1 **A FRAMEWORK TO OPERATIONALIZE A DEEP AND VAST LITERATURE FOR**
2 **PRACTICE:**

3 **TRANSLATING LAND VALUE UPLIFT LITERATURE TO ESTIMATE ECONOMIC**
4 **IMPACTS OF MULTIMODAL TRANSPORTATION SYSTEM PROJECTS**
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ABSTRACT

Traditional methods for evaluating transportation system investments typically rely heavily on one or two metrics of evaluations, such as vehicle travel time delay and level-of-service measures. Transportation projects often have substantial and significant impacts on many other aspects of society, including the economic vitality of our communities. The focus of this study was a practical one: operationalize a vast literature exploring the theories and findings that describe positive and negative economic impacts of transportation investments, in this case focused on the impacts on real estate value. It was completed with sponsorship from Smart Growth America to develop a pilot application for Washington DOT. The framework described in this manuscript allows analysts to estimate and compare changes in real estate value, and therefore changes in economic vitality, due to different investment decisions. The economic impacts estimated in change in US dollar value of single-family residential, multifamily residential, and commercial real estate can be used in combination with other performance measures (e.g., travel time savings, environmental impacts) to evaluate a more comprehensive picture of the impacts of transportation infrastructure. Because this framework was spatially developed, the analyst will be able to more readily identify which neighborhoods and corresponding populations may see the largest impacts on the cost of housing due to specific transportation projects. This, in combination with housing expertise and tools developed to understand the displacement of vulnerable populations, could also help agencies anticipate where there would be increased pressure in terms of cost of housing due to specific transportation projects.

Keywords: real estate value added (lost); economic vitality, performance metric, transportation system plan

1 INTRODUCTION

2 Transportation system project evaluations have historically relied upon a small handful of
3 automobile-focused metrics, namely level-of-service standards measured in volume to capacity
4 ratios or vehicle delay. Studies spanning across many disciplines have shown that transportation
5 investments have direct and indirect impacts on more than vehicle traffic delay—from public
6 health, to environmental quality, to economics. Many agencies have begun developing more
7 comprehensive suites of evaluative performance metrics that more closely align with their
8 interdisciplinary policy or planning goals and objectives. Supporting decisions that foster
9 economic vitality is often one of these goals. However, translating (often sophisticated) academic
10 studies—meta-analyses and systematic, repeated analyses included—into practical tools is a
11 challenge. This manuscript aims to bridge this gap by developing a framework to link the
12 theories behind one such economic impact of transportation infrastructure improvements,
13 changes in real estate value, into an operationalized geospatial framework for application.

14 The audience for this paper may include practitioners in both the public and private
15 practice, but researchers can also learn from this process. While research methods continue to
16 become more advanced, this effort aims to make this research more directly applicable for
17 practice. Meta-analyses and repeated, systematic studies produce significant and substantial
18 guidance for future research and policy direction. However, for practice, what is often needed is
19 the connective tissue that links these large academic efforts into a framework for application
20 (e.g., tools and structured guidance) that estimate these data as performance measures. This study
21 aims to provide this tissue.

22 This paper is organized as follows. First, we provide the origin of this manuscript and a
23 summary of the literature from which it was conceived. The analytical approach in developing
24 the framework is then explored in three subsections describing: use cases, providing context for
25 the local real estate markets through baseline value estimations, and summarizing literature-
26 based adjustments in value. The manuscript is concluded with the ‘guiding principles of use’ and
27 a discussion of future work related to expanding this framework for broader application,
28 adjusting it for more localized application, and considering operationalizing additional
29 alternative measures of economic vitality. The aim of this paper is to provide an overview of
30 how one broad and vast literature was distilled into a framework for application in practice. For
31 more thorough description of framework as well as the case study analysis provided for
32 Washington DOT and the development of the physical GIS tool for applying the framework, see
33 the full documentation (1).

34 BACKGROUND

35 To stimulate economic recovery while in the depths of America’s worst economic downtown
36 since the Great Depression, the federal government invested tens of billions of dollars into
37 transportation improvements and new systems. To help shape its national discussion, Smart
38 Growth America sponsored the preparation of a series of ten briefing papers (2) addressing the
39 following questions:

- 40 1. Which transportation investments will put more people to work sooner?
- 41 2. Which transportation investments will create an opportunity for the US to develop long-
42 term prosperity?

43 Key findings suggested that, among transportation infrastructure projects, mass transit
44 projects generated the greatest short-run economic impacts. Repair of existing roads and bridges
45 results in higher short-run economic impacts than new road construction (Briefing Paper # 2).

Moreover, investing in major transit facilities and services not only facilitates achievement of important environmental and quality of life goals, but can substantially advance private sector economic development objectives as well. The accessibility benefits provided by transit are being translated into significant enhancements to the value of nearby real estate, reflecting increased market interest in potential development on those lands. The evidence shows that these enhancements are both a function of a property's proximity to a transit station and that station's proximity to a regional activity center, such as a central business district (Briefing Paper # 5).

Theorists in urban economics have long evaluated the spatial structure of urban areas and the location decisions of firms and households, e.g., (3–5). For all land uses, economic theory (bid-rent theory) assuming that buyers or renters (businesses, homeowners, and investors) opt to pay for higher land or property values in return for better amenities (e.g., higher accessibility or better access resulting in lower transportation times or costs).

The use of hedonic price models is one such method for analyzing how the value of land varies by differences in the structure or environs. In hedonic models, the value of land and property can be decomposed into marginal costs of attributes that describe the structure of the land and property, the neighborhood, location of the market, and the time when the land was valued (assessed) or a price (sales, rent) observed. The hedonic price model findings are not meant to serve as the equivocal summary of impacts, but rather they are used for evaluating policies to act as a plausibility check for cost/benefit analyses (6). Understanding the overall changes in real estate value provides one of many such economic performance metric to evaluate how transportation infrastructure impacts the economy.

FRAMEWORK

At the outset of this study, we identified two approaches for the development of a system to estimate transportation impacts on real estate value: research-driven (developing a framework through original research and analysis), and literature-driven (developing it through summaries of existing, high-quality research). The former requires substantial original data collection, cleaning, and, to meet the standards of analytical rigor, longitudinal and spatially-sensitive analysis methods. As the original case study area explored here required application and sensitivity across a dozen regions in Washington, this approach was not deemed feasible in the scope of the project. Instead, we aimed to apply a literature-driven approach that provided some local context (e.g., relying partially on appraised property values within the study area) with adjustments to the real estate driven by high-quality literature identified by the research team. Therefore, the framework is made up of two parts:

1. First, 'baseline real estate values' are estimated using local assessor data for a sample of counties to capture and estimate real estate property values based on the regional accessibility of the area and controlling for variation in appraised values correlated with structural (e.g., building square footage, bedrooms) and temporal characteristics (e.g., date of appraisal).
2. Second, literature-driven adjustments are applied to the baseline value estimates to approximate the net impacts of transportation decisions at project-level.

Each of these modules are defined further in the following subsections. There are two basic outputs from the application of this framework. Each output is summarized for each land use considered (currently, single-family residential, multifamily residential, and commercial land uses):

- Estimated project-level net change in real estate value by census block group;

- Estimated project-level net change in real estate value (the sum total provided in the first output).

The data are summarized as both ‘estimated impacts per development/household’ as well as ‘estimated impacts for all developments/households’ within the census block group or neighborhood areas. These data provide “*the estimated project-level impact on real estate value in the project area.*” A positive/negative value suggests the project will cause real estate values to increase/decrease overall. For multimodal projects, the analyst may find that the project-level total impacts are positive but some block groups may observe a total decrease in real estate value, or that projects that increase single-family residential development may also decrease value of commercial development. It is recommended that both scales of outputs be considered to develop a more comprehensive picture of the impacts of any given project.

Three general land use categories were identified in the broader literature for framework development: single-family residential; multifamily residential (condos and/or apartments); and commercial (office and/or retail and services). The number of land use categories available is currently constrained by (a) the breadth of the literature across these land uses and mode-specific facilities, (b) the ability to reconcile different land use categories across assessor databases (related to estimating baseline property values), and (c) the study’s consistency with state-of-the-art theory (e.g., age of the study). Additional land uses, or subsets of land uses, could be added to this framework to provide a more comprehensive picture of the relationships identified in the literature (e.g., office or retail uses or rental and condominium uses).

The framework was then developed into a geospatial tool using ArcMap 10.3 and python coding. This Transportation Infrastructure & Real Estate Valuation Effects Tool, or TIREVET, actively demonstrates the framework described in this study with a GIS interface that allows for a more localized approximation of net (or per household/development) impacts observed across space. The approximate runtime for a unimodal, intercity project is currently 6-7 minutes.

Use Cases

This framework was developed with three main use cases in mind: (1) project-level impact comparisons, (2) scenario-level impact comparisons, and (3) identification of local residential pressure due to rising real estate values.

The first two cases derive project-level estimates of net changes in residential (single family and multifamily and commercial real estate values due to proposed transportation infrastructure. In project-level comparisons, two or more separate projects are considered in the framework to approximate the estimated change in real estate value. In scenario-level comparisons, two or more iterations of the same project are run through the framework to estimate change in real estate value. The output provides a net dollar real estate value impact that can be introduced into multi-objective decisions making as a measure of economic impact. In the project-level comparison, this allows for the impact on real estate values due to two different transportation projects (a commuter transit expansion project and a highway expansion project, for example) to be compared. In the scenario-level comparisons, this allows for the impact on real estate values due to two different scenarios of the sample project (a highway expansion with commuter transit expansion and a highway expansion project without additional transit, for example) to be compared. The process for implementing the framework in project-level and scenario-level comparison is the same: one project is run through the framework, and then the second, and the outputs are compared alongside additional performance metrics.

The third use case—identification of local residential pressure due to rising real estate values—was identified during framework development. Although application of this use case requires leveraging additional expertise—specifically housing and development departments—this framework may assist with identifying block groups in which rising real estate values (specifically single and multifamily residential uses) may place additional housing stress on existing vulnerable populations. The application of this use case is similar to the first two cases. However, instead of comparing net project-level impacts across two or more projects, the analyst considers the block-group-level changes in real estate value. This framework was not originally developed for this purpose, and it does not account for additional information to gain a more nuanced view of impacts (e.g., how populations would respond to changes in value, where they may be displaced, additional resources the neighborhoods may have at their disposal). But it may provide a useful approximation for identifying or anticipating potential pressure points in neighborhoods surrounding the project.

Baseline Real Estate Values

The purpose of the ‘baseline estimates’ in this approach is simply to provide the scale of value within a block group for a change in transportation facility. In other words, the baseline estimates allow us to approximate a dollar value from a percent-change value. As an example: if the literature indicates we should expect a new transit line should increase single-family home value by 5%, the total net value (dollars) is a function of how many homes are impacted and how much those homes are worth now. If the study area has 200 homes with an expected home value of \$200,000, we can determine the net impact would be approximately \$2 million (\$200,000 * 0.05 * 200). In this case, the baseline estimate gives us an average value (controlling for variation in housing and temporal characteristics, to the best extent possible) to approximate what a total net change in value would be for a study area.

It is important to note that this framework does not provide statistically robust and locally-derived hedonic models. However, to approximate the baseline real estate values for each block group, simple hedonic regression models can be used to ‘parse’ out residuals and temporal fluctuations in real estate value to provide an *expected real estate value* per development. Because of this, we begin with assessor data collected from a sample of counties throughout the state of Washington and process this data to provide locally-derived ‘baseline’ real estate values for each block group. A sample of the 39 counties provides the framework with the ability to generate approximations for other counties as well. The ideal approach to estimating baseline values provides the ability to estimate (a) approximate real estate value per development (based on size of development) and (b) number of such developments in the block group.

In this analysis, the general approach we used for each county was to regress assessed value of parcels (land and improvements) upon parcel-level control variable (Structural and Temporal) and accessibility (block group). Three models were estimated for each county observed, one for each land use: Single-Family (SF), Multifamily (MF) and Commercial (COM). Generally, the assessed value is regressed upon the independent variables as described:

$$\ln(V_{ij}) = \beta_0 + \beta_A * A_{ij} + \beta_{CON} * CON_i + \varepsilon$$

Where V_{ij} represents the assessed value of land and structure for each parcel, i , in each census block group, j . A_{ij} represents a matrix of accessibility variables, and CON_i represents a matrix of variables that CONTROL for structural and temporal characteristics of individual parcels, i . These controls vary by the land use type, but they include structural (land size, building size, bedrooms, bathrooms, and units) and temporal (year and season of appraisal) variables, as

available in archived data. The β represents the estimated coefficients for each corresponding independent variable which represent the average marginal value added (or lost) for each increment increase/decrease in the independent variable. And lastly, ε represents the uncontrolled for variation or model residuals.

In order to provide controls for locational variation, data were collected to capture variation in regional accessibility, a proxy for distance to the central business district and corresponding relative access to opportunities. Each development was associated with a corresponding census block group and linked to accessibility metrics captured through a third party programs (Sugar Access Tool by Citilab). Feasibly, this control provided a way to approximate relative changes in real estate markets, particularly to extrapolate the findings from the smaller subset of counties observed to those in which appraised data were not readily available or were outside of the scope of the study. Some transportation infrastructure, however, may induce changes in accessibility due to changes in the network. These impacts are captured by the ‘literature-based adjustments’ described in the next section.

As noted previously, only a sample of counties were observed in this analysis. The intention of the framework, however, is for statewide application. Because of this, a method for approximating change in value for non-sampled counties was needed. While this process allows us to translate the application of this framework across the state, this county-level sample of data impacts two components of this analysis: (a) baseline estimates of real estate value by block group, and (b) approximations of the relationship between accessibility and real estate value. It is important to emphasize the relative nature of this framework; approximations of net change in real estate value estimated by this framework are meant to be *relative*. So long as project-level outcomes are compared across similar regions (two or more projects in Okanogan County, for example) the output still provides relative estimates of impact.

The ‘baseline real estate value’ estimates for ‘unobserved’ counties were then based on similarities with ‘observed’ counties. For example, the relationships between real estate value and structural and locational characteristics for Skagit County (unobserved) were assigned to be similar to its neighbor Snohomish County (observed). The actual average structural characteristics for block groups in Skagit County were largely based on secondary data, such as the census. Some structural data—such as ‘average square footage of commercial space per property’ were more difficult to derive for ‘unobserved’ counties. Univariate relationships between these observed variables and measures of urbanness (here, regional accessibility) were estimated for ‘observed’ counties as a means for determining estimates of structural characteristics for those unobserved counties. As mentioned previously, the detailed analysis of developing these pseudo-hedonic proxy relationships and estimates for Washington state is more fully described in the documentation (I).

Literature-Based Adjustments

As a literature-driven framework, the selection of land use categories and mode-specific facilities are limited to published studies consistent with theory and those that provide information that allows the findings to be applied in a consistent way in the framework. However, this basic framework allows for the user to update the inputs to include additional types of adjustments (e.g., land use categories, mode-specific facilities) by modifying the inputs. This means that the framework (via the inputs) can be updated as more relevant information becomes available.

Decisions to Include/Exclude and Summarize Studies

The following four guidelines were used to decide whether any given study were to be excluded. Before describing this process, it is important to note that these steps are largely made at the discretion of the analyst. The analyst may choose to weight more heavily (or constrain all together) those studies that have been completed in the same or similar areas as the application. More work could be done to improve the selection guidelines and criteria in the future to provide more localized or accurate estimates as well as estimates more consistent with the nuances of the theory. This is discussed further in the section on ‘Discussion & Future Work’.

Consistency with Theory and Improved Practice. Perhaps the most important ‘filter’ for including or excluding a study is the study’s consistency with theory and improved planning policies and design in practice. Theory argues that, but for nearby negative externalities, transit accessibility is positive. The reason is that modern transit planning and urban design practices minimize negative externalities and have a corresponding positive effect revealed in the market. An important assumption made here is that stations are designed to reduce negative externalities (noise, glare, etc.) to such an extent that only positive effects are revealed in the market. In contrast, there is no theory, to the knowledge of the authors, showing this for highways. As a planning tool, this framework (as developed) assumes that planners will employ the ‘best practices’ in design (7, 8), and we filtered studies to include only those we believe reflect this.

Quality of Studies Included. Even if the results provided are consistent with theory, studies with indications of problematic methodologies are removed from the sample—generally studies that examine the before/after impacts of projects and control for spatial autocorrelation, adequate sample size, along with other ‘quality indicators’.

Studies with Non-Significant Findings. Studies that did not find a significant relationship were excluded from the calculation of the average impacts. Arguments for this step are similar to those in the first step of this process described in the section Consistency with Theory and Improved Practice.

Studies with Findings that Do Not Readily Translate. Many studies use methodological approaches that do not readily translate to application in this sort of framework. These approaches include those with inapplicable model forms, case control study designs, and those with limited background information.

Adjustment Type 1: Impact Due to Change in Area-Wide Metric

The first type of adjustment is applied based on changes in some measured value computed at polygon unit of analysis, currently calculated to a census block-group level.

The framework calculates the impact in value for a change in the metric for two measures: automobile accessibility and walkability. The impacts on value for changes in walkability (scaled from 0 to 100, 100 being extremely walkable) were collected from the literature. Commercial and single-family residential land uses saw a +0.9% and +0.5% increase per unit of walkability, respectively, while multifamily residential land saw an +0.4% increase per unit when the value was less than 25 and +0.2% per unit increase when the walkability was above 25 (9–12).

Reconciling the impacts of accessibility on real estate value becomes problematic because definitions of accessibility vary quite a lot and are not always transferable or applicable in this sort of tool. The adjustments to estimated real estate value that are made for changes in accessibility are therefore calculated using a sample of local assessor data. The result varies from county to county, but the findings indicate a zero to 6.5% increase in commercial real estate

value for every unit increase in automobile access to the population and a zero to 1.6% increase in residential real estate value for every unit increase in automobile access to jobs.

To adjust for this type of impact, the framework considers the relative changes in estimated real estate values for a proposed transportation mitigation compared with baseline data. Baseline values for these metrics were computed as part of framework development—in our Washington case study, using CitiLab’s Sugar Access tool—and are inputted into the framework as background data. These data should be updated periodically so that the differences calculated are due to proposed changes to the corresponding transportation networks.

Adjustment Type 2: Impact Due to Change in Proximity

The second type of adjustment is applied based purely on the relationship between the real estate parcel’s relative proximity to the facility (e.g., road, transit station, bikeway). This type of adjustment is applied in the majority of the mode-specific adjustments.

In the literature, the most common way to control for the locational characteristics of a parcel of land is by using the distance to the nearest facilities—either as a continuous variable (e.g., network distance from parcel to a freeway on-ramp) or as by using distance bands (e.g., parcel is between ¼ mile and ½ mile Euclidean distance from the nearest transit station). A finding for a ‘continuous variable’ approach may indicate a 0.5% decrease in real estate value on average for every additional ¼-mile of distance the parcel is located from a transportation facility. A finding for a ‘proximity band’ approach may indicate a 5% increase on average in all parcels located within a ¼-mile buffer around the study area, a 3% increase for properties between ¼ and ¾ miles, and no indication that there is a change in real estate value for properties between ¾ and 1 mile.

This process of aggregating continuous measure studies and ‘buffered band’ studies is graphically depicted in FIGURE 2 where the aggregated ‘proximity band’ buffers is shown in the solid black line. The dashed blue line represents ‘buffer’ study A. The dotted light orange line represents the original continuous distance finding and the dot-dashed dark orange line represents the continuous finding transformed into an average adjustment per proximity range that can be applied with ‘proximity bands’.

[Enter Figure 1 here.]

The literature is summarized by adjustment (positive or negative) in real estate value based on the available, high-quality and applicable literature, as cited (see TABLE 1).

[Enter Table 1 here.]

Once the buffers and adjustments have been defined, they can be used to adjust the ‘baseline value’ of real estate for corresponding block groups. To demonstrate how the buffers are applied, we consider the following example: a transportation facility (e.g., a commuter rail stop) is anticipated in the example block group (BG) as shown in FIGURE 3. Buffers are generated around the facility for each of the ranges; the area within each range is denoted by A_{buff} where $buff \in \{0.125, 0.25, 0.5, 0.75, 1.0, \infty\}$, A_{∞} describes the area in the BG that is not within one of these buffers, and the sum of all A_{buff} equals the total area of the BG (A_{BG}). While this example demonstrates this process on this single BG, this process would be repeated for every block group that intersections with a buffer.

[Enter Figure 2 here.]

The real estate value of the BG is this adjusted based on the distribution of areas that fall within each of the buffers—and their corresponding estimated ‘percent change’ adjustments or PC_{buff} —through a process of apportionment. This is described mathematically in the equation below:

$$VALUE_{adjusted} = \frac{VALUE_{baseline}}{Area_{BG}} \sum_{i=1}^{buff} A_{buff} * PC_{buff}$$

Additional Potential Adjustment Types

The facilities noted in this section emphasize only those facilities studied in the literature. For example, most studies focused on multiuse paths or separated “advanced” facilities (e.g., cycle tracks, buffered bike lanes, bike boulevards). There are additional metrics used to explore the relationship between bicycling facilities and responses in real estate, such as bike ‘sharrows’ and area-wide metrics such as ‘lane miles of facilities’ (10). Similarly, only one study was identified that explicitly examined the relationship in real estate value and the traffic volume on adjunct roadways (in Average Annual Daily Traffic or AADT) which suggested that for each 1000 AADT increase, the land value of adjacent properties (within approximately 1/8th of a mile) observed an 0.8% decrease in property values for single-family residential properties (31). An application of this framework would require a third type of adjustment that identifies developments within a short proximity to the facility and adjusts the estimated value using two user inputs: before and after AADT.

GUIDING PRINCIPLES FOR USE

Through this process, we maintained several guiding principles for the development of the framework and its application in practice. These were developed while considering the limitations of this literature-driven approach. The following are six guides to the application and use of this framework.

Guide 1: The impacts of transportation projects extend beyond economic outcomes.

Correspondingly, transportation investments may include other purposes other than increasing the value of real estate such as advancing social equity, access to opportunities, or improving environmental quality, health or wellness. Changes in real estate value should not be the only metric used in the decision making process. Instead, it should be used as one of several ways in which to help fairly compare impacts of multiple transportation projects or scenarios.

Guide 2: Similarly, changes in real estate value is one of many economic metrics that could be used to measure the (direct) economic impacts of transportation projects. Others could include direct or indirect changes in: jobs; spatial mismatch of employees/employment; agglomeration economies; local, national, or online retail or service sales; income; cost (in time or money) of the user; or unemployment. These qualifications aside, not every transportation project may have a known impact on real estate values, and not every impact on real estate values may be known.

Guide 3: The framework provides an approximation of impact for multimodal or unimodal projects for a few types of major transportation projects studied in the literature. For projects in which the inputs are not captured, caution should be used as the framework will estimate “no change in value.” The lack of change is due to less robust or non-existent literature

for inclusion in the framework. However, this does not always mean that there are no impacts on real estate value.

Guide 4: This framework provides an approximation of changes in net real estate value. These estimates are based on (a) current expected (estimated average) rates, and (b) impacts of facilities identified in the literature. This framework thus provides a ‘best guess’ of the direction of change (positive or negative) and scale (net change in dollar value) based upon today’s average experience under current market conditions, and it is not developed with the intention to approximate the actual future market rate of real estate for the purposes of acquisition or tax increment financing.

Guide 5: This framework assumes that projects will be built with consideration for the best practices in planning design of facilities. For example, early studies centered around fixed guideway transit often showed negative relationships between real estate value and proximity to stations. Over time research found negative relationships corresponding with the design of stations and their interfaces with local neighborhood including such issues as noise, perceived and actual crime, and pollution. Best practices have emerged over time to ameliorate negative externalities while improving positive ones in ways clearly consistent with theory.

Guide 6: This framework was designed for spatial application to better approximate changes in value based on where real estate is currently located at a more disaggregate level (census block group geographies). It can be useful to estimate the distribution of these impacts across space, estimated changes in value at a census block group level. These data can be overlaid with other variables (e.g., average income, home ownership/rental rates, average rent) to estimate the correlations with changes in real estate value with existing demographic information. This could be used in an equity context to help inform the question: “Who is most impacted by this project in terms of changes in real estate value?” Nonetheless, this framework was not built to approximate issues related to potential displacement and gentrification due to these changes in real estate value and answering the question with this framework requires great skill in understanding, defining, and manipulating demographic assumptions within the framework. While this framework may help inform a better understanding of secondary impacts in this area, *additional work is needed in collaboration with experts in housing and displacements to fully understand how (and how much) different changes in value due to changes in transportation impact the lives of the proximate population.*

DISCUSSION & FUTURE WORK

This manuscript describes the development of a framework to operationalize the theory and research identifying the impacts of economic vitality of our neighborhood from various multimodal transportation facility investments. This paper provides a framework for one such measure of economic impact: changes in real estate value. We consider this proposed framework an example for researchers and practitioners alike aiming to develop practical applications of a complex and deep literature. We have mentioned several different limitations of simplifying and operationalizing this literature for local contexts, but in this section we focus on ideas and concepts for future work that may bolster more robust, sketch-based tools than are proposed in this manuscript.

The application of this framework is not without challenges. As mentioned before, this framework was developed alongside a working GIS prototype that allows for an easier application for the practitioner and analyst to apply across dozens of projects. However, a coded tool allows for more complex configurations of adjustments that could be amended in the future. For example, non-linear relationships between value and transportation improvements could be

1 included in place of (or in addition to) the simplified buffer adjustments. Similarly, the literature
 2 could be grouped across similar regions or urban contexts, controlling for variable effects of
 3 increased access across place types. A more detailed ‘literature selection processes’ could
 4 improve and contextualize the process with which literature is selected for specific applications.
 5 In this current framework, the impacts of multiple mode infrastructure improvements are
 6 assumed to be additive because the literature often parses out mode-specific improvements.
 7 However, it is feasible that some configurations of multimodal improvements may lead to
 8 additive, synergistic, or complementary impacts on real estate value. This is largely a new area of
 9 research, but one that could better inform more comprehensive transportation planning
 10 approaches.

11 There exist several weaknesses in the literature that correspond with the weaknesses in
 12 this framework. A bigger focus on longitudinal analyses—particularly multi-modal system
 13 analyses—would strengthen the soundness of the literature-based adjustments. For example, bus
 14 transit, specifically, is often located more heavily in low-income neighborhoods; non-
 15 longitudinal studies will tend to observe lower real estate incomes for these areas, despite the
 16 positive economic outcomes of these investments. Few studies consider impacts on rural or
 17 exurban populations, or smaller metropolitan areas or cities. While larger cities with more
 18 expensive real estate markets may observe larger (and possibly more easily identified as
 19 significant) responses to transportation investments, smaller metropolitan communities may be
 20 more reliant on the transportation network, with fewer opportunities overall.

21 While several studies have identified a significant relationship with automobile
 22 accessibility and real estate value, the scale of this relationship is highly dependent on *how* the
 23 measure is calculated. More often than not, this measure is a more sophisticated proxy for
 24 distance to the central business district. Similarly, few studies consider the market responses
 25 corresponding with the *quality* of transit (e.g., transit accessibility to destinations, frequency of
 26 headways, etc.) in addition to the proximity. However, this brings up another issue with
 27 transportation system project evaluation as a whole. Many studies that evaluate transportation
 28 projects emphasize the need for closer ties between transportation and land use planning
 29 processes. Changes in real estate value due to accessibility-based changes (here, walkability and
 30 auto accessibility) are heavily dependent on changes in land use policies. It is likely that
 31 improvements to the sidewalk network (e.g., adding streetlight, ensuring sidewalks or walk
 32 spaces are present) will not results in huge changes in walkability. This is mainly because
 33 accessibility measures like walkability integrate land use and transportation. Improvements to
 34 reducing the travel time impedances due to walking may only matter for increasing real estate if
 35 the land use policies align with the desired multimodal transportation outcomes. Perhaps the
 36 most challenging work that may build from this line of thinking is to align zoning changes in
 37 land use into the transportation system projects evaluation process.

38 As mentioned previously and worth reiterating, this framework provides an
 39 approximation of one metric which should not be used alone in evaluating the economic (and
 40 social, environmental, health, accessibility) outcomes of any given project. It is possible,
 41 however, that framework output information could be supplement or used as inputs into
 42 externally developed frameworks, particularly those developed in relation to assess equity
 43 impacts or help proactively identify issues related to gentrification.

44 While this framework provides a method for estimating one such measure of economic
 45 vitality, this manuscript describes the successful implementation of this operationalized literature
 46 encourage the exploration of connecting other sophisticated research into practical frameworks

and toolkits for practice. This type of study can be among toughest types of applied projects that should be approached more often: operationalizing existing literature for practice and translating statistically robust findings into things practitioners and policy makers can use.

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AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: K. Currans; A.C. Nelson, S. Chambers; data collection: K. Currans; analysis and interpretation of results: K. Currans, S. Chambers; draft manuscript preparation: K. Currans, A.C. Nelson. All authors reviewed the results and approved the final version of the manuscript.

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FIGURE 1 The Graphed Representation of Study A and B Finding into One Consistent Adjustment

FIGURE 2 A Hypothetical Application of the Framework's Buffer Adjustments

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TABLE 1 Adjustment to Baseline Real Estate Value Due to Proximity from Facilities

Facility	Proximity to:	Source Summarized:	Land Use	Adjustment for Each Proximity Buffer Ring
Light-rail Transit	Stations	(13–17)	Commercial	+40% for 0–½ mile
			Multifamily	+11.5% for 0–½ mile
			Single-family	+4.5% for 0–1/8 mile +6% for 1/8 – ½ mile
Bus Rapid Transit	Stations	(18, 19)	Commercial	+13.3% for 0 – ¼ mile
			Single-family	+5% for 0 – 1/8 mile
Commuter Rail Transit	Stations	(13, 15, 19–22)	Commercial	+5% for 0 – ¾ miles
			Multifamily	+25.2% for 0 – ¼ miles +29.3% for ¼ - ½ miles
			Single-family	+10.5% for 0 – ½ miles +7.0% for ½ - ¾ miles +3.0% for ¾ - 1 miles
Metro Transit	Stations	(14, 22–25)	Commercial	+7.0% for 0 - ½ miles
			Multifamily	+3.3% for 0 – ¼ miles +8.7% for ¼ - ½ miles
			Single-family	+2.2% for 0 – 1/8 miles +4.3% for 1/8-1/4 miles +6% for ¼-1/2 miles +1.7% for 1/2 -1 miles
Separated Bicycle Facilities	Lane	(10, 26–29)	Single-family	+6.0% for 0 – 1/8 miles +13% for 1/8 – ¼ miles +21.8% for ¼ - ½ miles
Highway	Lane	(30–33)	Commercial	-0.2% for 0 – 1/8 mile -1.9% for 1/8 – ¼ mile -8.5% for ¼ - ½ miles -42% for ½ - ¾ miles
			Single-family	-6.9% for 0 – 1/8 miles -8.6% for 1/8 – ¼ miles -13.7% for ¼ - ½ miles -10.1% for ½ - ¾ miles -5.8% for ¾ - 1 miles
Freeway	Lane	(32, 34, 35)	Multifamily	-2.0% for 0 – 1/8 miles -3.4% for 1/8 – ¼ miles -5.6% for ¼ - ½ miles -14.8% for ½- ¾ miles
			Single-family	-2.7% for 0 – 1/8 miles -1.8% for 1/8 – ¼ miles -3.2% for ¼ - ½ miles -5.8% for ½ - ¾ miles -1.4% for ¾ - 1 miles
Major Road	Lane	(29, 34)	Multifamily	+5% for 0 – 1/8 miles
			Single-family	-2.0% for 0 – 1/8 miles -1.0% for 1/8 – ¼ miles -0.2% for ¼ - ½ miles
Notes: The majority of the transit-related adjustments were collected from Higgins & Kanaroglou (36). Generally, those graded as “A” and “B” quality studies were included. Currently, all applicable studies are weighted equally.				

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