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Impact evaluation of different types of transportation projects using meta-analysis

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Abstract

Local, regional and national government agencies have demonstrated increasing interest in the positive relationship between transportation infrastructure investment and economic growth. Investments in transportation are considered to have high economic returns, take advantage of underutilized resources, and support the day-to-day operations of businesses, including improved access to the work force and allowing increased labor force participation. While these assertions concerning transportation investment are positive, they are also generic in nature. There is no specificity with respect to geographical scale and type of transportation projects that can or do aid in the improvement of the economy. The paper aims to address this lack of detail. Using meta-analysis (MA), a framework is developed to effectively select and measure performance metrics for specific types or groups of transportation projects and evaluate their impact on the system features of the larger transportation systems.

Keywords: Impact evaluation; Performance measures; Infrastructure; Meta-analysis

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1. Problem statement

The primary performance attributes that most transportation projects aim to improve are accessibility and mobility. These attributes may be measured on a local, regional or national scale (Litman, 2012). Even though impact evaluation may include assessing these attributes and be common-place when planning for a transportation

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project, there is a dearth of research on the influence of projects on the performance of their respective transportation systems at different geographical scales.

This paper explores the use of performance metrics for specific types or groups of transportation projects to determine their impact on the features of the larger transportation systems. While non-economic impacts such as environmental and social impacts are important, this paper focuses specifically on transportation and economic impacts. Projects, grouped by geographical scale, are evaluated using a framework that employs the statistical methodology of meta-analysis or MA. Traditional frameworks for analyzing transportation projects, such as cost-benefit analysis, are useful. However, costs and benefits are sometimes hard to quantify, usually underestimated and often require assumptions about non-economic values (Lakshmanan, 2011). The proposed framework for the evaluation of project impact using MA is constructed in such a way that it can be applied to various project types and forms of impact.

The motivation for this research is partly due to the directives outlined in the United States 2012 surface transportation authorization bill, Moving Ahead for Progress in the 21st Century (MAP-21) and reinforced in the 2015 bill, Fixing America's Surface Transportation (FAST). These bills employ an outcome-driven approach that tracks performance in order to ensure accountability and improve the quality of transportation assets. Accordingly, the issue of obtaining a better understanding of the performance of transportation infrastructure is strongly aligned with the current direction of sustainable transportation policies in the United States (Lakshmanan, 2011).

1.1. Outline of paper

The paper is structured as follows: the next section provides background information on the topics of accessibility and mobility, impact evaluation and lastly, MA. The theory and societal implications of accessibility and mobility, as transportation performance measures, are presented as well as their distinction. The current practices for evaluating the direct impacts of different types of transportation projects are then discussed. This discussion is followed by an overview of the statistical methodology of MA. This overview includes the different types of MA models that exist, applications for MA, available software tools, as well as alternatives. Next, the data and methodology section presents a case study that uses a transportation project database of proposed capital projects for the state of Delaware in the United States. The section introduces the context and data, and presents a meta-analysis using the framework developed to evaluate the set of transportation projects. The results of the evaluation analysis are discussed, with the paper concluding with opportunities for future work.

2. Background

2.1. Accessibility and mobility: measures of transportation and performance

In order to gain a better understanding of the relationship between transportation infrastructure investment and economic growth, it is important to first recognize the fundamental purpose of a transportation project. One of the main purposes is to enhance accessibility and/or mobility. Accessibility and mobility are terms that are frequently used by engineers, planners and politicians in regards to describing "the ultimate goal" or performance attributes of transportation projects (Litman, 2012). However, often no distinction is made between accessibility and mobility, and in many cases, the two terms are used interchangeably.

There are several examples within the literature of accessibility and mobility being grouped together rather than defined separately, such as the Transportation Equity Act of the 21st Century (TEA-21), where accessibility and mobility are used, but not clearly defined (Handy, 2002). Other examples are in long-range transportation plans for Austin, Texas (CAMPO, 2000) and the Chicago metropolitan area (CATS, 2002). The major consensus in the literature is that while the two terms are related, they are distinct, equally important concepts. Accessibility relates to how difficult it is to move from one place to another, whereas mobility relates to the ability to move from one place to another. Policies or projects that increase mobility may increase accessibility, with all else being equal (Litman, 2012).

However, measuring mobility and accessibility is very context specific, where the existence or improvement of one doesn't inevitably ensure or depend upon the existence or improvement of the other (Handy, 2002). In the case of evaluating different project types or groups of projects using MA, projects that emphasize increased mobility, such as adding a lane to a highway, may increase accessibility but not necessarily. The tradeoffs between accessibility and mobility are important in project selection and relate directly to the end goal of transportation investment, which is the efficient movement of goods and people. Increased public and political interest in transportation infrastructure investment is heavily based upon economic benefits rather than improvement in the actual performance of the transportation network. This is directly supported by the set of project evaluation practices that are predominant, such as cost-benefit analysis, input-output tables and other econometric models.

2.2. Impact evaluation

The lifecycle of a transportation project consists of five main phases which are: 1) planning, 2) design, 3) construction, 4) operation and control, and 5) maintenance (Banks, 2001). The planning and design phases can be considered to be the most important, since they dictate whether a project is ever constructed and a commitment to the subsequent phases, costs and responsibilities. A major part of these initial phases is impact evaluation, which generically can be referred to as an assessment of the "positive and negative changes produced by a development intervention, directly or indirectly, intended or unintended" (IEGWB, 2006). As such, in the context of a transportation project, an impact evaluation can be a very open-ended endeavor. Banister and Berechman (2003) provide a comprehensive review of the literature and models. Similarly, Sinha and Labi (2011) review the mechanics of project evaluation, and Litman (2010) provides case studies. While there are many papers and books devoted to transportation investment and economic impact, many present techniques that require intensive data and sophisticated models. For example, Rietveld (1994) attempts to capture the spatial distribution of the economic impacts of transportation investments.

Evaluation techniques that permeate the impact evaluation literature can be categorized into three classes based on the scope and scale of the evaluation. These classes are described as: 1) comprehensive project analysis, 2) monetized impact evaluation and 3) planning objectives. These classes of techniques serve as a general representation of the current practices for evaluating land use impacts in transportation planning, where land use impacts are identified as economic, social or environmental in nature. However, these techniques are not necessarily a reflection of the process used in every transportation decision. For example, many transportation decisions are made with limited or no analysis and many impacts are not incorporated in the standard analysis (Litman, 2010). Environmental analyses tend to focus on specific issues, such as endangered species, rather than the affected surrounding environment as a whole. Finally, impact evaluation usually occurs only in the initial phases of a project lifecycle, where there is no review of the accuracy of the initial impact estimates (Litman, 2010). Nevertheless, these evaluation techniques provide a good baseline for impact evaluation.

For comprehensive project analysis, the goal is to incorporate as many of the economic, social and environmental impacts of the transportation investment over its lifecycle as possible in the evaluation process, where each type of impact can be quantified, as well as monetized. Comprehensive project analysis goes beyond the standard analyses and attempts to capture as much information as possible about a project. As a result, this type of impact evaluation requires the most time, money and resources.

Monetized impact evaluation can be considered to be a component of comprehensive project analysis. The focus of monetized impact evaluation is the measurement of non-market or non-economic attributes, social and environmental attributes, using economic measures such as physical measures, nominal price value measures or fixed price value measures. The objective is to incorporate these impacts into market or economic analyses. Sometimes these non-market impacts are difficult to capture and may require a more unique approach as compared to traditional economic analysis tools, such as cost-benefit analysis.

Planning objectives, or multiple account evaluation, uses qualitative descriptions to represent the changes or influence of a project on specific land use impacts. For example, for the environmental impact of reduced pollution emissions, the associated qualitative description for environmental impact for a project may be low, medium or high pollution reduction.

In comparing each of the evaluation techniques, it is evident that the level of effort required and the detail of the results vary a great deal. In addition, the majority of analyses seen in the literature tend to be economic impact analyses due to their intelligibility and effectiveness in communicating findings to diverse audiences. Nevertheless, MA provides an alternative or complementary approach to economic impact analysis.

2.3. Meta-analysis

Impact evaluation is an essential part of the lifecycle assessment process for a transportation project. Based on the previous section, it is evident that impact evaluations tend to be very piece-wise, with certain analyses providing more insight than others or a different perspective altogether. Consequently, varied approaches to analyzing the impacts of transportation projects are important. Meta-analysis is presented as an alternative approach to impact evaluation.

Meta-analysis is a methodology used for the systematic review of literature to determine the magnitude of the effect or the effect size of a specific phenomenon. Meta-analysis, which is also referred to as research synthesis or evidence synthesis, is a form of content analysis. Observations are obtained regarding a population from examining individual units within the population (Borenstein, 2007). The effect size of individual units within the population is combined to determine an overall mean effect size for the population, along with other useful statistical information, such as standard error, variance and lower and upper limits. In addition, the effect must be converted into the same units for each individual unit of analysis as a percentage or some other dimensionless generic measure for the results to be accurate. For meta-analysis, the effect being captured can be related to any of the attributes of the individual units of analysis.

Meta-analysis is a tool that is prominent in social and medical research. Examples of meta-analysis applications include measuring the effect of orthotic bracing (i.e., attribute A) on ankle injury (i.e., attribute B) or measuring the effect of athletic endurance training (i.e., attribute A) on resting blood pressure (i.e., attribute B) (Borenstein, 2007). In general, meta-analysis is used to obtain a quantitative estimation of the effect size of attribute A on attribute B. For meta-analysis, the main aspect of the approach is that the overall mean or combined effect for a group of studies is obtained by weighting the individual studies rather than treating each study as equal. In addition, the weight is based on some relationship between the individual unit of analysis and the larger population, such as the inverse of the variance or some other weighting scheme. In the case of analyzing the transportation database presented in this paper, the inverse of the variance is the weighting scheme that is utilized.

In terms of the mathematical formations for MA, the two main types are fixed effects model and random effects model. For the fixed effects model, the given or observed effect of an individual study is T_i and is equal to $\mu + \varepsilon_i$, where it is sampled from a distribution with true effect μ and a variance σ^2 plus the within-study or project error ε_i, as shown in equation 1.

$$T_i = \mu + \varepsilon_i \tag{1}$$

- i: the individual study
- T: the observed effect of individual study i
- μ: the true effect of population
- ε: the within-study error of individual study i

For the random effects model, the observed effect of an individual study is T_i and is equal to $\theta_i + \varepsilon_i$, where it is sampled from a distribution with true effect θ_i and variance σ^2 plus the within-study or project error ε_i. However, unlike μ in the fixed effects model, θ is sampled from a distribution with true effect μ and a variance of τ^2 plus the between-study or project error ξ_i, as shown in Equation 2.

$$T_i = \theta_i + \varepsilon_i = (\mu + \xi_i) + \varepsilon_i \tag{2}$$

- i: the individual study
- T: the observed effect of individual study i

- Θ_i: the true effect of population for individual study i
- ε_i: the within-study error of individual study i
- μ: the true effect of population
- ξ_i: the between-study error of individual study i

The main differences between fixed and random effects models is that the latter has two levels of sampling as well as two sources of error (i.e., within and between studies), whereas the former only has one level of sampling and one source of error (i.e., within-study). Overall, a primary goal for these MA models is to obtain an estimate for the combined effect or weighted mean (i.e., T-bar) for all studies analyzed using the relationships defined in equation 1 and equation 2. There are also several different variations of fixed and random effects models of meta-analysis that may prove to be useful (Hopkins, 2004).

In terms of applicable software, the R statistical software has a meta-analysis package called “metaphor,” which is able to run both fixed effects and random effects models (Viechtbauer, 2010). Comprehensive Meta-Analysis Version 2.0 (CMA V2) is another meta-analysis software package, which is standalone and is able to compute effect size automatically while displaying the computation procedure, store data in either a customized format or one of the more than 100 preset formats, as well as create forest-plots (Biostat, 2011). For the transportation database, CMA V2 is utilized to conduct the different analysis scenarios, and R is utilized to created dendrograms of the results.

3. Data and methodology

The application of MA in the evaluation of different types of transportation projects can prove to be useful due to its ability to incorporate various types of attributes. As an evaluation technique, MA can be classified as type of comprehensive project analysis, where the numbers of impacts examined is mostly based on the evaluator’s objectives and resource constraints. The main objectives for using MA in this exploratory analysis are as follows:

- To develop a framework using MA for the impact evaluation of different types of transportation projects across all modes
- To apply the framework to determine the magnitude and direction of the effects of highway projects using a transportation project database
- To compare and assess the magnitude and direction of the effects for the transportation projects analyzed in terms of project impact evaluation

3.1. Overview of data and analysis

To demonstrate the application of MA to the evaluation of transportation projects, a case study is developed using a transportation project database. The database is the 2013 Delaware Capital Transportation Plan (CTP). Delaware is a small state (the area is 6,452 square kilometers and the estimated 2016 population is 946,000) in the mid-Atlantic region of the United States approximately midway between New York City and Washington D.C. The state is divided into three counties, New Castle, Kent and Sussex, from north to south. Each is similar in area but with the majority of the population in New Castle and then Kent. Delaware Department of Transportation (DelDOT) is required to develop a fiscally responsible CTP each year covering a six year period. In 2013, DelDOT introduced a process for scoring projects that could then be used for prioritizing projects (DelDOT, 2013); however, the scoring and prioritization process provide little insight into the impacts of these projects as a whole and the impacts on different regional scales. MA offers an opportunity to obtain some additional insights.

The CTP is a database of potential or proposed capital projects. The 2013 Delaware CTP database has a total of 109 projects (DelDOT, 2013). The CTP is an ideal database for MA as the database includes all four project impact categories– transportation, economic, social and environmental impact. However, for this paper, only transportation and economic impacts are presented. The social and environmental impacts were analyzed but the MA results for these categories using the 2013 Delaware CTP database show no variation with respect to geographical scale and thus not included here (London, 2014). However, this may not be the case for all transportation databases, given that the magnitude of impact can vary based on the size of the geographic region analyzed. This in turn could be an area for future research.

For transportation impact for the 2013 Delaware CTP database, the attributes used are defined by DelDOT as the project prioritization criteria (DelDOT, 2013) and are an average of scores for: 1) Level-of-Service (LOS), 2) Multi-modal Mobility/Flexibility/Access, and 3) System Preservation (DelDOT, 2013). For LOS, the range of values is converted from letters F to A into a numerical range of one to six, where one is the lowest LOS and six is the highest LOS. Multi-modal Mobility/Flexibility/Access ranges from zero to one, where zero is the lowest level of mobility and one is the highest level of mobility. It is important to note that for the Delaware CTP, Multi-modal Mobility/Flexibility/Access is a single attribute and there is no distinction made between mobility and accessibility. Nevertheless, the attribute serves as a good indicator of transportation impact based on its description and is treated as a generalized measure of mobility. System Preservation is a measure of the State of Good Repair and addresses the improvement of the physical condition of existing transportation assets. It is a binary attribute, where zero represents a project that does not contribute to system preservation and one represents a project that does contribute to system preservation. These three attributes are each normalized across a range of 1 to 101. Then, the mean and variance of these attributes are inputted in CMA V2 in the mean and variance data entry format. For the data entry of variance, the variance is computed assuming the data are sampled from the population of all projects rather than assuming the data represents the entire population.

For economic impact for the 2013 Delaware CTP database, the attributes used are also defined by DelDOT as project prioritization criteria and are an average of: 1) transportation improvement district (TID) classification for a project and 2) freight corridor classification for a project (DelDOT, 2013). TID is a binary attribute, where zero represents a project that is not located in a TID and one represents a project that is located in a TID. It is assumed that a project located in a TID would have greater economic impact than a project not located in a TID. Freight corridor is a three tiered attribute, where zero represents a project not in a freight corridor, 0.75 represents a project in a secondary freight corridor and one represents a project in a primary freight corridor. It is assumed that a project located in a primary freight corridor would have a greater economic impact than a project not in a freight corridor or in a secondary freight corridor. TID and freight corridor classification are each normalized across a range of 1 to 101. Then, the mean and variance of these attributes are inputted in CMA V2 in the mean and variance data entry format, as with the transportation impact analysis.

3.2. Project Impact Evaluation Framework

In the case of the Delaware CTP database, separate meta-analyses for transportation impact and economic impact are presented. The overall decision-making process utilized to evaluate the results of these two analyses is referred to as the Project Impact Evaluation (PIE) Framework. There are a total of five steps in the PIE Framework which includes: 1) goals and objectives, 2) data conceptualization, 3) data collection, 4) analysis, and 5) evaluation. The intent of the framework is to transform data, whether it is quantitative or qualitative in form, into knowledge. The knowledge obtained can then be used to support the understanding, procedural process and actions of decision makers in regards to transportation infrastructure investment. In general, the PIE framework is about creating a link with the past in order to inform future decisions.

Developing the goals and objectives for implementing the PIE framework is essential. Whether it is to analyze existing or future projects, the first step of the framework dictates the level of detail for the subsequent steps. For the second step, data conceptualization connects the ideas or notions of interest, such as the project impacts, to concrete performance measures. For the third step, data collection is an outgrowth of data conceptualization. Once the ideas of interest have been selected by the evaluator, the data gathering and collection process can be begin. This step also includes data pre-processing and cleaning. For the fourth step, analysis relates to the different MA scenarios (see section 3.1) that the evaluator develops to address the goals and objectives in the first step of the PIE Framework. In the case of the 2013 Delaware CTP database, the two MA scenarios presented are related to transportation impact and economic impact respectively. For the fifth and final step, evaluation relates to four main components:

1. Summative Evaluation: effectiveness of data collected and analyzes and their alignment with the evaluator’s goals and objectives
2. Formative Evaluation: influence of the research process on formulating the MA scenarios

3. Impact Evaluation: implications of research conducted on practices for the assessment of project impact and the utilization of the MA approach
4. Context Evaluation: broader or wider impact of the research conducted

Within the four step evaluation process, the most relevant step is context evaluation. Specifically, context evaluation refers to situating the research conducted in a wider or different point of view. It is related to impact evaluation, but looks at it from a broader perspective. Context evaluation asks the question: How does or can the research conducted inform other areas of study, such as public policy? An example would be how the research conducted can inform the formulation of sustainable transportation policy.

4. Results and discussion

4.1. Delaware CTP transportation impact MA results

The mean and variance of the averaged normalized values of LOS, Multi-modal Mobility/Flexibility/Access and System Preservation for each project is inputted in CMA V2 in the mean and variance data entry format. Transportation impact results for all projects can be seen table 1. All values are significant to p=0.05.

Table 1. Transportation Impact Results for All Counties

ATTRIBUTE	MODEL	MEAN EFFECT	SE	VAR	LL	UL	Z
AVERAGE TRANSPORTATION IMPACT	FIXED	18.255	0.333	0.111	17.602	18.908	54.782
	RANDOM	37.042	2.279	5.195	32.575	41.510	16.252

For average transportation impact, both the fixed and random effects model results are shown. The results summarize the mean effect for all the projects and serves as the base analysis for the second tier or secondary results, which are MA results for projects grouped by county, and the third tier or tertiary results, which relates to conducting a sensitivity analysis. In terms of interpreting the mean effect, the higher the value for transportation impacts the better.

In terms of transportation impact by county, table 2 displays the mean effect for average transportation impact for Delaware's three counties, New Castle, Kent and Sussex. All values are significant to p=0.05. Table 2 includes only the results for the random effects model formation, since it accounts for two types of error rather than the only one type of error captured in the fixed effects model formation, and is used for comparison across the different MA scenarios.

Table 2. Average Transportation Impact by County for Random Effects Model

#	COUNTY	MEAN EFFECT	SE	VAR	LL	UL	Z
1	**New Castle**	35.907	2.909	8.463	30.205	41.608	12.343
2	**Kent**	45.180	7.211	52.003	31.046	59.314	6.265
3	**Sussex**	33.565	3.719	13.828	26.277	40.854	9.026

For the MA results, SE is standard error, VAR is variance, LL is lower limit, UL is upper limit, and Z is the number of standard deviations the effect size is from the mean.

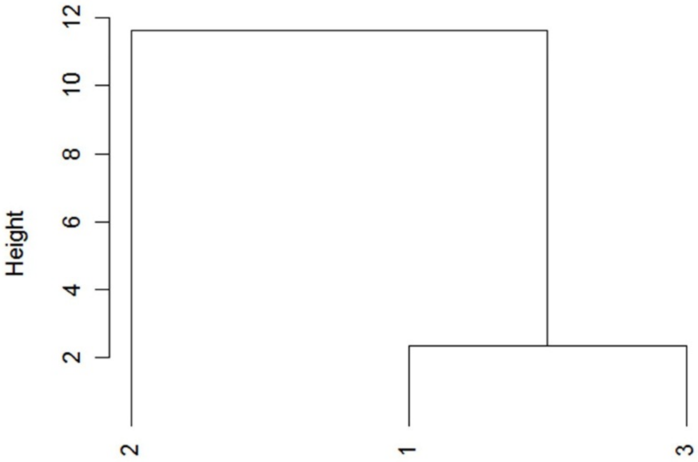

Fig. 1. Dendrogram for Average Transportation Impact by County for Random Effects Model

The mean effect for average transportation impact by county is compared using a dendrogram as seen in fig 1. The dendrogram compares the mean effect for each county calculating the Euclidean distance between the average transportation impact values, which is represented on the y-axis as height. Dendrograms are visual representations of the results of a cluster analysis, which analyzes groups of objects that are determined to be similar by some sort of measure. Euclidean distance is used for simplicity, where it measures the ordinary distance between two points using the Pythagorean formula. The larger the height the more dissimilar the values are from each other, and accordingly, the more dissimilar counties are from each other. In addition, the height represents the relative difference in the value for the attribute being examined for each of the counties or equivalent moderators. The county is on the x-axis and is labeled by its corresponding number as seen in table 2.

The county with the highest average transportation impact is Kent with a value of 45.180. The county with the lowest average transportation impact is the Sussex with a value of 33.565. In terms of comparing mean effect, the counties that are the most similar are New Castle and Sussex. According to the MA results, these two counties result in comparable mean effect sizes for average transportation impact with values of 35.907 and 33.565 respectively. The most dissimilar region is Kent. For the third tier or tertiary results, a sensitivity analysis is conducted, where Kent County is examined more closely. The reason for doing this is due to the fact that Kent has the highest value for average transportation impact compared to the other counties. By removing Kent from the MA, the new mean effect for average transportation impact for all counties changes from 37.042 to 35.144. The removal of Kent from the MA results in a slight decrease in mean effect. From the three tiered approach for results, it is evident that while Kent has the highest average transportation impact for the 2013 Delaware CTP database, it does not control the overall mean effect size results.

4.2. Delaware CTP economic impact MA results

The mean and variance of the average normalized values of TID and freight corridor classification for each project is inputted in CMA V2 in the mean and variance data entry format. The economic impact results for all counties can be seen in table 3. All values are significant to p=0.05.

Table 3. Economic Impact Results for All Counties

ATTRIBUTE	MODEL	MEAN EFFECT	SE	VAR	LL	UL	Z
AVERAGE ECONOMIC IMPACT	FIXED	24.877	0.149	0.022	24.585	25.168	167.376
	RANDOM	39.387	4.122	16.990	31.308	47.465	9.555

For average economic impact, both the fixed and random effects model results are shown. The results summarize the mean effect for all the projects and serves as the base analysis for the second tier results. In terms of interpreting the mean effect, the higher the value for economic impacts, the better the results are. In terms of the secondary results, table 4 displays the mean effect for average economic impact by county using the random effects model. All values are significant to p=0.05.

Table 4. Average Economic Impact by County for Random Effects Model

#	COUNTY	MEAN EFFECT	SE	VAR	LL	UL	Z
1	**New Castle**	44.656	6.287	39.527	32.334	56.979	7.103
2	**Kent**	25.765	6.883	47.376	12.275	39.256	3.743
3	**Sussex**	35.285	3.153	9.941	29.105	41.464	11.191

The mean effect for average economic impact by county is compared using a dendrogram as seen in fig 2.

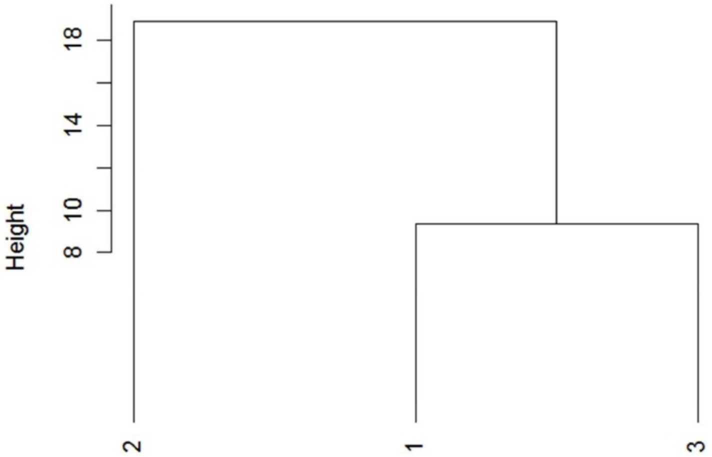

Fig. 2. Dendrogram for Average Economic Impact by County for Random Effects Model

The dendrogram compares the mean effect for average economic impact for the three counties in Delaware. The county with the highest average economic impact is New Castle with a value of 44.656. The county with the lowest average economic impact is the Kent with a value of 25.765. In terms of comparing mean effect, the counties that are the most similar are New Castle and Sussex. According to the MA results, these two counties result in comparable mean effect sizes for average economic impact with the value of 44.656 and 35.285 respectively. The most dissimilar region is Kent, as seen with average transportation impact.

For the tertiary results, Kent County is examined more closely as part of the sensitivity analysis since it has the lowest value for average economic impact compared to the other counties. By removing Kent from the MA, the new mean effect for average economic impact for all counties changes from 39.387 to 42.400. The removal of Kent from the MA results in a slight increase in mean effect. From the three tiered approach for results, it is evident that while Kent has the lowest average economic impact for the 2013 Delaware CTP, it does not control the overall mean effect size results.

The attributes and values used to measure impact are obtained directly from the 2013 Delaware Capital Transportation Plan. The Delaware CTP provides estimates for specific attributes for each of the 109 proposed projects for the 2015 to 2020 fiscal years, and the sample of 109 projects represents the entire population of projects within the 2013 Delaware CTP. In the capital plan, there is equal emphasis placed on the four project impact types based on the given attributes. Overall, Delaware met the data needs for the application of MA. Furthermore, the multiple attributes capturing the same project impact types are useful in regards to using the mean and variance data entry format in CMA.

4.3. Evaluation of MA results for Delaware CTP

With a total of sixteen attributes, there are several analysis scenarios that could be conducted. However, the focus of the evaluation for the 2013 Delaware CTP is on results that can inform public policy decisions, such as transportation and economic impact results. For the average transportation impact, this is based on attributes LOS, Multi-modal Mobility/Flexibility/Access and System Preservation of the proposed projects within a specific geographic region (i.e., county). For average transportation impact, the county that has the highest value is Kent, whereas Sussex has the lowest. In addition, New Castle and Sussex has similar average transportation impact values, where Kent is an outlier (see table 2). As such, the proposed projects in Kent County have the most impact on the larger transportation system in regards to these three attributes.

For the average economic impact, this is based on attributes TID and freight corridor classification of the proposed projects within a specific geographical region (i.e., county). For average economic impact for each of the three counties, the county that has the highest value is New Castle, whereas Kent has the lowest. The difference between average economic impacts for each the counties are relatively the same, with approximately a ten point difference (see table 4).

While Kent has the highest average transportation impact, it has the lowest economic impact. From the literature, the relationship between transportation infrastructure investment and economic growth is generally considered to be a positive one (Lakshmanan, 2011). However, the findings for the MA results for the 2013 Delaware CTP demonstrate the reverse relationship in the case of Kent County. The projects in Kent have high transportation impact but low economic impact. This finding illustrates the context specific nature of project impact, where there are several interdependent factors that could be at play. The main benefit with MA is that it serves as a strong basis for further discussion of the relationship between transportation investment and economic growth. MA allows the evaluator to identify the magnitude and direction of the relationship between transportation and the economy for a project type or group and supports future research in exploring the associated mechanisms of this relationship (Lakshmanan, 2011).

5. Future work

For future work, a portion of the research can be extended to formalize the process for the prioritization of different types of transportation projects at the local, state and national level, as well as determining the specific project attributes or thresholds that provide the greatest transportation or economic benefits, such as project type (e.g., new construction, reconstruction, rehabilitation, etc.) as seen in the case for Kent County which has the highest average transportation impact. The findings also demonstrate that the projects in Kent County add benefit to society but imposes economic opportunity costs. As such, the analysis validates the need for policies that promote innovative transportation solutions while still integrating economic factors in the development of these solutions.

Also, the application of MA on preexisting projects rather than proposed projects could be useful in gauging whether the impacts estimated correlate with the actual impacts. In addition, by soliciting the feedback of institutions and stakeholders directly involved in the planning, design and construction of transportation projects, the PIE Framework can be improved upon specifically in terms of the type of projects that are applicable to MA, the scale of analysis and attributes considered. This would in turn dictate the feasibility of implementing the aforementioned framework into practice from a long-term perspective. Overall, buy-in from various stakeholders would increase the credibility of the work as well as the likelihood that it would be utilized by transportation agencies for project analysis. Lastly, the research findings support future research in exploring the associated mechanisms between transportation investment and economic growth beyond determining magnitude and direction.

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