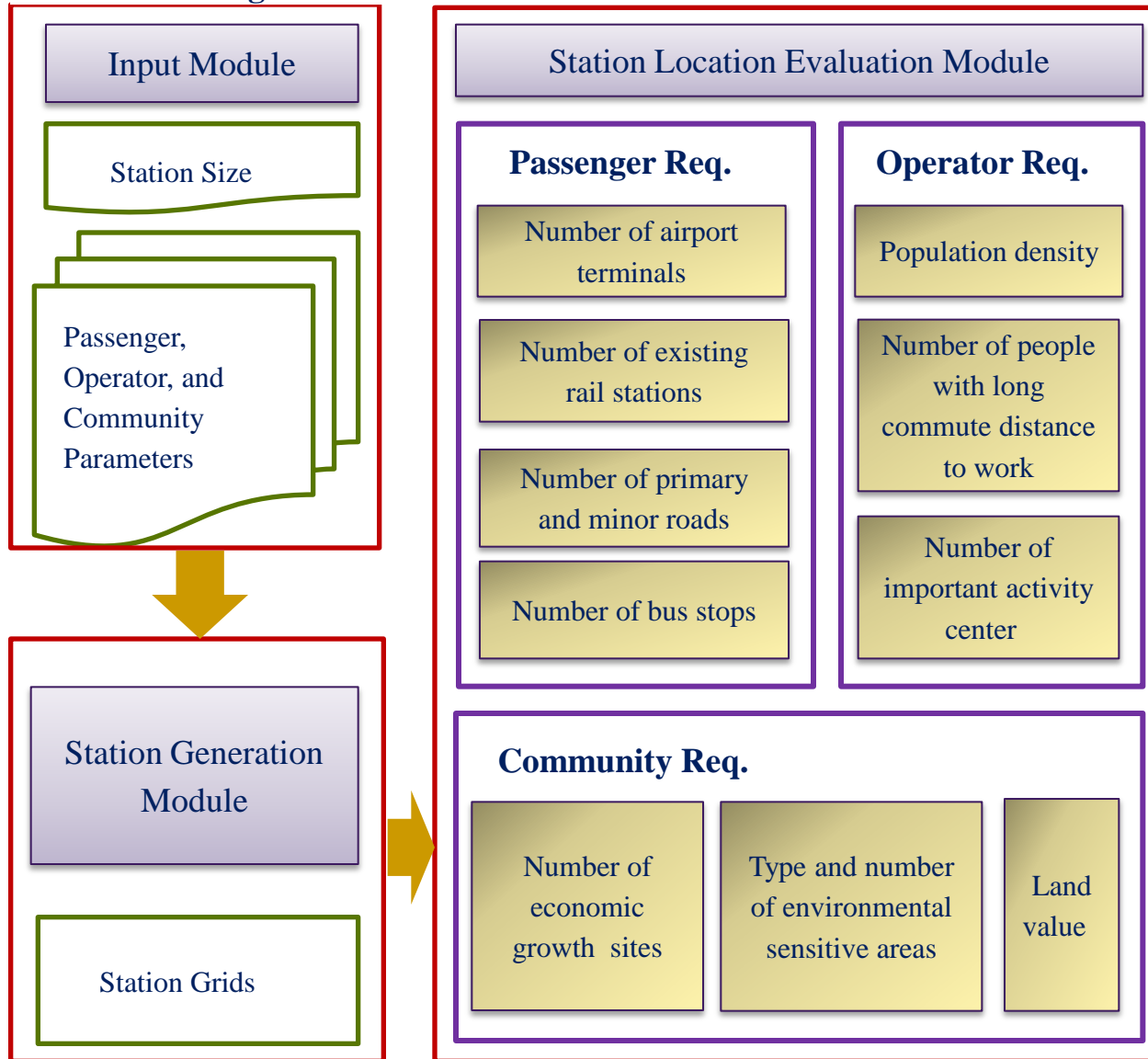
- Research contribution
 - Considers multiple objectives for rail station planning
 - Stations determined before line alignments
 - Considers multi rail lines with no need for predefined terminal stations

Methodology Framework

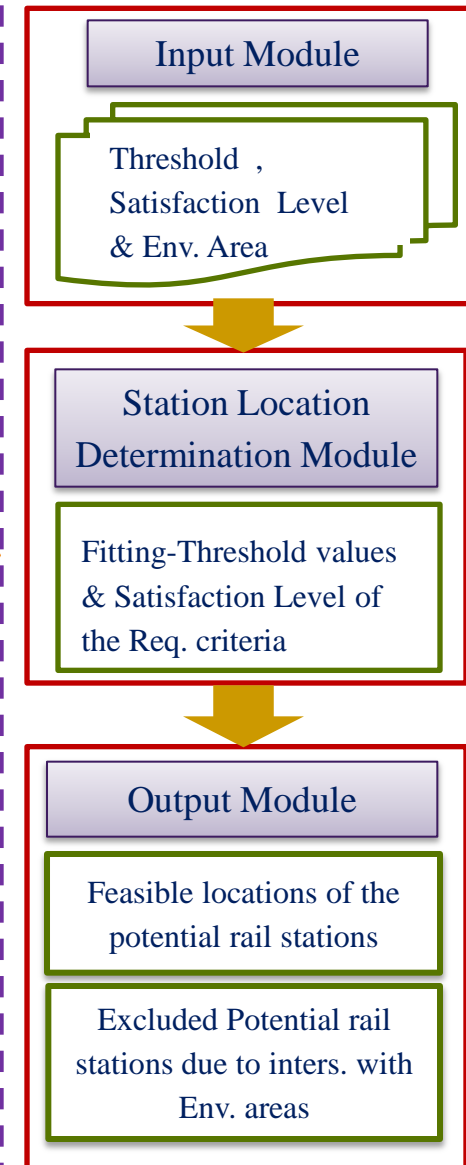


Level III – Determination of Feasible Station Locations

Evaluation-Stage



Decision-Stage



Evaluation-Stage (1/3)

1- Input Module: this is employed by transit rail planners (users) to input and adjust various planning parameters which include

a) Station Size

The screenshot shows a software dialog box titled "Station Location Evaluation SubModel". It contains the following elements:

- Input Station Width (Meters): A text input field.
- Input Station Length (Meters): A text input field.
- Input Served Area Boundary Layer (optional): A dropdown menu showing "Same as layer Boarder\LeicesterCityBoundary" with a folder icon to the right.
- Four input fields for a bounding box:
 - Left: 453157.000000
 - Top: 310751.000000
 - Right: 464641.000000
 - Bottom: 298430.000000
- A "Clear" button next to the bounding box inputs.
- Input a Directory (Feature Class) for Saving Station Grids In: A dropdown menu with a folder icon to the right.
- Buttons at the bottom: OK, Cancel, Environments..., and Show Help >>.

Evaluation-Stage (1/3)

b) Three stakeholders parameters:

- Passenger Parameters
- Operator Parameters
- Community Parameters

The screenshot shows a software window titled "Station Location Evaluation SubModel". It contains a list of 14 criteria, each with a green checkmark icon, a text input field, and a folder icon. The criteria are grouped into three categories: Passenger Requirement Criteria (Walking Distance to Stations, Airport Terminals Layer, Existing Rail Stations Layer (if any), Primary Roads Layer, Minor Roads Layer, Bus Stations Layer), Operator Requirement Criteria (Important Buildings Layer, Tourist Areas Layer, Population Density Layer, People Commute Distance between Home and Work Place Layer), and Community Requirement Criteria (Sites of Economic Growth Layer, Land Value Layer, Regeneration Areas). At the bottom, there are buttons for "OK", "Cancel", "Environments...", and "Show Help >>".

Station Location Evaluation SubModel

Passenger Requirement Criteria-Input Walking Distance to Stations Meters

- Passenger Requirement Criteria- Input Airport Terminals Layer
- Passenger Requirement Criteria-Input Existing Rail Stations Layer (if any)
- Passenger Requirement Criteria- Input Primary Roads Layer
- Passenger Requirement Criteria- Input Minor Roads Layer
- Passenger Requirement Criteria- Input Bus Stations Layer
- Operator Requirement Criteria- Input Important Buildings Layer
- Operator Requirement Criteria- Input Tourist Areas Layer
- Operator Requirement Criteria- Input Population Density Layer
- Operator Requirement Criteria- Input People Commute Distance between Home and Work Place Layer
- Community Requirement Criteria- Input Sites of Economic Growth Layer
- Community Requirement Criteria- Input Land Value Layer
- Community Requirement Criteria- Input Regeneration Areas
- Save Evaluated Requirement Criteria of the Potential Station Locations

OK Cancel Environments... Show Help >>

Evaluation-Stage (2 &3 /3)

2- Station Generation Module:

- Divides the study area into grids (G_i) based on the station size inputs
- Creates a layer (Ω_s) for stations.

3- Station Location Evaluation Module:

- Evaluates the locations of the station grids generated with respect to the:
 - a- Passenger requirements
 - b- Operator requirements
 - c- Community requirements

Evaluation-Stage Output

	OID *	Shape *	Rail_Station	Primary_Roads	Minor_Road	Bus_Stop	Pop_Dens	Long_Distance	Important_Building	Tourist_Area	LandValue	Development_Project	Regeneration_Areas
	1878	Polygon	1	24	105	16	21.121016	246.070583	18	<Null>	66.882437	2	1
	1879	Polygon	1	24	112	15	27.255444	299.336093	21	<Null>	66.076342	2	1
	1880	Polygon	1	15	128	17	32.786933	348.533909	22	<Null>	65.544067	2	1
	2085	Polygon	1	26	147	45	13.720133	146.305292	18	<Null>	54.752431	2	1
	2086	Polygon	1	27	143	38	14.07032	151.573933	17	<Null>	55.69769	2	1
	2087	Polygon	1	26	135	26	14.153523	152.756796	16	<Null>	57.440139	2	1
	2088	Polygon	1	21	129	21	15.892578	165.426995	15	<Null>	58.532339	2	1
	2089	Polygon	1	20	113	16	20.537627	198.665476	14	<Null>	58.944232	2	1
	2663	Polygon	<Null>	24	93	33	14.779471	154.316389	16	<Null>	58.966277	2	1
	2664	Polygon	<Null>	25	89	27	18.558676	186.212653	13	<Null>	56.219129	2	1
	2665	Polygon	<Null>	26	98	21	22.577298	216.651985	12	<Null>	53.510345	2	1
	2666	Polygon	<Null>	27	102	16	27.051599	251.036682	10	<Null>	50.763958	2	1
	2667	Polygon	<Null>	28	102	16	31.703506	289.546943	10	<Null>	48.211968	2	1
	2668	Polygon	<Null>	28	100	17	36.197305	327.384099	10	<Null>	45.844531	2	1
	2669	Polygon	<Null>	29	100	18	40.364367	362.754683	10	<Null>	43.608158	2	1
	2844	Polygon	<Null>	13	44	14	21.517979	269.489711	9	<Null>	69.935544	2	<Null>
	2845	Polygon	<Null>	16	52	15	27.416764	338.36154	10	<Null>	68.048699	2	<Null>
	2846	Polygon	<Null>	19	58	14	32.612603	398.633076	11	<Null>	65.951537	2	<Null>
	2847	Polygon	<Null>	21	66	15	37.472927	453.212895	11	<Null>	63.744952	2	<Null>
	2848	Polygon	<Null>	22	67	15	42.514938	509.655262	11	<Null>	61.535432	2	<Null>
	2849	Polygon	<Null>	23	73	17	47.771728	566.632737	11	<Null>	59.52087	2	<Null>
	2850	Polygon	<Null>	24	79	15	53.391798	624.435733	12	<Null>	57.586208	2	<Null>
	2851	Polygon	<Null>	24	80	16	58.955269	680.850201	11	<Null>	55.664891	2	<Null>
	2852	Polygon	<Null>	24	84	16	63.861688	733.01234	12	<Null>	54.092052	2	<Null>
	2853	Polygon	<Null>	25	94	17	68.878601	790.008143	9	<Null>	53.112495	2	<Null>
	2854	Polygon	<Null>	24	98	16	73.597298	843.504534	10	<Null>	52.329727	2	<Null>
	3021	Polygon	<Null>	4	33	8	21.04442	291.157073	11	<Null>	75.726881	2	<Null>
	3022	Polygon	<Null>	3	35	8	29.547464	406.823889	13	<Null>	75.611451	2	<Null>
	3023	Polygon	<Null>	9	40	11	38.148132	523.438691	14	<Null>	75.237565	2	<Null>
	3024	Polygon	<Null>	15	50	12	45.387323	619.001021	15	<Null>	74.392364	2	<Null>
	3025	Polygon	<Null>	17	51	11	50.869387	688.191019	14	<Null>	73.15416	2	<Null>
	3026	Polygon	<Null>	20	51	13	55.895425	748.913306	12	<Null>	71.661327	2	<Null>
	3027	Polygon	<Null>	22	60	15	61.069743	811.026052	14	<Null>	70.634897	2	<Null>
	3028	Polygon	<Null>	24	66	14	66.858366	881.699879	14	<Null>	70.895131	2	<Null>
	3029	Polygon	<Null>	25	68	14	73.033662	954.975603	16	<Null>	71.41909	2	<Null>
	3030	Polygon	<Null>	26	70	14	79.373855	1030.065877	13	<Null>	72.261307	2	<Null>
	3031	Polygon	<Null>	27	79	13	86.256915	1113.534493	12	<Null>	73.245027	2	<Null>
	3032	Polygon	<Null>	28	87	13	93.440913	1209.785832	12	<Null>	72.713614	2	<Null>

(0 out of 4566 Selected)

Decision-Stage (1/3)

1- Input Module: this is employed by transit rail planners (users) to input and adjust various planning parameters which include :

a) Threshold values

b) Satisfaction level

Station Location Decision SubModel

Passenger-Input Required Minimum Number of Airport Terminals (optional)

Passenger-Input Required Number of Existing Rail Stations (optional)

Passenger-Input Required Minimum Number of Primary and Minor Roads (optional)

Passenger-Input Required Minimum Number of Bus-Stops (optional)

Operator -Input Required Minimum Population Density (optional)

Operator -Input Required Minimum Number of People who have Long Commute Distance (optional)

Operator -Input Required Minimum Number of Important Activity Centers (optional)

Community -Input Required Minimum Number of High Economic Growth Sites (optional)

Community -Input Required Maximum Land Value (optional)

Input Required Satisfaction Level of Each Stakeholder (optional)

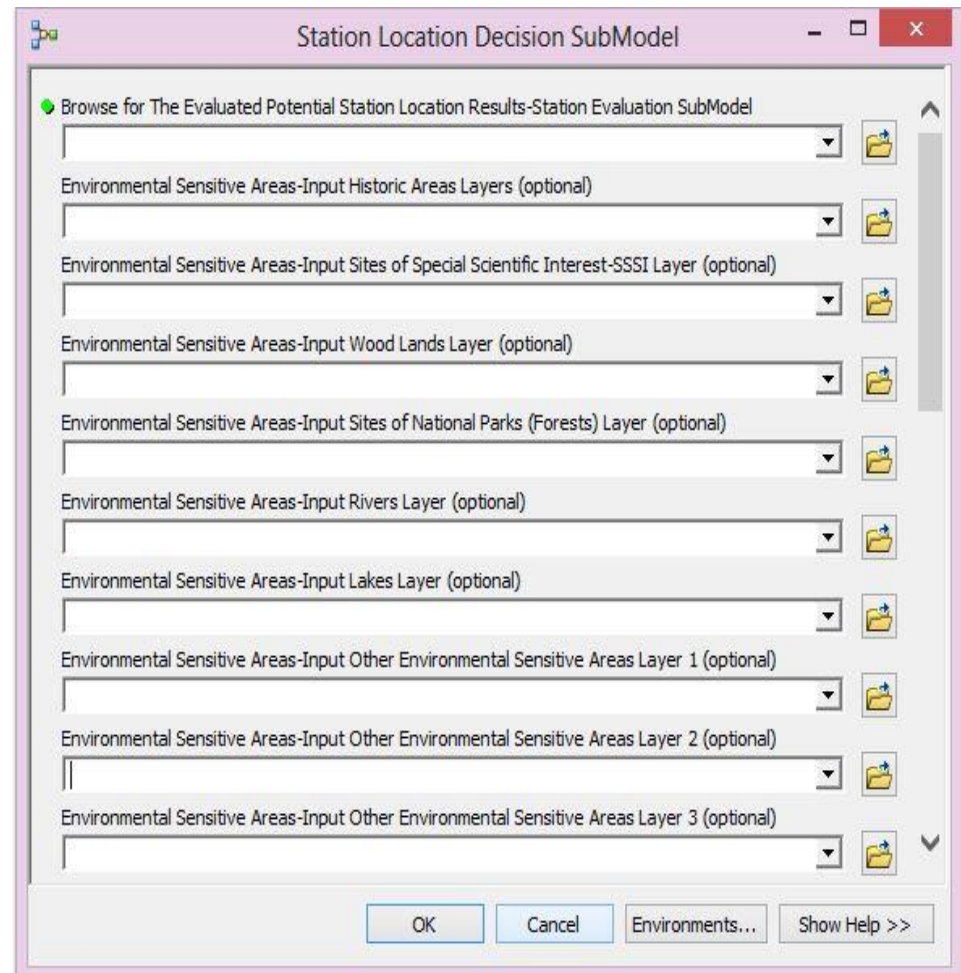
☒ Save the Excluded Station Candidates (Environmental)

Save Designated Station Location Candidates

OK Cancel Environments... Show Help >>

Decision-Stage (1/3)

c) Environmental Sensitive Areas



Decision-Stage (2/3)

2- Station Location Determination Module: consists of three subroutines:

a) Environmental Sensitive Area Exclusion ():

- **Find** Stn_Grid intersect from Env. Sensitive areas and **Exclude**

$$\Omega_f = \Omega_s \cap \Omega_i$$

b) Station Location Assessment ():

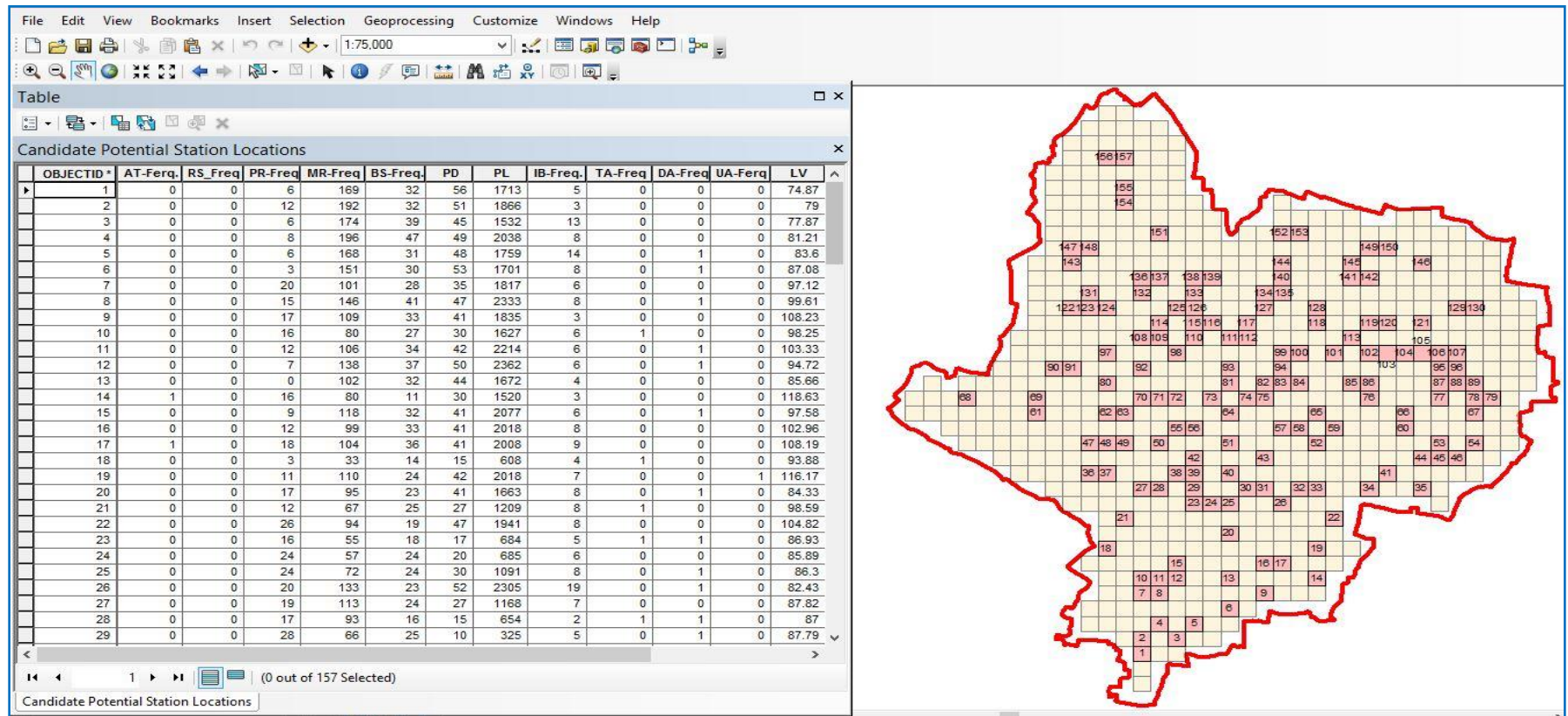
- **Compare** Stn_Grid_Requirement to Threshold Values
- **Assign** binary values to Stn_Grid

c) Station Location Determination():

- **Aggregate** weights of the requirement criteria satisfied by Stn_Grid
- **Determine** Stn_Grid that meet Satisfaction level

Decision-Stage (3/3)

3. Output Module



The Model Output

Case Study

Table 1: Input data and output results of the applied case study, Leicester City

Input Data		Output Results	
Station Size	50 m for width 300 m for length	Station Grids	4566
		Feasible Station Location	1031
Threshold values	50 th percentiles of all the Requirement criteria	Excluded Stations due to Intersection with Env. Areas	475
Satisfaction Level	More than 50% of each stakeholder	Excluded Feasible Stations due to Intersection with Env. Areas	60

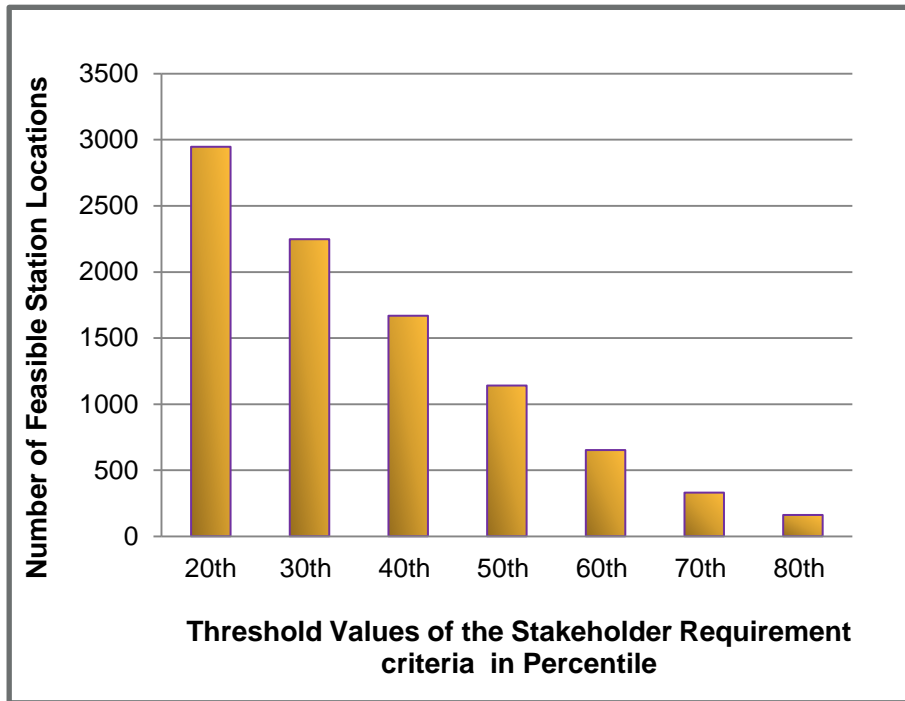
Sensitivity Analysis

Three categories of sensitivity analysis were carried out:

1. Impact of the requirement criteria threshold values.
2. Impact of the requirement criteria collectively at the stakeholder Level.
3. Impact of the requirement criteria individually at the stakeholder Level.

Sensitivity Analysis

1- Impact of the requirement criteria threshold values



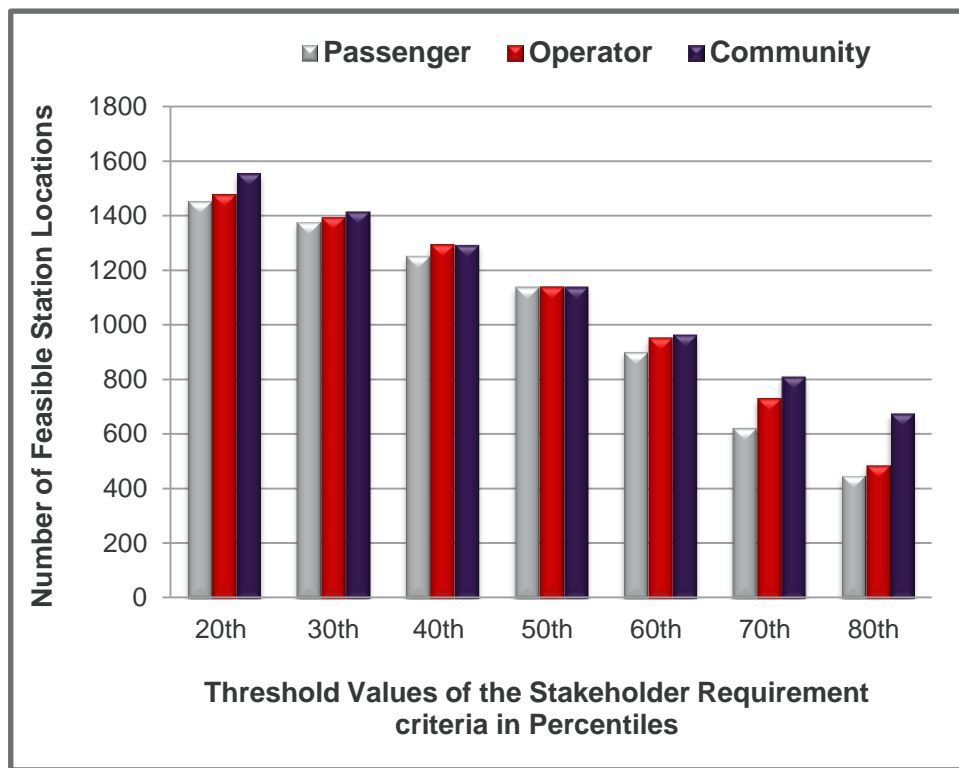
Threshold Value (Percentiles)	No. of Feasible Stations	Percentage Change
20 th	2946	-43.4
30 th	2247	
40 th	1668	
50 th	1140	
60 th	652	-80
70 th	330	
80 th	161	

Number of Feasible Station Locations with Different Threshold Values of the Requirement Criteria

Data sources: British Ordnance Survey and Leicester Council

Sensitivity Analysis

2- Impact of the requirement criteria collectively at the stakeholder Level



Threshold Value (Percentiles)	Passenger %Change	Operator %Change	Community %Change
20 th	0.0	0.0	0.0
30 th	5.2	5.6	8.9
40 th	13.7	12.4	16.8
50 th	21.5	22.9	26.7
60 th	37.9	35.5	37.9
70 th	57.1	50.4	47.7
80 th	69.0	67.1	56.5

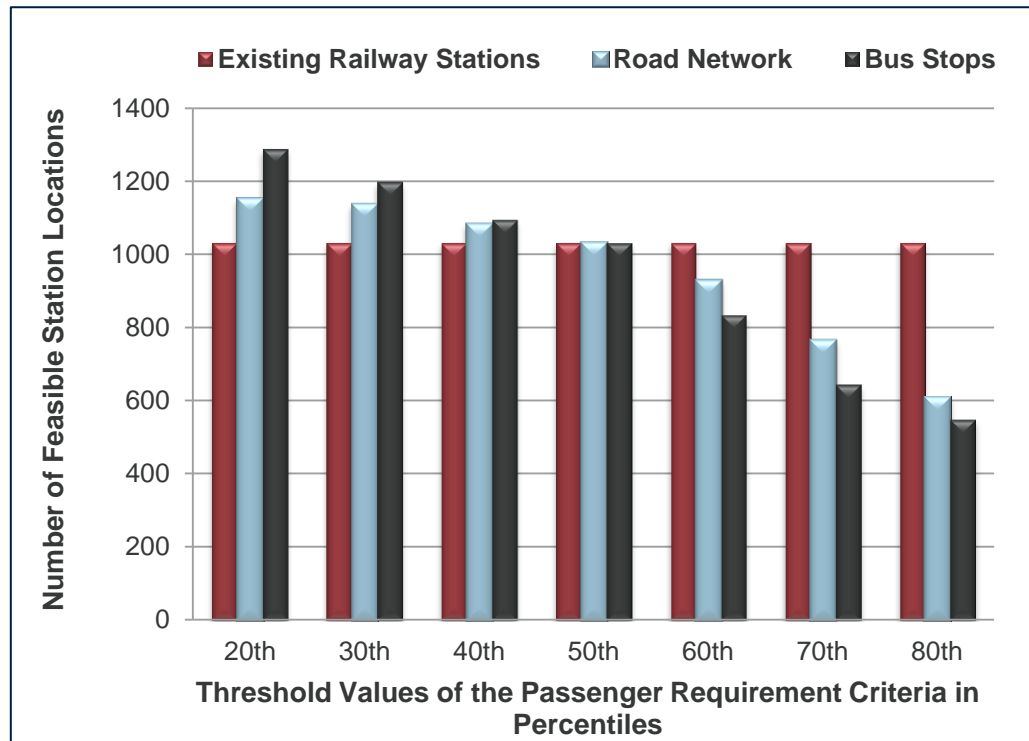
Number of Feasible Station Locations with Different Threshold Values of the Three Stakeholder Requirements

Data sources: British Ordnance Survey and Leicester Council

Sensitivity Analysis

3- Impact of the requirement criteria individually at the stakeholder Level

a- Passenger Requirements



Threshold Value (Percentiles)	Railway %Change	Road Network %Change	Bus Stops %Change
20 th	0	0.0	0.0
30 th	0	1.3	7.0
40 th	0	6.0	15.0
50 th	0	10.4	20.0
60 th	0	19.4	35.2
70 th	0	33.5	49.9
80 th	0	47.0	57.4

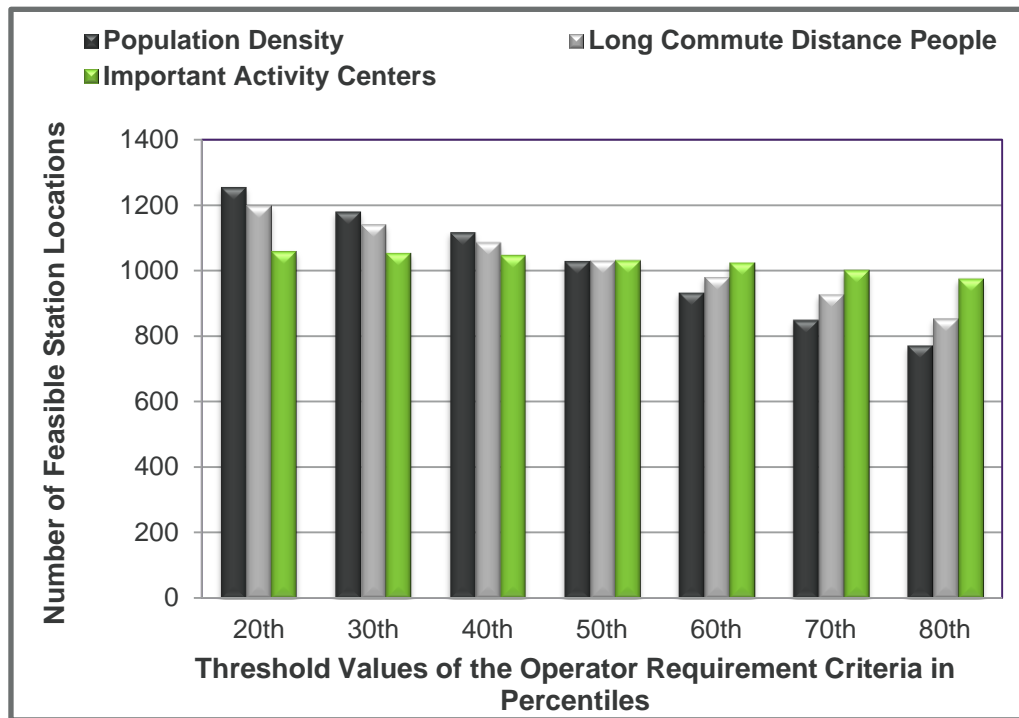
Number of Feasible Station Locations with Different Threshold Values of the Passenger Requirements

Data sources: British Ordnance Survey and Leicester Council

Sensitivity Analysis

3- Impact of the requirement criteria individually at the stakeholder Level

b- Operator Requirements



Threshold Value (Percentiles)	Population Density %Change	Long Commute Dist. People %Change	Important Building %Change
20 th	0.0	0.0	0.0
30 th	6.0	4.8	0.5
40 th	10.9	9.4	1.1
50 th	17.9	14.0	2.6
60 th	25.6	18.2	3.2
70 th	32.2	22.6	5.4
80 th	38	29	8

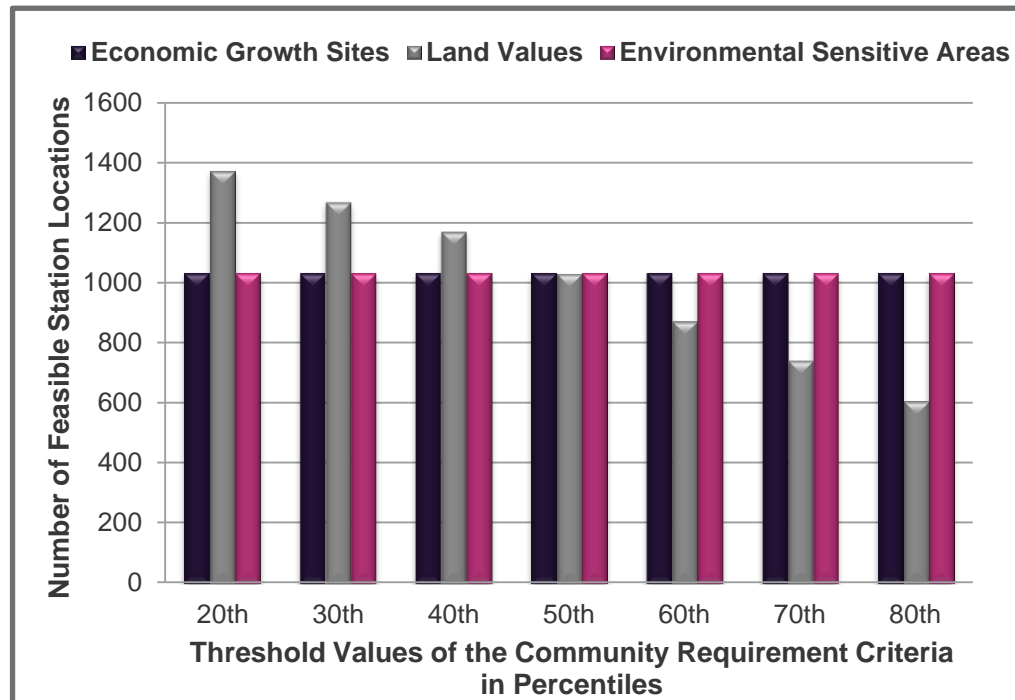
Number of Feasible Station Locations with Different Threshold Values of the Operator Requirements

Data sources: British Ordnance Survey and Leicester Council

Sensitivity Analysis

3- Impact of the requirement criteria individually at the stakeholder Level

c- Community Requirements



Threshold Value (Percentiles)	Economic Growth %Change	Land Values %Change	Env. Areas %Change
20 th	0.0	0.0	0.0
30 th	0.0	7.6	0.0
40 th	0.0	14.7	0.0
50 th	0.0	24.9	0.0
60 th	0.0	36.4	0.0
70 th	0.0	45.9	0.0
80 th	0.0	55.8	0.0

Number of Feasible Station Locations with Different Threshold Values of the Community Requirements

Data sources: British Ordnance Survey and Leicester Council

Conclusion

The proposed methodology can :

- (1) simultaneously consider multiple requirements and constraints.
- (2) incorporate both quantifiable and non-quantifiable requirement criteria.
- (3) find solution in large scale regions with complex topographies,
- (4) be expanded to include generation of the rail line network .

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