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Exploring transportation equity: Development and application of a transportation justice framework

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ABSTRACT

Recent efforts to emphasize social equity in transportation are emerging as local, regional and national governments have set initiatives to identify, existing and potential, disproportionate impacts to low-income and minority populations, also referred to as transportation justice (TJ). Currently, there are suggested methods for identifying transportation justice areas; however, there is no streamlined method instituted across transportation agencies. Each jurisdiction identifies transportation justice (or environmental justice) areas based on their own methodology, typically based on either average regional thresholds, graduated thresholds, or a more unique in-house index methodology. This research explores and evaluates existing methods and develops a rigorous and comprehensive method called the Transportation Justice Threshold Index Framework (TJTIF) using Geographic Information Systems (GIS), as well as factors based on demographics, socio-economics, and transportation/land use. The framework is applied to a case study region in Pennsylvania reflective of the Marcellus Shale impact area, highlighting Sullivan County, PA. The methodology and the case study application serve as an example for how transportation agencies throughout the country can promote social sustainability and enhance transportation equity.

1. Introduction

Interest in sustainable practices throughout the transportation engineering sector continues to rise, and as a result, pressure to adopt more equitable, environmentally-friendly and affordable mobility, is necessary. In order to support the issue of social equity, transportation agencies are looking to environmental planning strategies to identify and avoid impacts (disproportionately) to low-income and minority populations, also referred to as environmental justice (EJ) areas (Rock et al., 2014). In 1993, the National Environmental Justice Advisory Council was established to provide recommendations to the Environmental Protection Agency on emerging issues, and since then, efforts to bridge EPA recommendations with the transportation sector have grown (EPA, 2014). More recently, the Federal Highway Administration has begun to promote environmental justice guidance for local transportation planning agencies as well as state Department of Transportation agencies through training, workshops and case studies (FHWA, 2014a). As a result, Department of Transportation (DOTs) agencies and Metropolitan Planning Organizations (MPOs) throughout the country have begun to focus on transportation justice (EJ applied to transportation planning) as a key component of their planning process.

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1.1. Motivation

Currently, there are guidebooks and suggested methods for identifying transportation justice (TJ) areas; however, there is no formal method for evaluating TJ areas across the country. Each jurisdiction identifies TJ (or EJ) areas based on their own methodology, typically based on average regional thresholds, graduated thresholds, or a more unique in-house index methodology (Parsons Brinckerhoff, 2004). The factors used for the existing methods tend to be focused on easily accessible demographic data (such as income level, and number of people per household); however, the opportunity to incorporate more specific travel data into the analysis is needed.

With agencies using a variety of methods and factors, consistency as well as the opportunity for comparison, is lacking between jurisdictions. Also, since a variety of methods are being used, the validity as well as rigor of the TJ plans can vary amongst the jurisdictions. As a result, there is a need to evaluate existing methods as well as an opportunity to develop a new, formalized method that expands the traditional EJ definition to transportation, using Geographic Information Systems (GIS).

1.2. Objectives

The primary objective of this research is to develop a formalized method for identifying transportation justice (TJ) areas using socio-economic factors correlated specifically to transportation mobility. The development of the Transportation Justice Threshold Index Framework (TJTIF) draws on existing methods, and tools developed by federal, state, and local transportation agencies in order to develop a more rigorous approach to identifying EJ populations (beyond the traditional demographic data currently used). A case study application based on Pennsylvania counties within the Marcellus Shale impact area (Bradford, Clinton, Lycoming, Sullivan, Susquehanna, Tioga, and Wyoming), with a spotlight on municipalities in Sullivan County, PA, is used in order to explore application to a real world network. The results of the case study provide the opportunity to enhance transportation equity within the region, as well as serve as an example for how agencies can apply TJTIF as part of their long range transportation planning process.

1.3. Research methodology

The following methodology is used to complete the research objectives:

1. Inventory existing EJ methods (transportation as well as other applications) through literature review.
2. Identify existing factors used for EJ areas and correlate to GIS databases/sources (publicly available) for spatial analysis.
3. Identify additional socio-economic and transportation factors not currently included in existing methods and correlate to GIS data layers.
4. Develop a rigorous GIS-based TJ method specific to transportation, Transportation Justice Threshold Index Framework (TJTIF), based on average regional thresholds (ARTs) and index values.
5. Apply the proposed TJTIF method to a case study region (Marcellus Shale impact area including seven counties and highlighting Sullivan County, PA) to determine applicability, as well as identify framework improvements.
6. Analyze the case study results based on location (regional differences) and identify future correlations to transportation-related issues such as Marcellus Shale impacts.
7. Identify future work including expansion of TJTIF and recommendations for agency application.

The results of this research will be beneficial not only to the local jurisdictions included in the case study, but also regionally, as the process is applicable throughout the country. Streamlining the process will allow for comparison between jurisdictions, opportunity for spatial analysis, as well as a rigorous identification of EJ populations as they apply to transportation and mobility.

2. Background

The following section includes a literature review on environmental justice, transportation equity, as well as current efforts by transportation agencies to address social sustainability. In addition, existing methods and factors used in identifying environmental (or transportation) justice regions are explored.

2.1. Transportation equity and environmental justice

Interest in sustainable practices throughout the engineering sector continues to rise, and as a result, pressure to adopt more equitable, environmentally-friendly, and affordable mobility is necessary. A balance between these three principles is required in order to achieve sustainability; however, there is a stronger focus on environmental criteria and system performance rather than on economic criteria and social objectives (Oswald, 2012). In order to equally balance the goals of the triple bottom line of sustainability (environment, economics, and society), environmental justice efforts that build on social equity principles are emerging (Rock et al., 2014).

Environmental justice is defined as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies" (EPA, 2014). Fair treatment refers to the goal of ensuring that all people, regardless of racial, ethnic or socioeconomic minority group, have a similar impact as a result of environmental consequence. As a result of Title VI of the Civil Rights Act of 1964, all federal agencies are required to integrate environmental justice into their mission, including the transportation sector (FHWA, 2012). Title VI, as well as other executive orders and legislation, protect environmental justice populations, defined as low-income and minority (U.S. Department of Labor, 2014).

2.2. Transportation justice

Recent efforts to emphasize social equity in transportation are emerging as local, regional and national governments have required agencies to identify and avoid impacts (disproportionately) to low-income and minority population. The U.S. DOT has identified three strategies to address environmental justice (FHWA, 2012):

- Reduce adverse human health and environmental effects on minority and low-income populations.
- Include all potentially affected communities in the transportation decision-making process.
- Ensure that minority and low-income populations receive equitable benefits.

Some agencies have expanded the concept of EJ areas to encompass transportation constrained populations, such as households without vehicles, disabled persons, and seniors (age 65+) (WILMAPCO, 2013), referred to as transportation justice (TJ) areas. Transportation justice can be referred to as the expansion of environmental justice principles to transportation through investigating mobility, access, and modal opportunity.

Studies have shown that low-income, minority, and transportation constrained communities are more at risk for being impacted by the environmental and systematic burdens of transportation development (Forkenbrock and Schweitzer, 2007). Therefore, transportation justice requires that transportation system planning, design, and construction processes be carefully evaluated to identify the nature, extent, and incidence of probable consequences, both favorable and adverse.

2.3. Current efforts

As efforts to promote social equity continue, research studies as well as practical applications have emerged. In terms of research efforts, the NCHRP Project 8-36 (11) includes a review of existing justice issues, as well as an investigation of analysis methods used by MPOs, local transit agencies, and state DOTs (Cambridge Systematics, 2012). Amekudzi et al. (2012) explores the application process of EJ efforts and establishes an EJ Maturity-Scale Model which reflects three phases of EJ involvement. Differences in EJ accessibility (Preston and McLafferty, 1999), travel opportunity (Law, 1999), safety issues (Deka, 2004), and public involvement (Bailey and Grossardt, 2012) have also been explored. In addition, Chakraborty et al. (1999) and Mills and Neuhauser (2000) have used GIS-based proximity analysis to evaluate environmental justice. However, Chakraborty (2006) suggests that "practical indicators and standardized measures are necessary" in order to ensure that EJ analysis is a fundamental component of the long range transportation planning process. More recently, FHWA (2015) released an *Environmental Justice Reference Guide* for FHWA staff in order to ensure compliance with EJ requirements through clarifying expectations, identifying best practices, and providing resources.

In terms of case study applications, environmental justice studies in specific localities including California (Martin Clark et al., 2013; Seo et al., 2013; Johnston et al., 2011), and New Jersey (Kravetz and Noland, 2012) have been completed and suggest that governmental support as well as improved methods and models can promote environmental justice awareness with regard to both passenger and freight transportation systems.

Through a review of existing EJ (or TJ) methodologies at various scales (federal, state, and local), three primary methods emerged: threshold approach, graduated scale approach, and the index approach. The following sections describe the individual methods as well as provide strengths and weaknesses for each.

2.3.1. Threshold approach

The threshold approach uses an established threshold for identifying whether a community meets or exceeds a specific demographic attribute. The thresholds are typically based on regional averages and are then used to identify whether or not the localities exceed the average (PennDOT, 2012). Currently, agencies such as SEDA-COG (2014) and DVRPC (2013) use a threshold-based approach, however, there are variations in how the average threshold is calculated and applied. Parsons Brinckerhoff (2004) suggests two methods in order to determine EJ areas; using a statewide/regional representation, or using a flat percentage of minority composition.

The major strength of the average threshold approach is the ease with which it can be calculated. However, the main two weaknesses are relativity and failure to convey intensity. This can be especially problematic if the regional average is already high, relative to the national average, resulting in a number of communities falling below the threshold despite having a need in comparison to the national level (PennDOT, 2012).

2.3.2. Graduated scale approach

The second approach is a graduated scale approach, which allows the factoring of intensity in identifying EJ populations (PennDOT, 2012). Similar to the threshold approach, graduated thresholds are identified and the degree of "need" can be determined based on a rating scale. For example, a scale of 100 points can be applied to each metric. If there are five metrics, then the total point value that can be achieved is 500 and then the corresponding point value of each locality would be compared to the total. This scale approach is reflective of traditional sustainable rating systems, such as LEED (USGBC, 2014), which are based on points and are compared to a rating scale to determine project sustainability.

2.3.3. Index approach

In contrast to the threshold approach, agencies such as the Wilmington Area Planning Council (WILMAPCO, 2013), are using an index method where points are assigned to each region based on their attainment (or non-attainment) of a metric. Although thresholds are not used, the points assigned to each area are totaled and compared to each other to determine high priority areas.

In terms of research studies, Chakraborty (2006) identifies two index methodologies; a Buffer Comparison Index and an Area Comparison Index. Both of these indices involve calculating ratios of the percentage of those impacted who met a specific factor, to the ratios of those impacted who did not meet a specific factor (Chakraborty, 2006)

The methods described above have both strengths and weaknesses, as explored by PennDOT (2012); however, this research aims to incorporate the strengths of each and identifies a synthesized method that utilizes regional averages, relative threshold scales, and index values to determine level of intensity when identifying TJ areas.

2.4. GIS integration

Geographic Information Systems (GIS) can serve as a fundamental tool in the process of identifying EJ (or TJ) regions. The use of GIS allows agencies to map spatial information, while also performing quantitative data analysis. Geospatial tools can enhance communication, decision-making, and data-sharing (FHWA, 2014b). Layers of demographic data, transportation infrastructure systems, and land use features can be overlaid and used to quantify transportation justice metrics as they pertain to jurisdictional areas. Studies such as Tresidder (2005) explore ways to measure connectivity and other transportation-related needs using GIS. FHWA (2012) suggests that transportation agencies should have employees with GIS expertise to help identify the spatial analysis process needed for mapping EJ areas, which can be used to further identify transportation investment projects.

This research integrates the use of GIS into the development of a rigorous methodology for identifying TJ areas, based on the strengths of existing methods. There is a need to develop a framework that includes a comprehensive list of environmental and transportation justice factors and incorporates regional averages, relative threshold scales, and index values to identify TJ areas. The development of the Transportation Justice Threshold Index Framework (TJTIF) provides the opportunity for agencies to have a well-defined, step-by-step method that can be integrated into the long range transportation planning process.

3. Development of TJTI F

In order to develop a comprehensive method that draws on the strengths of existing environmental justice methods with an application to transportation, the Transportation Justice Threshold Index Framework (TJTIF) was developed. The following

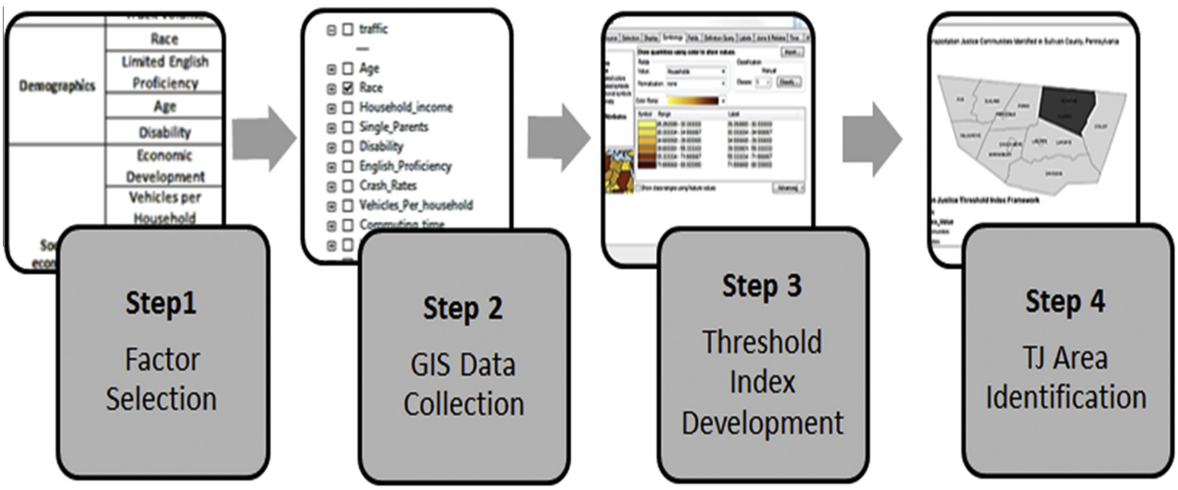

Fig. 1. TJTIF methodology.

section includes the step-by-step process of how TJTIF was developed, as shown in Fig. 1: (1) Factor Selection, (2) GIS Data Collection, (3) Threshold Index Development, and (4) TJ Identification. These four steps can be followed by an agency in order to identify transportation justice areas within their jurisdiction.

3.1. Factor selection

Based on a literature review of research articles, agency plans and methods, as well as a variety of national and international case study applications, a list of environmental justice and transportation equity factors was collected. A total of 18 factors were identified and they were then organized based on three major categories: (1) Demographics, (2) Socio-economics, and (3) Transportation & Land Use. The demographics and socio-economic factors are strongly correlated to existing EJ methods, however, location-based (transportation and land use) factors were added to the list in order to emphasize transportation and urban planning equity issues.

Including demographic factors (such as race, English proficiency, and age) and socio-economic factors (such as household income, vehicles per household, and cost of living) provide insight into the variability of modal options and mobility services across various communities in order to identify specific needs to support equity. The cost of transportation, the accessibility, as well as language barriers can influence mode choice in addition to just whether or not the infrastructure is in place. Therefore, identifying community needs is essential in order to provide effective and equitable transportation services. This relates to the transportation and land use factors (such as public transit access, school proximity, and network connectivity) which provide insight into the availability of mode options based on infrastructure design and land use planning. Facilities such as transit stops, pedestrian walkways, and bike lanes are required in order to encourage modal alternatives in place of the automobile (especially for the non-driving population). Therefore, ensuring all communities have access to mode choice is essential and can be supported with well-connected street networks, mixed land uses, and context sensitive planning.

As this list of factors was developed, identification of overlapping factors as well as data accessibility was determined. Since each factor would be measured based on readily accessible data, factors included in TJTIF were based on typical data formats, ideally from U.S. Census (2010), the Bureau of Transportation Statistics (BTS, 2014), or other government sources. For example, Duvarci and Yigitcanlar (2007) discuss the importance of determining travel conditions of commuters and school students, including travel time, costs, methods, and comfort levels. As a result, factors such as Travel Time and School Proximity were added to the list and specific definitions (tied to a quantitative measurement) were determined.

Table 1 shows the list of the factors, the quantitative definition, and a potential data source. This list is not exhaustive as agencies can identify jurisdiction-specific TJ factors and/or expand the list based on emerging environmental justice issues. In addition, agencies should identify factors that are not applicable to the jurisdiction in order to exclude them from the analysis. For example, if a jurisdiction does not have fixed route public transit service, then the Public Transit Access factor can be removed.

3.2. GIS data collection

GIS is a fundamental tool in applying TJTIF as it can be used to spatially map demographic, socio-economic, and transportation/land use factor data. Based on the study area under analysis, a base map is created including the jurisdictional boundaries, municipalities, roadways, school locations, transit network, etc. Once the base map is established, data files corresponding to each of the TJ factors (listed in Table 1) should be imported and joined into GIS. For example, for the Race factor, demographic shapefiles from the U.S. Census (2010), organized by municipality, can be overlaid and joined with the municipality boundary file. The U.S. Census (2010) measurement of "percentage of non-white population with two or more races" is used and the corresponding values for each municipality are determined. In general, the factors within the Transportation & Land Use category can be directly based on agency data, and if the agency maintains a set format for data collection, the information can be readily accessible for the TJTIF application.

Once the data files are joined, GIS can be used to create graduated scale spectrums for each of the TJ factors. Using the individual GIS data files to determine a graduated scale allows for the scale of each factor to reflect the relativity of the areas under evaluation. For example, rather than setting a standard 0–100% scale where a factor application to a region may only result in values from 0 to 51%, the scale would be set based on the minimum (0%) and maximum (51%) value. This relative graduated scale serves as the foundation for the development of the threshold index.

3.3. Threshold index development

The next step includes the development of the thresholds and index values. For each TJ factor, the Average Regional Threshold (ART) value is calculated (for the entire jurisdiction) by determining the average value for each factor all municipalities in the region. Then, the index is created by applying the results of the relative graduated scale determined using GIS for each factor. The scale was calculated by dividing the scale into seven different categories, based on the distance between the ART (representing the mid-point) and the minimum and maximum values for every factor. For example, if a factor has a minimum value of 0%, a maximum value of 51% and an ART of 10%, then the scale would be as follows: −3 points (0–3%), −2 points (3.01–7%), −1 points (7.01–9.99%), 0 points (10%), 1 point (10.01–23%), 2 points (23.01–37%), and 3 points (37.01–51%). Therefore, any municipalities with more than 10% (greater than the ART) would receive a positive value, indicative of a higher need.

Table 1
Transportation justice factors.

Category	TJ Factor	Definition (Measure)	Possible source	Direction of need
Transportation and land use	Public transit Access	Percentage of area that is within one mile buffer of a fixed route transit or rail stop	BTS (2014)	Below average
	School proximity	Percentage of area within one mile buffer of a school	NCES (2014)	Below average
	Network connectivity	Percentage of area within one mile buffer of highway access point	BTS (2014)	Below average
	Mixed land uses	Percentage of area that is mixed land use	Local zoning board	Below average
	Flood hazard	Percentage of area that is designated by FEMA as 100 year floodplain	FEMA (2014)	Above average
	Crash rates	Percentage of crashes per year that are fatal	NHTSA (2014)	Above average
	Truck volume	Percentage of truck traffic per current annual average daily traffic rate	FHWA (2014c)	Above average
	Intermodal facilities	Percentage of transportation facilities with two or more types of connecting modes	BTS (2014)	Below average
Demographics	Race	Percentage of non-white population including two or more races	U.S. Census (2010)	Above average
	Limited english proficiency	Percentage of people who speak another language at home, and who speak English "less than very well"	U.S. Census (2010)	Above average
	Age	Percentage of population below the age of 18, and above the age of 65	U.S. Census (2010)	Above average
	Disability	Percentage of civilian non-institutionalized population with a disability	U.S. Census (2010)	Above average
Socio-economic	Economic development	Percentage difference in people employed between two different census years	U.S. Census (2010)	Below average
	Vehicles per household	Percentage of households with less than two vehicles per household	U.S. Census (2010)	Above average
	Household income	Percentage of households that are making less money than the average median household income of the area	U.S. Census (2010)	Above average
	Single parent household	Percentage of single parent household regardless of whether or not they have children under 18 as a compared to familial households	U.S. Census (2010)	Above average
	Cost of living	Percentage of people with a median Monthly Housing Costs for occupied housing units below the regional average	U.S. Census (2010)	Above average
	Travel time	Percentage of commuters spending more than the median travel time to work	U.S. Census (2010)	Above average

When assigning the scale values, it is important to identify the direction of need in comparison to the ART. Based on the last column of Table 1 (Direction of Need), the factor scale can be determined based on whether a lower percentage indicates a higher need (Below Average), or if a higher percentage indicates a higher need (Above Average). For example, for the factor, School Proximity, a lower percentage of area that is within the one mile buffer indicates a higher need, therefore, the relative graduated scale should reflect this direction of need.

3.4. TJ region identification and recommendations

Once the index value for each metric is determined, the composite index value can be calculated (sum of all metric index values) for a municipality. The composite index value (shown in Eq. (1)) can be calculated for all municipalities under evaluation.

$$\textit{Composite Index Value} = \sum_{i=1}^{n}(F_i),\ \textit{if} > 0\ \textit{then TJ region} \tag{1}$$

where F = factor index value, i = factor, and n = total number of factors.

A positive composite index value (greater than 0) indicates a TJ area, while a negative composite index value suggests that the municipality is not a TJ area. If a composite index value equals 0, it is suggested that the municipality be investigated more in depth as it may be a potential TJ area in the near future. The composite index values can be calculated either manually or using GIS attribute tables. If GIS is used, the composite index values can be displayed using symbology to indicate TJ areas within the jurisdictional region. This helps planners as well as constituents visualize the communities that are in need, which can be useful in planning for future projects and allocating resources.

4. Case study application

In order to test the applicability and relevance of TJTIF to a real world jurisdiction, a case study application is used. The case study area is based on a connected region with similar impacts related to the Marcellus Shale drilling initiative. The following section includes a description of the study area, the application and results of TJTIF, and reflections on the framework and case study process.

4.1. Study area selection

A case study area was selected including counties within the northern and central region of Pennsylvania that have a unifying characteristic of being located within the Marcellus Shale drilling initiative area. As a result of new fracking techniques, the exploration, development and recovery of Marcellus Shale natural gas reservoirs within Pennsylvania has been an increasing focus (PA DCNR, 2009). Although efforts to maintain safety with regard to water use and drilling impacts continue (PA DEP, 2014), traffic has increased since trucks are the primary mode used to transport materials needed for drilling (Considine et al., 2011). Therefore, by applying TJTIF to municipalities within this Marcellus Shale region, there is the opportunity to identify TJ areas based on demographic, socio-economic, and transportation/land use factors. In addition, this allows for future work with regard to identifying Marcellus Shale-related factors and future planning initiatives to promote transportation equity within the region.

Seven counties within the Marcellus Shale impact region (Bradford, Clinton, Lycoming, Sullivan, Susquehanna, Tioga, and Wyoming) were selected based on the fact that they are on the list of top 15 "Counties by Number of Wells" (PA DEP, 2012) and have adjoining jurisdictional boundaries. Fig. 2 displays the seven counties, which serve as the basis for calculating the Average Regional Thresholds (ARTs). In order to show the complete TJTIF application process, Sullivan County (with 13 municipalities) was analyzed and the composite index values were calculated for each TJ factor based on comparing each municipality to the ART value (based on the seven counties). Although Sullivan County is highlighted in this case study, a similar process can be used and applied to all municipalities within the seven county region (total of 247 municipalities).

4.2. Application of TJTIF

The following section includes the application of the four step process of TJTIF including the factor selection, GIS data collection, threshold index development, and the TJ identification. These steps reflect the method shown in Fig. 1 and are applied to the case study region, highlighting Sullivan County.

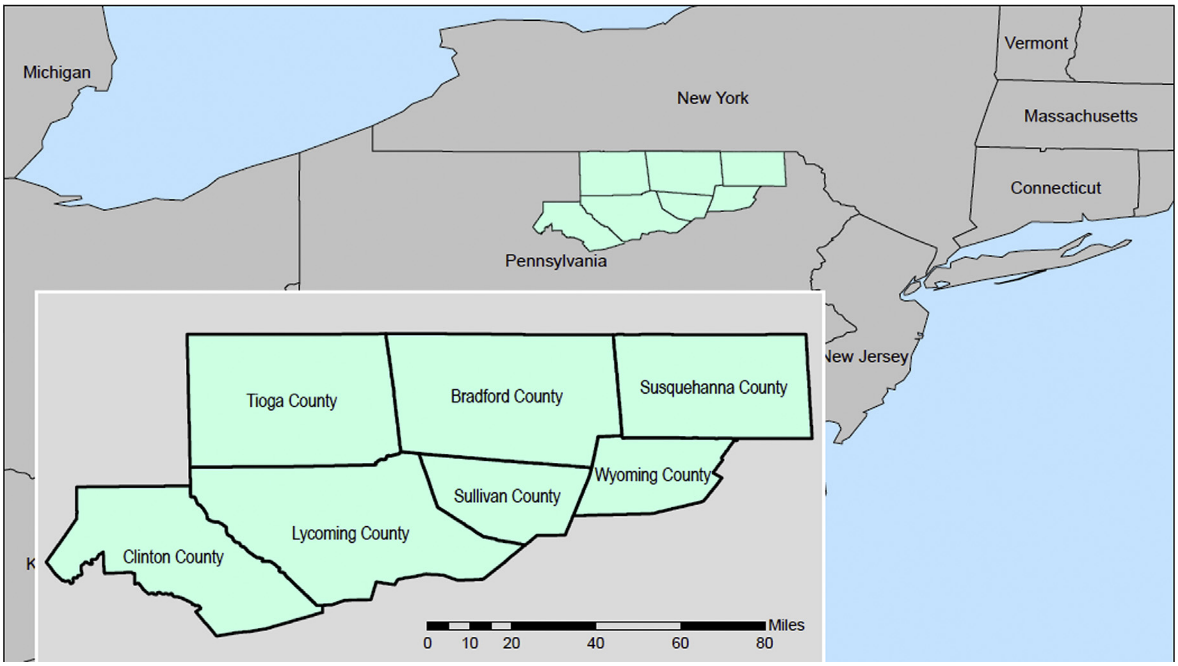

Fig. 2. Case study area- seven county region in PA.

4.2.1. Factor selection

Based on the list of 18 TJ factors identified previously, the list was reviewed and the factors that did not pertain to this region were eliminated. For example, Public Transit Access was not included since the area does not have a fixed route public transit service. In addition, factors that did not have supporting publicly available information and/or the data supporting the factors was not readily accessible for the case study region, the factor was removed from the analysis. This primarily was the case for factors within the Transportation and Land Use category since many of the data sets would be based on agency-specific information. The factors that could be gathered for the seven counties based on accessible national or statewide sources, included Crash Rates (PennDOT, 2014) and Traffic Volume (FHWA, 2014c). Since an agency would be completing the study based on their own jurisdiction, access to the Transportation and Land Use factor data would be more readily accessible. All of the factors under the Demographics and Socio-economic categories were included. This resulted in a total of 12 TJ factors that were included in the TJTIF case study application.

4.2.2. GIS data collection

The list of 12 TJ factors identified for the case study application was examined and the data was gathered using a tabular as well as GIS-based spatial format. The data that supported the Demographic and Socio-economic factors was acquired using the American Fact Finder, U.S. Census (2010) website. As mentioned previously, Transportation and Land Use factors were not as readily accessible and publicly available for the seven counties; therefore, the two factors that were included were Crash Rates (PennDOT, 2014) and Traffic Volume (FHWA, 2014c).

The data was collected for all 274 municipalities within the seven county region in order to calculate the Average Regional Threshold (ART). In order to show the complete application process of TJTIF, Sullivan County (including 13 municipalities) was chosen since the process would be identical for all counties. For each TJ factor, data was collected and calculated based on the definition shown in Table 1. For example, the Race factor was calculated based on U.S. Census (2010) data for each municipality in order to determine the percentage of non-white population including two or more races. The percentage was calculated by taking the sum of the total of people who identify as non-white including two or more races, divided by the total number of people included in the survey and multiplied by 100. A percentage was calculated for all 274 municipalities and then the average value was determined which represents the Average Regional Threshold (ART). In addition, the minimum and maximum values were calculated based on all 274 municipalities within the seven counties. Table 2 shows the regional values including the minimum, maximum, and ART based on the seven counties. The raw data for each of the factors applied to each municipality in Sullivan County is also shown in Table 2.

4.2.3. Threshold index development

In order to integrate the threshold method with the index value to reflect relative gradients between the factor values for the region, a threshold index was applied to the case study. Using the ARTs as well as the minimum and the maximum values for all seven counties, scales were developed for each of the 12 TJ factors, using three levels above and below the ARTs. The ART represents the equilibrium point receiving a value of 0 points with the minimum and maximum set as the lowest and highest value of the scale. For example, for the factor Vehicles per Household, a minimum value of 10%, a maximum value of 76%, and an ART of 34.3% were calculated. The relative graduate scale based on three levels above and below was determined to be the following: 10–18.1% (−3 points), 18.11–26.21% (−2 points), 26.22–34.29% (−1 points), 34.3% (0 points), 34.31–48.21% (1 point), 48.22–62.11% (2 points), and 62.12–76% (3 points).

Table 3 displays the relative graduated scale for each factor based on the seven county region. This scale was then applied to the 13 municipalities within Sullivan County in order to determine the TJ areas. Again, the same process would be followed if all 274 municipalities were evaluated for TJ identification, however, Sullivan County is highlighted in this case study.

4.2.4. TJ identification and recommendations

Once the relative graduated scales for each factor are calculated and the threshold index is complete, the index values can then be assigned to each factor for each of the municipalities. All 13 municipalities within Sullivan County were compared to the scales shown in Table 3. Table 4, displays the index values assigned to each factor for each municipality based on the data being above or below the ART.

The final step was to calculate the composite index value (based on Eq. (1)) for each municipality, as shown in Table 4. A positive composite index value (1 or more) indicates a TJ region reflective of need (in comparison to the seven county average regional threshold). In contrast, a negative value suggests that there is less of a need, and therefore, should not be considered a TJ area. If a value of zero is calculated, this would suggest that the region requires additional investigation as it may become a future TJ area.

The results of the case study showed that there were three municipalities, Cherry Township (2 points), Davidson (1 point) and Dushore Borough (3 points), within Sullivan County that should be identified as TJ areas. The ten other municipalities resulted in composite index values less than zero suggesting that they are not a high priority based on the TJ factors included in the case study. Table 4 displays the tabular results for the 13 municipalities and Fig. 3 displays the results in GIS based the composite index values.

Table 2
Sullivan county TJTIF application compared to seven county region.

		Regional Values (based on 7 counties)			Municipalities in Sullivan County												
	TJ Factor and Source	**Region Min**	**Region Max**	**ART**	**Cherry**	**Colley**	**Davidson**	**Dushore Borough**	**Eagles Mere Borough**	**Elkland**	**Forks**	**Forksville Borough**	**Fox**	**Hillsgrove**	**Laporte Borough**	**Laporte Township**	**Shrewsbury**
Transportation & Land Use	**Crash Rates** (PennDOT, 2014)	0%	50%	1.9%	3.57%	0%	7.69%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Truck Volume (FHWA, 2014b)	0%	51%	9.8%	13%	10%	11%	9.9%	6%	13.3%	13.8%	12.75%	9.7%	10.6%	11.9%	12.5%	6.8%
Demographics	**Race** (U.S. Census, 2010)	0%	19%	2.3%	5.43%	14.49%	4.29%	0.85%	4%	0.68%	2.52%	0%	2.55%	0%	1.25%	0%	12.4%
	Limited English Proficiency (U.S. Census, 2010)	0%	14%	0.83%	0%	1.54%	0%	0.21%	0%	0%	0.42%	0%	0%	0.82%	0%	0%	0%
	Age (U.S. Census, 2010)	21%	75%	39.7%	43%	31.17%	34%	38%	75%	52%	37.89%	47.06%	49.3%	46.69%	46.25%	45.62%	35.84%
	Disability (U.S. Census, 2010)	2.6%	37%	16.1%	16.71%	20.27%	27.15%	20.24%	2.63%	26.82%	17.4%	30.59%	31.91%	26.87%	15.43%	14.5%	17.79%
Socio-economic	**Economic Develop.** (U.S. Census, 2010)	-25%	14.1%	-0.5%	0.29%	14.1%	-0.05%	0.18%	0%	0%	-1.05%	0%	7.74%	-9.54%	-2.21%	-4.49%	2.15%
	Vehicles per Household (U.S. Census, 2010)	10%	76%	34.3%	35%	35.52%	28.71%	66.34%	46.15%	24.84%	18.68%	62.75%	41.58%	18.05%	44.44%	36.07%	25%
	Household Income (U.S. Census, 2010)	26%	88%	55.5%	56.82%	59.56%	63.64%	77.24%	76.92%	63.64%	43.95%	84.3%	75.25%	47.22%	60.32%	37.7%	55.7%
	Single Parent Household (U.S. Census, 2010)	0%	53%	20%	18.3%	13.1%	21.74%	29.63%	0%	4%	8.39%	0%	9.46%	0%	7.69%	15.29%	4.76%
	Cost of Living (U.S. Census, 2010)	11.6%	100%	52.5%	62.6%	67.9%	48.8%	82.4%	66.6%	61.4%	65.6%	47%	64.6%	60.4%	35.5%	48.6%	59.7%
	Travel Time (U.S. Census, 2010)	17%	91%	63%	56.26%	62.04%	64.2%	79.91%	50%	52.68%	47.81%	47.06%	35.7%	26.59%	78.63%	69%	45.91%

Table 3
Case study relative graduated scale based on regional minimum, maximum, and ART values.

Category	Factor	Regional Values (based on 7 counties)			Index Point Value						
					-3	-2	-1	0	1	2	3
		Region Min	Region Max	Avg. Regional Threshold	Relative Graduated Threshold Scale (based on 7 counties)						
Transportation and Land use	Crash Rates	0%	50%	1.9%	0 to 0.63%	0.64 to 1.26%	1.27 to 1.89%	1.9%	1.91 to 17.94%	17.95 to 33.97%	33.98 to 50%
	Traffic Volume	0%	51%	9.8%	0 to 3.26%	3.27 to 6.53%	6.54 to 9.79%	9.8%	9.81 to 23.53%	23.54 to 37.23%	37.24 to 51%
Demographic	Race	0%	19%	2.3%	0 to 0.76%	0.77 to 1.53%	1.54 to 2.29%	2.3%	2.31 to 7.88%	7.89 to 13.44%	13.45 to 19%
	Limited English Proficiency	0%	14%	0.83%	0 to 0.28%	0.29 to 0.55%	0.61 to 0.82%	0.83%	0.84 to 5.23%	5.24 to 10.46%	10.47 to 14%
	Age	21%	75%	39.7%	21 to 27.2%	27.21 to 33.46%	33.47 to 39.69%	39.7%	39.71 to 51.47%	51.48 to 63.23%	63.24 to 75%
	Disability	2.6%	37%	16.1%	2.6 to 7.1%	7.11 to 11.6%	11.61 to 16.09%	16.1%	16.11 to 23.08%	23.09 to 30%	30.01 to 37%
Socio-economic	Economic Development*	-25%	14.1%	-0.5%	14.1 to 9.18%	9.17 to 4.34%	4.33 to -0.49%	-0.5%	-0.51 to -9%	-9.01 to -17%	-17.01% to -25%
	Vehicles per Household	10%	76%	34.3%	10 to 18.1%	18.11 to 26.21%	26.22 to 34.29%	34.3%	34.31 to 48.21%	48.22 to 62.11%	62.12 to 76%
	Household Income	26%	88%	55.5%	26 to 35.8%	35.81 to 45.66%	45.67 to 55.49%	55.5%	55.51 to 66.34%	66.35 to 77.17%	77.18 to 88%
	Single Parent Household	0%	53%	20%	0 to 6.67%	6.68 to 13.33%	13.34 to 19.99%	20%	20.01 to 31%	31.01 to 42%	42.01 to 53%
	Cost of Living	11.6%	100%	52.5%	11.6 to 25.23%	25.24 to 38.86%	38.87 to 52.49%	52.5%	52.51 to 68.33%	68.34 to 84.16%	84.17 to 100%
	Travel Time	17%	91%	63%	17 to 32.33%	32.34 to 47.66%	47.67 to 62.99%	63%	63.01 to 72.34%	72.35 to 81.67%	81.68 to 91%

[*] Direction of need is below average so lower percentage indicates higher need.

Table 4
TJTIF case study application to Sullivan County, PA.

Category	TJ Factor	Municipality in Sullivan County												
		Cherry	Colley	Davidson	Dushore Borough	Eagles Mere Borough	Elkland	Forks	Forksville Borough	Fox	Hillsgrove	Laporte Borough	Laporte Township	Shrewsbury
Transportation & Land Use	Crash Rates	1	-3	1	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
	Truck Volume	1	1	1	1	-2	1	1	1	-1	1	1	1	-1
Demographics	Race	1	3	1	-2	1	-3	1	-3	1	-3	-2	-3	2
	Limited English Proficiency	-3	1	-3	-3	-3	-3	-2	-3	-3	-1	-3	-3	-3
	Age	1	-2	-1	-1	3	2	-1	1	1	1	1	1	-1
	Disability	1	1	2	1	-3	2	1	3	3	2	-1	-1	1
Socio-economic	Economic Development	-1	-3	-1	-1	-1	-1	1	-1	-2	2	1	1	-1
	Vehicles per Household	1	1	-1	3	1	-2	-2	3	1	-3	1	1	-2
	Household Income	1	1	1	3	2	1	-2	3	2	-1	1	-2	1
	Single Parent Household	-1	-2	1	1	-3	-3	-2	-3	-2	-3	-2	-1	-3
	Cost of Living	1	1	-1	2	1	1	1	-1	1	1	-2	-1	1
	Travel Time	-1	-1	1	2	-1	-1	-1	-2	-2	-3	2	1	-2
Composite Index Value*		**2**	**-2**	**1**	**3**	**-8**	**-9**	**-8**	**-5**	**-4**	**-10**	**-6**	**-9**	**-11**

*Positive values (>0) are indicative of higher need and reflective of TJ regions (based on Average Regional Threshold for 7 counties).

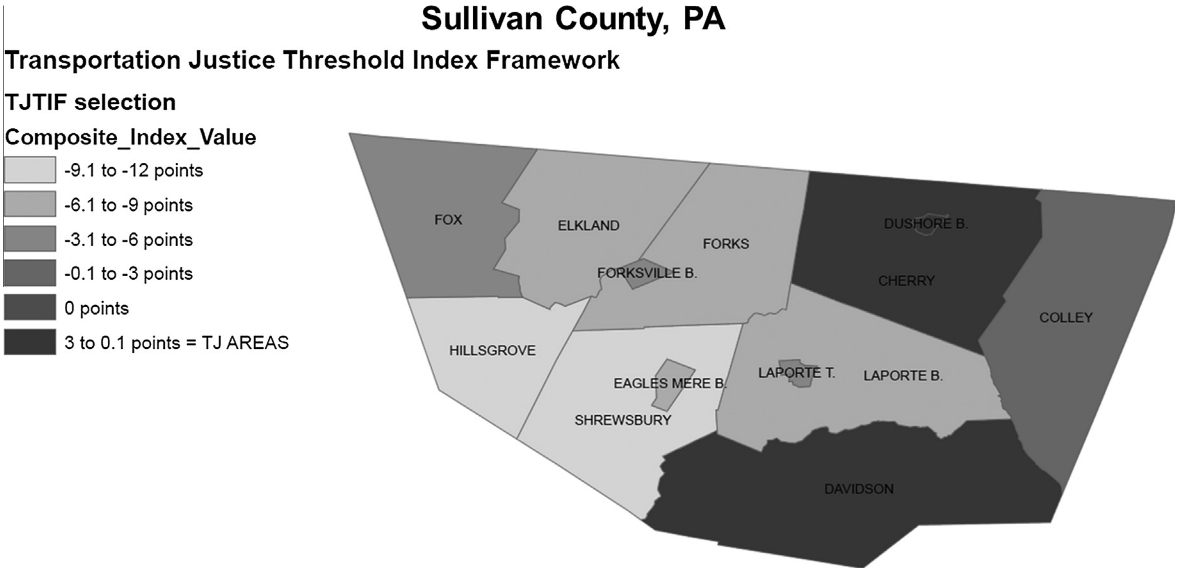

Fig. 3. TJTIF case study results for municipalities in Sullivan County, PA.

4.3. Reflections

The case study application suggests that the process of applying TJTIF is applicable and relevant to a real world network. In addition, the case study indicates that Sullivan County has three municipalities that should be emphasized when applying transportation equity improvements. Cherry Township, Davidson Township, and Dushore Borough are identified as TJ areas based on the TJTIF application of the seven county region including Bradford, Clinton, Lycoming, Sullivan, Susquehanna, Tioga, and Wyoming. In addition, the index method allows for a prioritization of all municipalities under investigation. So although the ten remaining municipalities did not result in a composite index value that suggests it should be identified as a TJ area, the point value does reflect a level of need (higher value represents higher need).

Based on these results, correlations to existing environmental justice plans as well as Marcellus Shale data can be made. For example, Cherry Township (the municipality with a composite index value of 2) currently has the most number of wells in the county (26 pads out of a total of 72) for Marcellus Shale drilling (PA DEP, 2012). Further analysis of the associated transportation-related issues such as truck traffic, air quality, and road degradation, can be explored as transportation planning design and development decisions are made.

A more detailed analysis of the individual factor index values can be used to determine specific areas of need. If an agency has funding to support specific initiatives (corresponding to specific factors), the agency can quickly identify which municipalities have a higher priority of need. For example, Dushore Borough and LaPorte Borough both received a value of 2 for Travel Time; therefore, transportation planners can apply demand management strategies to reduce commute times.

4.3.1. Limitations

The application process of TJTIF to the case study region had limitations that can be addressed by an agency when they are directly applying it to their own jurisdiction. In general, agencies should aim to include as many factors as possible into the analysis, given that data is accessible and relevant. Specifically, the factors within the Transportation and Land Use category are based on data that may be more readily accessible by the agency. However, similar to the case study, selected factors that only pertain to the region should be applied. For example, since there is no fixed route transit service within the seven county region, the Public Transit factor was not incorporated, however, the factors that are not included could be considered as an opportunity or improvement for the entire region. In addition, the list of TJ factors can be adapted and expanded to incorporate needs of the agency as well as unique features of the jurisdiction.

Sullivan County was highlighted in this research; however, a similar process can be completed for all 247 municipalities within the seven county region. Since the process is identical and the case study was used to test the process, the 13 municipalities in Sullivan County were selected. Also, the results of the case study may vary with the addition or subtraction of specific TJ factors, therefore, the results should always be reported with the list of factors included in the application.

In addition, using a larger case study area that compares counties impacted by Marcellus Shale with those outside of the impact area would provide a larger context for the degree of impact. In particular, factors such as Truck Volume would be valuable to compare so that the relative scale reflects a wider range of variability rather than just based on the areas which have experienced a similar impact (such as increased truck volumes as a result of the Marcellus Shale drilling). Since the scale is based on a comparison of other regions, a municipality with an increase in truck traffic may still result in a low point value when compared to other municipalities. Therefore, including more municipalities and counties within the case study is of interest in order to identify a scale that is applicable to all jurisdictions under analysis.

4.3.2. Future work

In order to address some of the limitations as well as explore opportunities to improve TJTIF, future work is proposed. In the case study application, Sullivan County was highlighted, however, all 247 municipalities can be included to determine the TJ regions for the remaining six (out of seven) counties. Although the process is the same, the results can then be used to compare the TJTIF results to existing EJ areas determined by regional transportation planning organizations. Additional case studies of TJTIF are recommended and should include a variety of regions that differ with regard to geography, level of urbanization, and size. Again, TJTIF results can then be compared to existing EJ plans.

In terms of the threshold index development step of the framework, additional work with regard to the calculation of the relative graduated scale can be completed. Currently, in order to determine an index value, three levels above and below the ART are calculated; however, future work is recommended to explore how an increase in the number of levels (more than 3 thresholds above and below the ART) can impact the final result. In addition, there is the opportunity to determine factor weights that reflect the level of importance toward TJ regions. In this study, it was assumed that all factors were equally important as it is challenging to prioritize one inequity over another. Although ranking inequities may be challenging, the opportunity could be explored (using multi-criteria decision analysis tools) and compared to the results of equal weighting. For example, the Analytic Hierarchy Process (AHP) is a process that assigns weights based on level of importance to the overall goal using pairwise comparisons (Saaty, 1982). Future work could include developing a pairwise comparison survey and using the AHP process to weight the individual factors based on value toward addressing transportation justice. This could be done at the regional or state-wide level in order to account for context sensitive issues such as a lack of data available for specific factors. Similar weights would have to be used in order to allow for a comparison amongst regions when identifying TJ areas and also the effect of ecological correlation (comparison of two group means) would have to be considered when evaluating the results. Lastly, the influence of the survey participant backgrounds and their perspectives toward the individual factors would have to be considered when finalizing weights as the results are directly related to the participants included.

In order to enhance the application process, data collection methods should be standardized in order to streamline the process and allow for yearly updates. In order to capture changes within the transportation network as well as demographic and socio-economic changes, TJTIF should be implemented yearly. Therefore, future work includes repeating the study in future years to see how changes in individual data can influence the overall composite index values and final TJ identification. Evaluating data over time can also be useful in refining the factors in order to capture longitudinal results, such as using a five-year rolling average to determine temporal trends. Also, future work on exploring the influence of jurisdictional size on factor results as well as applicability of factors to all jurisdictions is recommended. The opportunity for refining the factor measures relative to spatial as well as modal differences is valuable to understanding the final composite index value.

Lastly, it should be noted that although the TJ method presented in this research has a systematic process, it is recommended that the social dimension and public outreach of connecting with constituents is of value, prior to the identification of the TJ areas. Public participation and inclusion in the process can provide insight into non-quantifiable factors as well as understanding context specific needs. Public engagement should be included as one of the first steps in order to allow for factor identification and applicability as well as to provide opportunities for comprehensive data collection. Therefore, future work can include identifying opportunities for public engagement at the beginning and throughout the process so that the results reflect the multiple dimensions of transportation justice as well as more accurately reflect the needs of the communities involved.

5. Conclusion

Transportation justice is an issue of rising importance as suggested by current efforts in federal, state, and local application of EJ areas to transportation planning. Currently, there are suggested methods for identifying Transportation Justice (TJ) areas; however, each jurisdiction identifies TJ areas based on their own methodology using average regional thresholds, graduated thresholds, or a more unique in-house index methodology.

In order to streamline the TJ identification process, this research explores and evaluates existing methods and develops a rigorous and comprehensive method called the Transportation Justice Threshold Index Framework (TJTIF) using Geographic Information Systems (GIS) as well as factors based on demographics, socio-economics as well as transportation and land-use. The method includes four primary steps: (1) Factor Selection, (2) GIS Data Collection, (3) Threshold Index Development, and (4) TJ Identification and Recommendations. In order to test the applicability of TJTIF, the method is applied to a case study region in Pennsylvania reflective of the Marcellus Shale impact area, highlighting Sullivan County, PA. The results indicate that there are three municipalities within Sullivan County, including Cherry Township, Davidson Township, and Dushore Borough, that should be considered as TJ areas based on 12 TJ factors included in the case study evaluation.

The results of the case study suggest that the framework is applicable to a real world network and they can be used for future transportation equity improvements within Sullivan County. Future work includes additional case studies on other jurisdictional locations with variations in size and demographics, exploring factor weights, and integrating public participation into the process. The results of additional case studies can be used to enhance and improve TJTIF with the goal of streamlining and integrating transportation equity into the transportation planning process across the country.

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