**Title Page with Author Information*

Evaluating the quality of inter-urban cycleways

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Abstract

This paper presents the results of research into the development of a decision support tool for use in the route selection stage of inter-urban cycle routes. The study initially focuses upon designing routes for commuter and / or leisure purposes and the differences in the routes required for each user type. The evaluation tool developed was trialled through application to different candidate route options on the Dublin to Mullingar section of the National Cycle Network. A desk study was carried out to develop a list of key design considerations, which was used to inform an initial criteria matrix for the decision support tool. This tool was tested on two candidate route options between Dublin and Mullingar.

A survey of experts in the fields of planning, design and cycling promotion was undertaken to identify the relative criteria weightings and tolerance thresholds for each type of cycle route. The results were then integrated into the criteria matrix framework. The candidate route options were reclassified using the new matrix.

The results of this paper show that safety is the highest ranked concern when designing a cycle route for either commuters or leisure cyclists. The requirements for each differ thereafter however, resulting in a different order of importance for the criteria headings.

1. Introduction and Background

Globally, there is a drive to try and reduce the level of carbon emissions with the promotion of sustainable modes of transport. These developments have seen increased attention paid to travel mode alternatives to the private car; with public transport, walking and cycling receiving improved focus. In recent years the Irish Government has outlined its commitment to the promotion of sustainable transport modes such as cycling. In 2009, the Department of Transport (DoT) published Ireland's first 'National Cycle Policy Framework' (NCPF) (DoT, 2009a). In the same year the DoT also published a document that outlines the national commitment to 'Smarter travel' (DoT, 2009b). The NCPF document outlines several policy positions on the provision of cycling in Ireland and goals for achieving an increase in the use of this mode (DoT, 2009a). Responses to the public consultation for the 'Smarter travel' document found that there was a need for investment in safe cycleways, secure bicycle parking and bicycle rental schemes. It was felt that such investments would support cycling. As well as these responses, support was expressed for encouraging cycling to school, provided children could do so safely.

In 2008, the DoT launched a public consultation called '2020 Vision' (DoT, 2008). The results of this consultation process were then taken on board in forming the policy for achieving more sustainable travel by 2020. This consultation identified the need to support "healthy" modes of travel, and the support of cycling policies was identified as one way in which this can be achieved. The '2020 Vision' consultation document reports that the benefit / cost ratio for a cycleway is 20:1 (DoT, 2008). The document acknowledges the benefits of developing the National Cycle Network (NCN) as a network which is a "well-signed cycle network with good connections between urban areas on traffic-free paths, quiet lanes, and traffic-calmed roads". There is also encouragement for the development of school travel plans which incorporate cycling. Previous research on the NCN have shown the economic, tourism and health benefits of investing in these cycleways (Deenihan and Caulfield, 2015; Deenihan and Caulfield, 2014; Deenihan et al, 2013).

The Irish government has proposed the development of a National Cycle Network. It was stipulated that the routes designed within the network should allow people to travel between “urban centres” around the country (NRA and DoT, 2010). With the requirements of “access for all” on the routes and that the routes would be attractive to those embarking on both long and short distances. It was decided that a subsequent action would be to select a “major route corridor” such as the Dublin to Galway leg, or the route for a subsection of this leg (NRA and DoT, 2010).

The provision of facilities for cyclists must take into account many aspects regarding what it is that a cyclist requires in order for them to be willing to use the facilities, or to be attracted to cycling in the first place. Van der Waerden et al. (2005) found, in a stated preference survey on the provision of facilities for pedestrians and cyclists, that, for the most part, cyclists prefer “smooth pavement, lighting from the top, a small slope”, the presence of exits from buildings, and “the absence of pedestrians”, while pedestrians similarly prefer there to be no cyclists. As such, it is concluded that shared-use facilities are not preferable and where applicable, the facilities for each user should be separated. However, Tolley (2003) suggested that rural cycleways could afford to be shared use between cyclists and pedestrians, as there was likely to be fewer pedestrian users. Vehicular traffic is highlighted by the author as the greatest danger to the cyclists outside of urban areas. A survey and subsequent analysis of data in Calgary, Canada, found that cyclists considered cycling on a residential road 1.9 times as onerous as cycling on a path in a park (Abraham et al., 2002).

Parkin et al. (2007) found that the presence of special facilities, such as a dedicated bicycle lane, at junctions did not greatly improve the sense of risk associated with cycling. They found that facilities on “trafficked routes contribute only a little to moderation of perceived risk”, but that making facilities that are off road, or “adjacent to the road” would be a significant factor in improving perceptions regarding cycling risks. Cho et al. (2009) revealed that there is an increased perception of risk in areas in which the density is low, and areas which are “single-family residential neighbourhoods”. However, the authors ultimately could conclude that where there was an “actual crash risk”, there would be a corresponding increase in the perception of the risk of crashing. Conversely, where there was a heightened sense of “perceived crash risk”, and a reduction in the “actual crash risk”. It is also suggested that implementing both marketing and “physical projects”, targeted at suburban dwellers, will aid in encouraging them to cycle and walk more.

Sener et al. (2010) found that cyclists indicated that they would rather a “general purpose lane” as this avoids them being restricted to the facilities provided. However the authors found that people stated no clear preference for 3.75 feet or 6.25 feet lanes. The results also showed that female cyclists will seek to avoid steep hills on their commute, but they prefer moderate hills to flat routes for leisure routes. Men are shown to prefer moderate hills to steep hills and flat routes on their commute, but look for steep hills on leisure routes. The results also show that experienced cyclists indicate a preference for roads with “moderate” versus “low” speed limits for motor vehicles. The authors assume that travel time considerations need only be taken into account for commute trips. The results show that respondents would rather shorter journey times for their commutes.

Correspondingly, a comparison of surveys previously conducted showed that; where there were more recreational trips in a location (Chicago in this case) the average trip length was longer (Madera and Smith, 2009). The surveys compared had been carried out in Philadelphia, Chicago and Winston-Salem. In Chicago, the median trip length was found to be 60 minutes, compared with 45 minutes in Philadelphia. However, in Philadelphia recreational trips were also found to be longer than the average trip length at 76 minutes. Whereas the average duration of commuter trips in each location was much shorter; at 29 minutes in Philadelphia and a median of 25 minutes in Chicago (Madera and Smith, 2009). Both the Philadelphia and Winston-Salem surveys ranked "bicycle lanes" as their most preferred facility, and picturesque/greenway routes as their second most preferred facility. The authors conclude that the similarities between the expressed preferences of respondents in the two locations imply that "the differences in the expressed needs and desires of bicyclists and non-bicyclists are not very great". However, the comparison also revealed that there was very little convergence of opinion across the three locations with regard to the motivations of people for cycling. For the purposes of this study, two types of cyclist were examined; tourists/leisure cyclists and commuter cyclists.

In Ireland, the National Cycle Manual (NTA, 2011) has introduced a quality of service (QoS) scale for cycling, though the manual is mainly targeted at urban design. The QoS scale ranges from a "Level A+" rating, which corresponds to a route satisfying the criteria to the highest standards, down to a "Level D" rating. The rule regarding how a route qualifies for a particular grade is as follows: "To achieve any particular QoS, at least 4 of the 5 criteria must be achieved. The fifth may be no more than one level lower, e.g., a route meeting four criteria at Level B and one at Level C has an overall QoS Level B." The five criteria under which the routes quality of service is judged are:

- "Pavement Condition Index (PCI)"
- "Number of adjacent cyclists"
- "Number of conflicts per 100m"
- "Journey time delay (% of total travel time)" this takes into account the amount of time lost at junctions on the route. A speed of 15km/hr. is assumed.
- "HGV influence (% of total traffic volume)"

The QoS is clearly laid out in table format with defined thresholds for each "level" under each of the criteria.

As much literature already exists regarding cyclists' preferences, this project will take the existing knowledge and seek to expand on it by integrating it into a decision-support tool for the route selection stage of cycle route design and for the evaluation of existing facilities. This will be complemented by surveying experts in related fields, in order to refine the tool into a usable implement for practitioners.

This paper contributes to the body of knowledge by developing a decision-support tool, which will allow for the research to be structured into a format which can be implemented by planners and designers, as well as tourism officials and marketers. For ease of implementation, the tool will take the form of an appraisal matrix, similar to the level of service tables (TCRP, 1999; NTA, 2011) as this is a format with which professionals will already be familiar. The matrix will provide a heuristic approach for use in the route selection stages of inter-urban cycle routes in Ireland, where, as the literature review has shown, there is a lack of dedicated national policy documents or guidelines. Furthermore, the matrix will contribute to closing the gap identified by

Fáilte Ireland (2006a) for the development of holidays in Ireland, which include cycling, by giving a structured approach to the rating of cycle routes for the purposes of tourist information and marketing.

The following section details the methodologies used in this study. Section 3 of the paper details the results from the expert survey conducted to determine the weights for the different cycleway attributes. The fourth section details the evaluation matrix used to evaluate each of the route options, the results of which are presented in section 5. The final section of the paper presents the main conclusions of the study.

2. Methodology

In order to define the design standards for this inter-urban cycle route a number of national and international design standards were consulted (DTO, 1998; CROW, 2007; DoT, 2009a; TFL, 2005, NTA, 2011, Sustrans, 2009). The accompanying lists were recurring themes from a selection of literature about cycling and cycle routes (Fáilte Ireland, 2006a and Sustrans, 2009). Listed below are the five "main requirements", of a successful cycle network, used in the DTO (1998) document on the provision of cycle facilities and in the CROW (2007) manual. They are: 'road safety', 'coherence', 'directness', attractiveness' and 'comfort'. Here, each requirement is accompanied by a list of key design considerations, which have been compiled from the above and supplemental sources (TRL 1999; Patterson, 2007; McClintock and Cleary, 1996; Wardman et al, 2007) as well as the other documents used in the project.

Road Safety

- Proximity to traffic
- Type and volume of traffic using route
- Integrated / Segregated track
- Appropriate designs for each choice
- Lighting
- Barriers / Fencing
- Motorcycle proofing – Necessary in rural areas also?
- Lane width
- Junction layouts (Advanced stop lines, kerbs)
- Signal Timings (Priority)
- Sight lines – walkers
- Warning signs for drivers
- Interaction with heavy goods vehicles & buses
- Head clearance
- Old bridges over the canals
- Road signs, where cycle tracks are being added to existing roads, the height of anything which overhangs the road will have to be reviewed.
- Interaction with private dwelling access

Coherence

- Freedom of route choice
- Lane markings, identifiable by both cyclists and drivers
- Uniformity of cycle lane markings and junction layout

- Continuity of network

Directness

- Conveying cyclists to their destination as quickly as possible, with minimum detours or delays.

Attractiveness

- Location
- The use of plants along the route
- Security and safety
- Facilities

Comfort

- Material
- Surface material
- Colour
- Durability
- Initial cost Vs. intended commitment to maintenance costs
- Ride comfort
- How well it fits with the surrounding environment.
- Route
- Gradients

This list includes some criteria which could potentially conflict with each other. The aim of the cycle network is to attract both commuter and leisure cyclists. In some cases, there is a convenient overlap between criteria, such as with the attractiveness of a scenic route, like a towpath, combining with route safety, as the route is segregated from the main roads.

The literature studied did not appear to provide much guidance in terms of inter-urban cycling. The CROW (2007) manual, as well as Sustrans (2009) and research by Fáilte Ireland (2006a) did provide some instruction regarding recreational cycling. The National Trails Office (NTO) also provides guidance for trail routes, which include rural trails designed for recreational purposes only (NTO and Irish Sports Council, 2010). However, in terms of the national design standards consulted (DTO, 1998; NTA, 2011) inter-urban routes appear not to be catered for. The research findings, presented in this paper, aim to close this gap in the literature, by providing a comprehensive tool for evaluating inter-urban cycleways in Ireland.

3. Expert Survey Results

3.1 Details of the sample

A survey was conducted of experts (in the construction and provision of cycling facilities) to determine the importance of a number of attributes of cycleways. There were 6 question areas in the survey; 1) ranking of criteria; 2) route safety; 3) directness; 4) attractiveness; 5) comfort and 6) qualifying data. The requirements for the responses to be qualified as valid for inclusion in the analysis are outlined below.

This section also includes how the results of the expert survey were integrated into the criteria matrix.

There were 168 responses received to the expert survey, of which 113 (67.26%) were usable. The respondents were also asked to indicate for which type of organisation they worked. 'State agency' was the most commonly selected organisation type, with 25.66%. 'Local authorities' were represented by 21.24% of respondents and 'Academic' was chosen by 15.04%. 'Other' was chosen by 9.73% of respondents followed by 'Cycle campaign/lobbyist group' (7.96%), 'Government Department' (7.08%); 'Local Sports Partnership' (5.31%); 'Expert' (4.42%) and 'Consultant' (3.54%) (See Table 1).

Table 1: Organisations represented by respondents

Criteria	N	%
Cycle campaign/lobbyist group	9	7.96
Local authority	24	21.24
Local Sports Partnership	6	5.31
Government Department	8	7.08
State agency	29	25.66
Academic	17	15.04
Expert	5	4.42
Consultant	4	3.54
Other	11	9.73
Total	113	100.0

3.2 Ranking of the criteria

The results for the five criteria are shown in Table 2. The scores represent the weighted mean score for each criterion, for the number of respondents who recorded a preference for it. The criteria were ranked out of 6 and each response was weighted in accordance with its ranking (for example; if a criterion was ranked 1st, it scored 6 out of a possible 6, 2nd scored 5 out of 6 and so forth). Therefore, the higher the weighted mean value, the greater the importance of the attribute. This method of calculation and interpretation can be used for all of the subsequent weighted mean scores presented in this paper. Table 2 presents the results segmented by the user type. An important aspect of this study was to ensure the cycleway would attract both commuters and leisure cyclists. As such the respondents to the expert survey were asked to rank the criteria in terms of importance for both commuters and leisure cyclists.

Table 2: Ranking of Main 5 Criteria

Ranking of Main 5 Criteria	Weighted mean	Number of Responses	Weighted mean	Number of Responses
	Commuter		Leisure	
Attractiveness	2.162	111	3.909	110
Coherence	3.111	108	2.981	107
Comfort	3.327	110	3.734	109

Directness	4.165	109	1.757	111
Safety	4.990	111	5.009	111
Perceived security	3.303	109	3.750	108

The resulting orders of priority for each commuter and leisure routes are as follows;

Commuter
1. Safety
2. Directness
3. Comfort
4. Perceived security
5. Coherence
6. Attractiveness

Leisure
1. Safety
2. Attractiveness
3. Perceived security
4. Comfort
5. Coherence
6. Directness

Safety ranks as the most important criterion regardless of whether the route being planned is aimed at commuters or leisure cyclists. As such, it can be used as the standard against which all the other criteria are measured. This will result in a scale of relative importance for each criterion. However, the increments in relative importance are not equal, and so a sliding scale from 1 to 6 is not a reasonable scale to choose. As safety is the highest ranked criterion for both route types (4.99 for commuter routes and 5.01 for leisure routes), this can be used to normalise the other criteria with respect to a standard (that is safety), see Table 3. A scale of positive values less than 1 (where safety has the value of 1) could be achieved by dividing the scores of the other criteria by the score for safety. This scales the results linearly with respect to the standard (safety), see equation 1. Linear scaling was used by Ramani et al (2009), though that paper defined a 0 valued criterion as well as a criterion valued at 1. Sayers et al. (2003) also used an approach whereby one "criterion weight" was set to 1.

The equation for calculating the weighting $\mathcal{W}$, for each criterion is as follows;

Equation 1

$$\mathcal{W}_i = \frac{\mathcal{S}_i}{\mathcal{S}_{Safety}}$$

Where; $\mathcal{S}_i$ is the score, and $\mathcal{W}_i$ the corresponding weighting, for either commuter or leisure routes for each of;

- Safety
- Directness
- Comfort
- Perceived security
- Coherence
- Attractiveness

Table 3: Scale of importance for Main 5 Criteria

Commuter	Score ($\mathcal{S}_i$)	Weighting ($\mathcal{W}_i$)	Leisure	Score ($\mathcal{S}_i$)	Weighting ($\mathcal{W}_i$)
Safety ($\mathcal{S}_{Safety}$)	4.991	1.000	Safety ($\mathcal{S}_{Safety}$)	5.009	1.000
Directness	4.165	0.833	Attractiveness	3.909	0.780
Comfort	3.327	0.667	Perceived security	3.750	0.749

Perceived security	3.303	0.662	Comfort	3.734	0.745
Coherence	3.111	0.622	Coherence	2.981	0.596
Attractiveness	2.162	0.432	Directness	1.757	0.351

3. New Criteria Matrix and appraisal methodology

This section of the paper describes the criteria matrix. The methodology to be followed in implementing the criteria matrix and identifying a preferred route option from a selection of candidate route options is also outlined. The following sections will detail the steps involved in calculating the final route score using the criteria matrix.

3.1 Route safety

The route is categorised as good medium or poor based on the site visit records and the route safety matrix, as is seen Table 4. The average frequency with which junctions are encountered is based on the number of junctions in the section length and the design speed for the route.

Table 4: New route safety matrix

Route Safety	Good	Medium	Poor
Segregation	Physical segregation from road	Visual segregation only	Shared road space
Volume of motorised traffic	Less than 3 Vehicles/min.	More than 3 but less than 8 Vehicles/min.	More than 8 vehicles/min.
Junctions	1 junction or less encountered every 6mins.	1 junction encountered every 3.75 – 6mins.	Junctions encountered more frequently than 1 every 3.75 mins.
Speed limits	30km/h or less.	less than 60 km/h	Traffic speed >60 km/h.
Space available (width)	3.00 – 5.00m	2.00m to 3.00m	2.00m

The appropriate weights for either commuter or leisure routes are included in Table 5. These are multiplied by the rating awarded to the route (3 for good, 2 for medium and 1 for poor) for each criterion, giving the weighted score. The sum total of the score achieved is expressed as a percentage of the maximum achievable score (which is a score of 3 under each heading, multiplied by the criteria weights). See equation 2. If this score is less than 40%; then the route is classed as poor overall for route safety (1 mark). If the score is between 40% and 70% then the route is classed as medium (2 ticks) and it is given 3 marks (good) for a score of 70% or more. This number of marks is then input into the main criteria matrix, and the relevant weighting is applied.

Equation 2

$$\frac{\Sigma \mathcal{S}_{w}}{3 \times \mathcal{W}_{t}} \times 100 = \%$$

Where;

$\Sigma\mathcal{S}_{w}$: is the sum of the weighted scores, and;
$\mathcal{W}_t$: is the total sum of the criteria weights

Table 5: New route safety weighted scores

Route Safety			
Commuter	**Criteria Weights ($\mathcal{W}$)**	**Leisure**	**Criteria Weights ($\mathcal{W}$)**
Segregation	1	Segregation	1
Volume of traffic	1	Volume of traffic	1
Junctions	0.962	Junctions	0.958
Low Speed	0.922	Low Speed	0.907
Wide	0.857	Wide	0.866
Maximum score $(3 \times \mathcal{W}_t)$**: 14.223**		**Maximum score** $(3 \times \mathcal{W}_t)$**: 14.194**	

3.2 Directness

The criteria matrix for directness is shown in Table 6. The time delay will be calculated based on the difference between the length of time it would take the cyclist to travel the route at the given design speed and the time it would take to travel the straight line distance between the origin and destination at a speed of 20km/hr.

Table 6: New directness matrix

Directness	Good	Medium	Poor
Detour	0 - 20%	20% - 40%	40% +
Delay	0 - 20%	20% - 40%	40% +

The average score is then calculated and the number of marks assigned based on the academic grade thresholds as explained previously. This will be the score, which will be input into the main criteria matrix. The appropriate weighting for directness will then be applied depending on whether the route is targeted at leisure or commuter cyclists.

3.3 Perceived security

For this criterion, there are no thresholds. It is instead treated like the attributes of desirability. If a measure exists for the majority of the route, then it is recorded in the matrix. For example; if passers-by or buildings such as residences overlook a route then it receives one tick for overlooked. The overall number of marks to be carried forward to the main criteria matrix is then worked out based on the percentage achieved out of the maximum score achievable. One mark is awarded for up to 40%; two marks are awarded between 40% and 70% and three marks are awarded for more than 70%.

3.4 Comfort

The score for comfort is based on the surface material and the general gradient on the route. The order of preference of the surface materials is as in Table 7. The average score awarded is then calculated (the route is categorised again using the percentage of the maximum possible score). The number of marks awarded is then input into the main criteria matrix in order to calculate the weighted score for the route.

Table 7: New comfort matrix

Comfort	Good	Medium	Poor
Surface material	Asphalt or Concrete	Paving slabs or grit	Grass or compacted soil and stone
General Gradient	3% or less	3 – 5%	Greater than 5%

3.5 Attractiveness

The desirability score is based on the list of attributes and the ranked scores awarded to them by the experts and based on the target users (commuter or leisure). The scores for the two amenities headings are categorised in Table 8. The overall result for attractiveness is based on how many marks out of the maximum achievable (which is 9 marks) the route has managed to achieve.

Table 8: New Attractiveness matrix

Attractiveness	Good	Medium	Poor
Amenities: Towns	Less than 30 minutes	30-45 minutes	Greater than 45 minutes
Amenities: Resting places	Less than 8km	8-12km	Greater than 12km
Desirability	More than 70%	Less than 70% but more than 40%	Less than 40%

3.6 Main criteria matrix

The numbers of marks (based on the good, medium or poor ratings) achieved overall by the route under each of the criteria, are entered into the main criteria matrix (See Table 9). In this table, the appropriate weightings for each criterion relative to the others (with safety as the standard) are applied (that is the number of marks for each criterion is multiplied by the relevant criterion weight). The results are added (giving $\Sigma\mathcal{S}_{w}$ for equation 3) and the total expressed as a percentage of the maximum achievable score. As three is the maximum number of marks, the maximum achievable score is the sum of the criteria weights multiplied by three. As was the case in the previous sections, the marks are then awarded based on the thresholds of one mark up to 40%, two marks between 40% and 70%, and three marks thereafter.

Equation 3

$$\frac{\Sigma\mathcal{S}_{w}}{3 \times \mathcal{W}_t} \times 100 = \%$$

Where;

$\Sigma\mathcal{S}_{w}$ Is the sum of the weighted scores, and;

$\mathcal{W}_t$ Is the total sum of the criteria weights.

$3 \times \mathcal{W}_t$ For commuter routes is 12.658 and for leisure routes is 12.661.

Table 9: New Main Criteria Matrix

Ranking of Main Criteria			
Commuter	**Criteria Weight**	**Leisure**	**Criteria Weight**
Safety	1.000	Safety	1.000
Directness	0.833	Attractiveness	0.780

Comfort	0.667	Perceived security	0.749
Perceived security	0.662	Comfort	0.745
Coherence	0.622	Coherence	0.596
Attractiveness	0.432	Directness	0.351
Sum Total ($\mathcal{W}_t$)	**4.219**	**Sum Total ($\mathcal{W}_t$)**	**4.220**
Maximum score ($3 \times \mathcal{W}_t$)	**12.658**	**Maximum score ($3 \times \mathcal{W}_t$)**	**12.661**

4. Application of the criteria matrix to an inter-urban cycleway

This section of the paper applies thresholds developed in the previous section to a route selection situation. The scores reflect the weighting applied to the attributes of the cycleway based on whether they fell into the good, medium or poor category. The average score will appear in the tables in square brackets [ ].

✓= Poor, [1 – 1.33]; ✓✓= Medium [1.34 – 2.00]; ✓✓✓= Good [2.01 – 3.00].

4.1 Route options considered
The road route mainly follows a number of national roads between Dublin and Mullingar over a distance of approximately 68km. In general, the speed limit on the road route, for vehicular traffic, is 80km/hr. outside of the towns. The motor vehicle traffic volumes are moderate to high in most cases. There are sections of the route with little or no hard shoulder, and so there is insufficient space currently on the road for provision of segregated cycle facilities. The canal route follows the towpath of the Royal Canal between Collins Bridge (near Dublin) and Mullingar (approximately 72km). The canal towpath is more isolated than the road route and has less access to facilities. However all sections are at the edge of a town at their start or finish points, and most often at both ends of the section. A third route option was also condidered which is a hybrid of both the road and the canal routes. This option has a distance of 69km.

4.2 Road route
This section will detail the results for the road route between Dublin and Mullingar under the defined thresholds and methodology for the criteria matrix. The tables below give the summary of the route's scores, over all sections, under each criterion. This matrix takes all of the scores achieved by the route under each of the previous sections. The weights as worked out in the expert survey are then applied and an overall score for the route, as each a commuter route and a leisure route, is calculated. As can be seen in Table 10, the road route scored 77.45% as a route for commuters and 74.42% as a route for leisure cyclists. The route therefore scores 3 marks (ticks) as a route for commuters and as a leisure route.

Table 10: Dublin-Mullingar road route; main criteria matrix

Ranking of Main Criteria							
Commuter	**Criteria Weight**	**Ticks**	**Weighted score**	**Leisure**	**Criteria Weight**	**Ticks**	**Weighted score**
Safety	1.000	✓	1.000	Safety	1.000	✓	1.000
Directness	0.833	✓✓✓	2.504	Attractiveness	0.780	✓✓	1.56
Comfort	0.667	✓✓✓	2.000	Perceived	0.749	✓✓✓	2.246

				security			
Perceived security	0.662	✓✓✓	1.985	Comfort	0.745	✓✓✓	2.236
Attractiveness	0.433	✓✓	0.866	Directness	0.351	✓✓✓	1.052
Sum Total	**3.596**		8.355	**Sum Total**	**3.625**		8.904
Maximum score	**10.788**			**Maximum score**	**10.876**		
Percentage			77.45%	**Percentage**			74.42%
Overall rating for route			✓✓✓	**Overall rating for route**			✓✓✓

4.3 Canal route

This details the results for the canal route between Dublin and Mullingar under the defined thresholds and methodology for the criteria matrix. Table 11 gives a summary of the route's scores over all sections under each criterion. As can be seen, the route rates more highly as a leisure route (93.12% versus 87.75%). The canal scores 3 ticks as a both a leisure route and a commuter route.

Table 11: Dublin-Mullingar canal route; main criteria matrix

Ranking of Main Criteria							
Commuter	**Criteria Weight**	**Ticks**	**Weighted score**	**Leisure**	**Criteria Weight**	**Ticks**	**Weighted score**
Safety	1.000	✓✓✓	3.000	Safety	1.000	✓✓✓	3.000
Directness	0.833	✓✓✓	2.504	Attractiveness	0.780	✓✓✓	2.341
Comfort	0.667	✓✓✓	2.000	Perceived security	0.749	✓✓	1.497
Perceived security	0.662	✓	0.662	Comfort	0.745	✓✓✓	2.236
Attractiveness	0.432	✓✓✓	1.300	Directness	0.351	✓✓✓	1.052
Sum Total	**3.596**		9.466	**Sum Total**	**3.625**		10.127
Maximum score	**10.788**			**Maximum score**	**10.876**		
Percentage			87.75%	**Percentage**			93.12%
Overall rating for route			✓✓✓	**Overall rating for route**			✓✓✓

4.4 Hybrid route

The hybrid route is a combination of the road and canal options. The overall criteria matrix result is presented in Table 12. As can be seen below, the hybrid route scores 3 ticks each as a leisure route and a commuter route. The advantages this route has over the canal route are that it exploits existing infrastructure and avoids a number of dangerous junctions. It is also more direct, where the canal route had a time delay of 97.69%.

Table 12: Dublin-Mullingar hybrid route; main criteria matrix

Ranking of Main Criteria							
Commuter	**Criteria Weight**	**Ticks**	**Weighted score**	**Leisure**	**Criteria Weight**	**Ticks**	**Weighted score**
Safety	1.000	✓✓✓	3.000	Safety	1.000	✓✓✓	3.000
Directness	0.833	✓✓✓	2.504	Attractiveness	0.780	✓✓✓	2.341
Comfort	0.667	✓✓✓	2.000	Perceived security	0.749	✓✓	1.497
Perceived	0.662	✓	0.662	Comfort	0.745	✓✓✓	2.236

security							
Attractiveness	0.432	✓✓✓	1.300	Directness	0.351	✓✓✓	1.052
Sum Total	**3.596**		9.467	**Sum Total**	**3.625**		10.127
Maximum score	**10.788**			**Maximum score**	**10.876**		
Percentage			87.75%	**Percentage**			93.12%
Overall rating for route			✓✓✓	**Overall rating for route**			✓✓✓

5. Conclusions

The primary aim of this research was to develop a route selection support tool which could be easily incorporated into the route selection phase for inter-urban cyclways. The appraisal matrix and corresponding methodology tools presented in this paper, fill a gap in the literature for inter-urban cycle planning internationally.

The results presented in this paper show that a single route appraisal methodology for all target users is unadvisable for inter-urban cycleways, based upon the results of the expert survey. The results of the expert survey show that directness was the second most important criterion for commuter routes and was more important for commuter routes than for leisure routes. For leisure routes; attractiveness was ranked second, perceived personal security, comfort and coherence were ranked third, fourth and fifth respectively, while directness was considered to be the least important aspect by the experts. The third most important criterion for commuter routes was comfort, followed by perceived security, coherence and finally attractiveness.

The appraisal matrix and methodology was tested on candidate route options in the Dublin to Mullingar corridor of the proposed National Cycle Network (NRA and DoT, 2010). Based on the assessment conducted it is clear that the preferred route option would be the hybrid route. The assessment shows that overall a route which satisfies the safety and attractiveness criteria aspects for leisure cyclists can still be appealing as a commuter route, as in the case of the canal route. However, a route which does well as a commuter route may not be as attractive as a leisure route if it fails to satisfy the safety criteria, as was the case with the road route.

Disclaimer

The research presented in this paper are the results of an academic exercise, and the findings of public consultation were not included in the research and that at the time of publication of the paper there was no to commitment to funding of the cycleway project.

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References

Abraham, J.E., McMillan, S., Brownlee, A.T. and Hunt, JD. (2002) Investigation of cycling sensitivities. 81st TRB annual meeting and for consideration of publication in Transport Research Record. (CD-ROM), Washington, D.C.

Cho, G., Rodríguez, D. and Khattak, A. (2009). What is the role of the built environment in relationships between perceived and actual pedestrian safety. *88th Transport Research Board annual meeting* (CD-ROM), Washington, D.C.

CROW. (Original Dutch version 2006; English Version 2007). *Record 25: Design Manual for Bicycle Traffic*. Ede: Crow.

Deenihan, G., Caulfield, B., O'Dwyer, D., Measuring the success of the Great Western Greenway in Ireland, *Tourism Management Perspectives*, 2013, 7, 2013, p73 – 82

Deenihan, G., Caulfield, B. Estimating the Health Benefits of Cycling, *Journal of Transport & Health*, 1, (2), 2014, p141 – 149

Deenihan, G., Caulfield, B. Do tourists value different levels of cycling infrastructure?, *Tourism Management*, 46, 2015, p92 - 101

Department of Transport. (Ireland) (2008). *2020 Vision – Sustainable Travel and Transport: Public Consultation Document*, Dublin.

Department of Transport. (Ireland) (2009a). *Ireland's First National Cycle Policy Framework.* Dublin: Department of Transport.

Department of Transport. (Ireland) (2009b). *Smartertravel – A Sustainable Transport Future – A New Transport Policy for Ireland 2009 – 2020*. Dublin: Department of Transport.

Dublin Transportation Office. (1998). *Provision of Cycle Facilities: National Manual for Urban Areas*, Dublin.

Fáilte Ireland (2006a). *Summary of Cycling Research Survey 2005*. [Online] Available at: http://www.Fáilteireland.ie/Word_files/research/Product-Summary/Cycling-Summary [Accessed 14 October 2010].

Madera, J. and Smith, C. (2009). Surveys of bicyclists and the general population in three cities: a comparison of methods and results. *88th TRB annual meeting and for consideration of publication in Transport Research Record*. (CD-ROM), Washington, D.C.

McClintock, H., and Cleary, J.(1996). 'Cycle facilities and cyclists' safety: Experience from Greater Nottingham and lessons for future cycling provision'. *Transport Policy.* Vol. 3, No. l/2. pp. 61-77.

National Roads Authority and Department of Transport. (2010). *National Cycle Network-Scoping study report - Draft.* Available at: http://www.smartertravel.ie/download/1/FINAL%20NCNScopingStudyAugust2010.pdf [Accessed: 3 October 2011].

National Trails Office (NTO) and the Irish Sports Council. (2010) *Classification and Grading for Recreational Trails.* [Online] Available at:

http://www.irishtrails.ie/National_Trails _Office/Publications/trails_classification.pdf [Accessed 15 October 2010].

National Transport Authority (2011). *National Cycle Manual* [Online]. Available at: http://www.cyclemanual.ie [Accessed: 21 June 2011].

Parkin, J., Wardman, M. and Page, M. (2007). Models of perceived cycling risk and route acceptability. *Accident Analysis & Prevention*, 39 (2): 364-371

Patterson, S., (2007). Cycling and walking on the towpaths of the Lagan and Newry canals. Towpaths for the future: seminar. Tullamore Court Hotel, Tullamore, Co. Offaly, 20 June 2007. Kilkenny: The Heritage Council. pp25-27.

Ramani, T.L., Quadrifoglio, L., Zietsman, J., and Knowles, W. (2009) Improving the performance-measurement based MCDM approach for transport planning applications. *88th TRB annual meeting and for consideration of publication in Transport Research Record*. (CD-ROM), Washington, D.C.

Sayers, T.M., Jessop, A.T. and Hills, P.J. (2003) Multi-criteria evaluation of transport options - flexible, transparent and user-friendly. *Transport Policy*, 10: 95 - 105

Sener, I.N., Eluru, N. and Bhat, C.R. (2010). An analysis of bicycle route choice preferences in Texas, U.S. *89th TRB annual meeting* (CD-ROM), Washington, D.C.

Sustrans (2009). *Connect2 and Greenway Design Guide*. Bristol. [Second Draft].

Transport for London. (2005). *London Cycling Design Standard*. [Online]. Available at: http://www.tfl.gov.uk/businessandpartners/publications/2766.aspx. [Accessed 11 October 2011].

Transport Research Laboratory, (1999) Achieving the aims of the NCS – A summary of TRL research, Cycling into The Millennium: Selected TRL Research and Guidance. Crowthorne: Transport Research Laboratory. Pp.115-153.

Tolley, Rodney (2003). Sustainable Transport - Planning for Walking and Cycling in Urban Environments. Woodhead Publishing.

Transportation Cooperative Research Programme, (1999). Transit Capacity and Quality of Service Manual, *Transportation Research Board,* Washington D.C.

van der Waerden, P., Borgers, A. and Timmermans, H. (2005). User evaluation of pedestrian infrastructure: functional or by design. *84th TRB annual meeting and for consideration of publication in Transport Research Record*. (CD-ROM), Washington, D.C.

Wardman, M., Tight, M., and Page, M., (2007) Factors influencing the propensity to cycle to work', *Transportation Research Part A: Policy and Practice*, 41 (4): 339–350.

Highlights

- The paper produces a matrix for the evaluation of inter-urban cycleways
- The case study applies this evaluation to a cycleway in Ireland
- The research adds to the body of work producing methods of evaluating cycling infrastructure