Are all transit stations equal and equitable? Calculating sustainability, livability, health, & equity performance of smart growth & transit-oriented-development (TOD)

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ABSTRACT

Purpose: While "Smart Growth", Transit-Oriented-Development, and "Livability" have been around for years, little research has provided a framework to *measure* and *understand* their performance so we can *realize* key sustainability, livability, health, and equity outcomes.

Procedures: In response, this paper builds on literature and practice to evaluate over 350 light rail stations throughout the US, using smart growth, livability, and Transportation/Land-use Coordination (TLC) principles. Using recently developed Livability and Smart Growth Equity calculators (http://bit.ly/SmartGrowthEquity), and a smart growth/livability place-typology framework, this research assesses and grades "livability opportunity access" performance of these station areas along such key dimensions as regional/local access to jobs, services, transit, walkability. Using analysis of variance (ANOVA) methods, we show the significant associations between this livability access and the potential for realizing key quality-of-life benefits important for both individuals and society. But are all people able to equitably access these livability opportunities around transit so they can work towards realizing their desired quality of life?

Findings: This study provides a unique evaluation of urban quality performance related to Transportation Land-use Coordination (TLC), "Smart Growth" and "New Urbanism. We find stations with higher levels of livability opportunity access to be significantly associated with key quality of life outcomes for individuals and society, such as lower rates of obesity, cardiovascular disease, asthma, driving, carbon emissions, and even lower poverty and unemployment. These higher-performing stations also have higher rates of walking, bicycling, transit use associated with lower household transportation costs which offset higher housing costs. Unfortunately, these stations are not socio-economically inclusive – in sum, all stations are not equal, or equitable.

Using livability-opportunity-access-assessments with *livability ethics*, we recommend transportation and land-use agencies coordinate policies to provide equitable access to opportunities so all people can pursue and realize sustainability, livability, health, and equity outcomes for themselves and society.

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1. Introduction

"Smart Growth", also often referred to by academics and practitioners as transportation/land use integration or coordination (TLC), has been an important approach for planners, engineers, and urban designers for years, but few studies have formally linked smart growth around transit stations, or transit-oriented developments (TOD), to sustainability, livability, health, and equity outcomes.

In response, this research builds on a multi-year analysis of the literature, theory, and practice, followed by an extensive quantitative and qualitative study of over 350 transit corridors and thousands of transit station areas throughout the United States (Appleyard et al., 2016; Ferrell et al., 2016). While light rail transit systems have received criticism in the past for falling short of justifying their expense over regular bus service, achieving high enough ridership, or providing competitive service (Hook et al., 2013; Pickrell, 1992), our study focuses on assessing these and other outcomes for the greater health of communities and the environment, and suggests LRT has significant, measurable livability and quality of life benefits. Specifically, this paper identifies important characteristics of smart growth/transportation-land use-coordination (TLC) and livability opportunity access at over 350 light rail transit (LRT) station areas throughout 12 metro areas in the U.S. It then applies these findings to develop a planning framework to assess the livability-opportunity-access performance of current LRT stations throughout the country.

Building on previous work (Appleyard et al., 2016; Ferrell et al., 2016), this study offers a bridge between (1) a definition of smart growth and "livability opportunity" performance at light rail transit stations and transit-oriented-developments (TOD); (2) a performance measurement framework to help us *measure* and *understand* how "livability opportunities" can give people the chance to achieve higher livability, health, and wellness quality of life outcomes, as well as help society achieve key objectives for sustainability, and perhaps most importantly, equity; and (3) this research provides a unifying typology and set of planning support tools that people can help people evaluate smart growth, TLC, and livability, sustainability, health, and equity performance, not only around station areas and corridors, but in any place in the US and throughout the world.

2. Background: the transportation/land use, smart growth, & livability connection

For years, top researchers in urban and transportation planning have focused on developing effective strategies for transportation/land use coordination (TLC) and smart growth to achieve a wide range of goals associated with livability (Appleyard, 2005; Moore et al., 2007; Appleyard, 2011b; Cervero, 2003, 2001). In a 2001 speech to the Australian Planning Association, Robert Cervero described fundamental elements needed to advance "smart growth", directly characterizing this as the coordination between transportation and land use planning (Cervero, 2003, 2001). In 2005, Susan Handy, published an article in the International Regional Science Review in which she reviewed recent research on the transportation and land-use connection (Handy, 2005).

At its core, transportation and land use coordination (TLC) is an integrative concept that ties together access through both a) mobility via transportation policy, and b) access through proximity, or via land use policy (Cervero, 2000; Cervero et al., 1999; El-Geneidy and Levinson, 2006; Levine et al., 2012, 2009; Levinson, 1998; Wagner and Caves, 2012). Therefore, TLC can be viewed as a key component of best planning practices connected to the provision of access to "livability opportunities" (Appleyard et al., 2014; US EPA, 2016; Moore et al., 2007) and "smart growth" (Cervero, 2000) by both practitioners and academics alike. For example, in chapter 11 of Wagner and Cave's book on Community Livability, Dr. Ruth Steiner establishes the EPA's 10 Smart Growth Principles as a mainstay of livability planning through transportation and land use integration. Along these lines, there is a strong resemblance between the 6 Livability Principles of the HUD/USDOT/EPA Sustainable Communities Partnership (SCP), outlined in the next paragraph below, and EPA's 10 Smart Growth Principles (US EPA, 2016; Wagner and Caves, 2012).

However, in large part due to the institutional imbalances between the transportation and land use sectors (Appleyard, 2005, 2011; Appleyard et al., 2014; Moore et al., 2007), smart growth and TLC have been hard to achieve and realize in the United States. To illustrate this point, we should recognize how the transportation sector, in comparison to the land use sector, has a powerful vertical public/private organization that can effectively coordinate technical expertise and programmatic knowledge to both fund and deliver projects, from road to rail transit. In contrast, land use decision-making follows a much more complex multifaceted and loosely coordinated horizontal structure of actors including local governments, developers, real estate agents, financial institutions, community members, and advocates, with interests ranging from pro-smart growth to not-in-my-back-yard (NIMBY) interests. This mismatch, or imbalance, between the organization and wherewithal of these two sectors to deliver and coordinate their activities can be referred to as the transportation/land use imbalance and/or disconnect (Appleyard, 2005, 2011; Appleyard et al., 2014; Moore et al., 2007).

In response, work endeavors to rebalance and re-integrate this transportation and land use disconnect through effective performance measurement frameworks and policy responses that elevate land use and urban design, to specifically dealing with livability opportunities, sustainability, health and equity, to be more on par with transportation.

2.1. A framework for evaluating smart growth, transportation land use integration, and livability equity

Research and practices focused on combining transportation land use integration with livability reached an important milestone in 2009, when a more complete definition of livability was adopted by the Secretaries of Housing and Urban Development (HUD), U.S. Department of Transportation (USDOT), and Environmental Protection Agency (EPA) through their Sustainable Communities Partnership (SCP). In 2016, a National Academies of Sciences' project was completed that worked to better operationalize these six principles for measurement, analysis, and policy guidance through an online Smart Growth Equity Calculator, *A Livability Calculator*

Fig. 1. The Six "Livability Principles of the 2009 Sustainable Communities Partnership (SCP) between Housing and Urban Development (HUD), U.S. Department of Transportation (USDOT), and Environmental Protection Agency (EPA), and the six principles used to operationalize the measurement, analysis, and policy guidance of these SCP principles through a *Livability Calculator for the Handbook for Building Livable Transit Corridors,* and the associated handbook (Appleyard et al., 2016; Ferrell et al., 2016).

for the *Handbook for Building Livable Transit Corridors,* and the associated handbook (Appleyard et al., 2018; B Appleyard et al., 2016; Ferrell et al., 2016). Fig. 1 below shows the six associated "Operationalized Livability Principles" of the original HUD/USDOT, & EPA SCP Principles.

Overall, the detailed language of these Six SCP Livability Principles of HUD/USDOT/EPA and the associated "Operationalized Livability Principles" reveal how the federal officials, and arguably many other professionals, were combining concepts of livability with concepts of urban quality, smart growth, and by extension, transportation/land use integration. From our previous research, we developed a framework within which the measure of urban quality, or transportation/land use coordination (TLC) is determined by what we refer to as "livability opportunities" (affordable housing, jobs, safe and accessible walkability). These opportunities can then be converted into quality of life outcomes, which can include things like health, safety, social inclusion and emissions reductions (Appleyard et al., 2014, 2016).

These findings are also consistent with other previous studies linking higher levels of built environment performance, in terms of smart growth and TLC, to health outcomes. For example, several articles find that more compact communities are associated with lower traffic collision rates (Ahangari et al., 2017). Other studies show a connection between transit service, ridership, and improvements in traffic safety (Litman, 2016; Stimpson et al., 2014). Additionally, scholars have examined the relationship between greater walking, bicycling, and transit access providing increased public health benefits from greater physical activity (Frederick et al., 2018; Lachapelle, 2010; Lachapelle and Frank, 2009; Sallis et al., 2016). And there have been other efforts to quantify the benefits of TOD, by the Center of Neighborhood Technology (CNT)("TOD Database," n.d.) and Smart Growth, by the Center of Neighborhood Technology (CNT)("TOD Database," n.d.) and Smart Growth America, which includes their work measuring sprawl and its impacts (Ewing and Hamidi, 2014). Another recent study by Hamidi et al. (2018) found that life expectancy was significantly higher in compact than in sprawling counties in the US, but the causal mechanisms are still unclear. And finally, there are new studies indicating how more compact and multimodal built environments increase economic mobility (Ewing et al., 2016; Frederick and Gilderbloom, 2018).

In sum, the these principles reflect normative, best planning practices related to smart growth, new urbanism, and transportation and land use coordination (TLC) as a measures of urban quality that can hopefully achieve a spectrum of "livability opportunities" that can, in turn achieve a range of quality of life, sustainability and equity outcomes (Appleyard et al., 2014; US EPA, 2016)–all key goals of this research.

2.2. Livability Justice and Ethics: linking transportation & land use coordination with equitable access to "livability opportunities"

As discussed in detail in (Appleyard et al. (2014) the HUD/USDOT/EPA livability principles are a mixture of descriptive and prescriptive elements, inspired in-part by Moudon's seminal work (Moudon, 1992) outlining descriptive-prescriptive based

components of urban design approaches (Appleyard et al., 2014, 2016). To review, while the descriptive elements focus on performance characteristics related to such elements as "affordable housing," "health and social services," and "transportation choice", prescriptive elements focus primarily on specific actions decision-makers can take, such as to "[c]oordinate and leverage federal policies and investment."

Furthermore, as access to opportunities creates the foundation for livability, previous research has also identified concerns about providing equitable access to such livability by improving opportunities. In response, the concept of Livability Ethics was introduced (Appleyard et al., 2014), which in basic terms states that one's pursuit of livability should not obstruct the livability pursuits of others, especially the less powerful.

Building on our previous work (Appleyard et al., 2014; Appleyard et al., 2016; Ferrell & Appleyard et al., 2016), an overarching definition to guide the balanced coordination of transportation and land use to produce equitable access to livability opportunities for all people so they can realize their desired quality of life is needed. This "mission statement" has three dimensions: Livability Justice, Ethics and Equity, Access to Opportunities, and Transportation/Land Use Coordination. Pulling all the prescriptive and descriptive elements together, our definition/mission statement to achieve the HUD/EPA/USDOT SCP livability principles is as follows:

> As stewards of the built environment, planners, designers and engineers should seek to coordinate transportation and land use to provide all people easy and equitable access to opportunities to improve and maintain their desired quality of life, prioritizing the needs of society's less powerful and most vulnerable, and placing highest value on people's humanity, at rest and in motion.

While there may be refinements to this definition of Livability Justice and Ethics, and we do hope others will try to improve on this one, at least this gives us a starting point to build on towards providing equitable access to opportunities for people to improve, or just simply maintain, their desired quality of life. As outlined in Appleyard et al. (2014), realizing this Livability Justice and Equity will require planners, designers, and engineers to prepare to mediate between livability pursuits in conflict over such things as providing affordable housing near transit stations and providing bicycle facilities that may reduce curbside parking.

2.3. Developing a light rail station area typology in the U.S. – a brief literature review

In the early 1990s Peter Calthorpe presented and popularized the term "transit oriented development" or "TOD". This definition identifies the station area as a fundamental building block for transportation and land use integration. Calthorpe in the *Next American Metropolis*, provides a definition (consistent with our aforementioned definitions for TLC and Livability), that TODs "… mix residential, retail, office, open space, and public uses in a walkable environment, making it convenient for residents and employees to travel by transit, bicycle, foot or car" (p. 56). Calthorpe adds to this definition by saying that a TOD is: "… a mixed-use community within an average 2,000-foot [0.38-mile] walking distance of a transit stop and a core commercial area" (p.56), which supports our use of a half-mile catchment area in this study.

More recent work by Renne (2009) and Renne and Ewing (2013) applied a 3-D (density, diversity, design) framework first conceptualized by Cervero and Kockelman (1997) to develop a station area typology organizing along a continuum from Transit-Oriented Developments (TODs) to *emergent*, Transit Adjacent Developments (TADs) – "station areas that are not compact, mixed-use, or pedestrian-friendly" (p.14). In this work by Renne and Ewing, stations were categorized on a TAD – TOD spectrum based on the following thresholds and point-based system:

- Greater than 30 jobs or residents per gross acre = 1 point
- Not having 100% of land uses as either residential or commercial = 1 point
- Average block size less than 6.5 acres1 = 1 point

  Renne and Ewing (2013), then applied a point-based categorization system as follows:

- TAD = 0 or 1 points
- Hybrid = 2 point
- TOD = 3 points

Renne and Ewing acknowledge the door is open for improving on their method, advocating for additional research to better determine the residential to commercial spectrum so as not to penalize places that are solely residential or commercial (Renne and Ewing, 2013). Research by Aston et al. (2016) outlines another method of measuring TOD quality by using similar population density, land use entropy, and walkability as the criteria for - density, diversity and design - finding light rail (tram) catchment areas have better transportation land use integration compared to other transport mode such as train, local bus and rapid bus.

Building primarily on station typology scoring system developed by Renne and Ewing (2013), this study uses various built environment indicator thresholds, such as density, diversity, design, and additional "D" variables that go beyond local attributes to capture regional effects, such as *Distance* to transit, and *Destination/Regional* (mostly job) accessibility (Cervero and Kockelman, 1997; Ewing and Cervero, 2010, 2001).

This study incorporates the work of others as well, including Dittmar and Ohland's (2004) focus on location efficiency, which aligns with this study's measures of regional as well as local accessibility between home and livability opportunities related to work, shopping and leisure. This study's methods also incorporates Austin et al.'s (2010) recommendations to also provide a confirmatory analysis regarding travel (VMT) rates, and other measures that we call "quality of life proxies", such as walking, bicycling, obesity

Table 1
Study light rail system.

Metropolitan Area (MSA)	Population (2015)	Name	Lines	Total Stations	Network Length	Ave. daily ridership*	First Operation
Charlotte, NC	5,072,300	CATS	2	32	9.6 miles	16,700	2007
Dallas, TX	7,102,796	DART	4	64	93 miles	104,800	1996
Denver, CO	2,814,330	RTD	6	53	47 miles	76,600	1994
Houston, TX	6,656,947	METRO Rail	1	35	22.7 miles	60,600	2004
Minneapolis-St. Paul, MN	3,524,583	METRO	2	37	23 miles	71,400	2004
Phoenix, AZ	4,574,531	Valley Metro Rail	1	35	26 miles	58,700	2008
Portland, OR	2,389,228	MAX	5	97	60 miles	122,900	1986
Sacramento, CA	2,274,194	SCRT	3	54	42.9 miles	45,300	1987
Salt Lake, UT	1,170266	TRAX	3	50	44.8 miles	67,300	1999
San Diego, CA	3,299,521	TROLLEY	3	53	53.5 miles	123,300	1981
San Jose, CA	11,030,400	VTA	3	61	42.2 miles	33,400	1987
Seattle, WA	3,733,580	LINK	2	20	20.4 miles	41,000	2003

(*Weekday ridership: Q4 2015: ATPA).

rates, etc., which can be used to validate the livability opportunity qualities of this paper's presented LRT Station Typology.

3. Methodology

3.1. Light rail stations and systems in this study

This study covers LRT stations from 12 metro areas in the United States. Table 1 compares the system profile of study light rail systems. Based on data availability, explanatory variables related to built environment, transportation, economic opportunity, greenhouse gas emissions, bicycling/walking rates, and obesity were identified, collected, processed and analyzed for 357 stations outside of Central Business Districts (CBDs). Through a GIS apportioning method, we calculated straight-line distance catchment areas for all stations, and then gathered and apportioned data from the underlying Census geographies based on the proportion of the geography that falls within the catchment area. For example, in the case of whole number variables, such as the number of affordable housing units, if 50% of a Census Block Group falls within the catchment area, 50% of the value is added. In the case of rates, such as population per acre, an average of all the selected CBGs within the catchment area is calculated. Through this extensive GIS geospatial processing, data for these variables were gathered within the half-mile station catchment area and a station typology was developed based on previous research and utilization of the *Livability Calculator* (Appleyard et al., 2016).
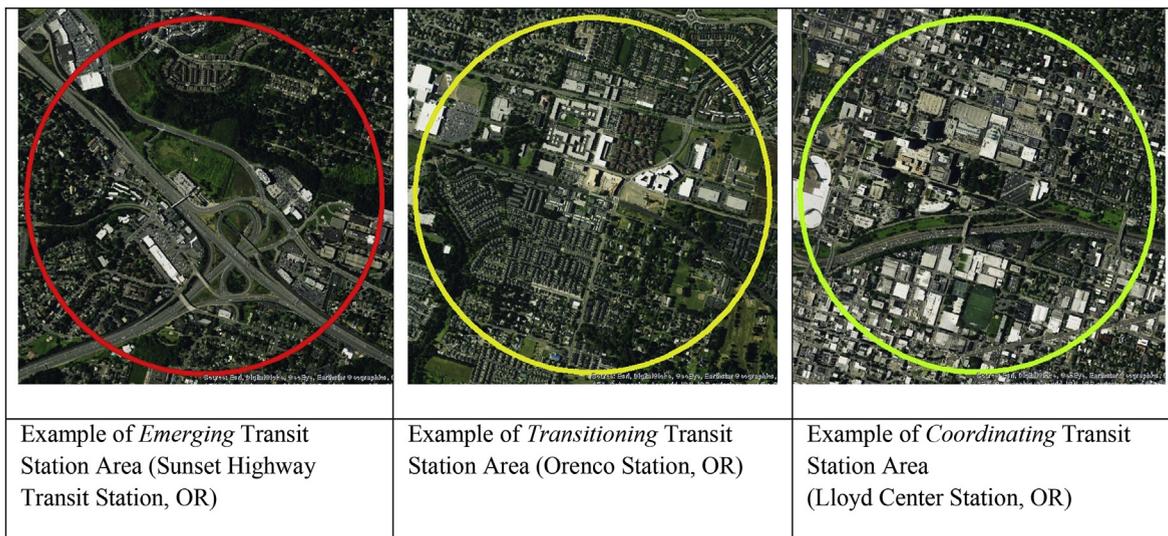
3.2. A note about stations within and outside of central business districts

Central business districts (CBDs) are unique urban places that—when comparing transportation/land use integration and livability characteristics—are much different than station areas outside of a CBD. Consequently, this study draws important distinctions between stations outside and inside of central business districts. The CBDs of this study all have concentrations of livability opportunities (housing, jobs, retail) and transportation services (transit and walking accommodations) that are consistently greater than transit stations outside of a CBD. As there are also many other synergistic effects of CBDs, such as parking scarcity, taking CBDs out of this analysis seems to allow for a clearer evaluation of the performance of these peri-CBD stations. Therefore, we chose to focus the current efforts on stations outside of CBDs. Separate analyses of these CBD station areas will be forthcoming in future publications. Nevertheless, we include the average values for CBDs in Table 4. These results show CBDs to have demonstrably higher values (except in the case of retails jobs) than *Coordinating* stations. This finding about retail jobs could be related to land use policies around peri-CBD stations, and deserves further study.

3.3. Station area data and metrics

Building on this research team's previous corridor typology development efforts, as well as earlier work by Renne and Ewing (2013), a comprehensive array of data was gathered and analyzed through the *Livability Calculator* (Appleyard et al., 2016). An important task in this process was to properly determine thresholds between various station types. Following an iterative, heuristic process using GIS, satellite imagery, and Google Streetview, we applied and tested quantitative thresholds to distinguish station types, based mostly on measures of transportation and land use integration and access to opportunities (such as housing, jobs, & retail) and facilities such as transit frequency and walkability.

The Livability Calculator (LC)—developed as a companion tool for *TCRP Report 187: Livable Transit Corridors: Methods, Metrics, and Strategies*—proved useful in dynamically fine-tuning new thresholds to understand finer-grained details of station area typology characteristics outlined in the section below.

| Example of *Emerging* Transit Station Area (Sunset Highway Transit Station, OR) | Example of *Transitioning* Transit Station Area (Orenco Station, OR) | Example of *Coordinating* Transit Station Area (Lloyd Center Station, OR) |

Fig. 2. Using this paper's Smart Growth/TLC/Livability-Opportunity-Access place-typology framework, and data being processed through recently developed Livability- and Smart Growth Equity - Calculators (see http://bit.ly/SmartGrowthEquity), all light rail stations were assessed and graded for their performance along such key dimensions as regional/local access to jobs, services, transit, walkability, affordability, and inclusion. The above figure shows examples of the following station area performance levels, from lowest to highest: Red = Emerging; Yellow = Transitioning; Green = Coordinating. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.4. Station area typology

The station area typology was developed using an iterative process of measuring the characteristics of our LRT station study areas, analyzing their commonalities and differences, and developing a series of typology categories that described their characteristics in a narrative. At the end of this process, the following LRT station area categories were created:

- **Emerging** (infrequent transit, limited transport connectivity, and segregated/low intensity land uses
- **Transitioning** (moderate transit frequency, moderate street connectivity, moderate-to-high intensities, and some mixes of uses), and
- **Coordinating** (high transit frequency, high connectivity, moderate-to-high intensity, and a mix of complementary uses).

In all cases, action words were chosen to convey that these station areas, like much of our urban spaces, should be viewed as works-in-progress, and where we likely need to constantly work toward their comprehensive achievement of sustainability, livability and equity for all.

3.5. Defining thresholds

The thresholds for the LRT station area types outlined above allowed us to quickly and easily classify LRT station areas, as shown in Fig. 2, which emerged from an iterative process observing all the LRT stations, a pattern of a natural break between stations became evident based on Density, Mixed-Use, Design, Destination (job) Accessibility, and Transit Service variables. The following is an itemized discussion of the foundations for the station typology thresholds, as shown in Table 2 at the bottom of this discussion.

3.5.1. Density and mixed use

The topic of minimum densities necessary to support transit ridership is related to developing a minimum benchmark definition of

Table 2
Livability calculator station thresholds.

Metric	Emerging to Transitioning	Transitioning to Coordinating
Transit jobs accessibility (within 45 minutes by Transit)	7,500	30,000
Transit service coverage (aggregate frequency of transit service per square mile)	350	4,000
Jobs density (employees/acre)	5	10
Population density (population/acre)	5	20
Retail jobs density (retail employees/acre)	0.5	1.5
Pedestrian environment (intersections per sq. mile)	64	100

TOD. Cervero and Guerra (2011) found that 30 people per gross acre was a minimum density that light rail systems needed to perform in the top quarter of cost effectiveness across all transit systems. As Renne and Ewing (2013) used 30 jobs OR residents per gross acre, the study thresholds was set at 5 for jobs and 5 for population, to move from emerging and transitioning, and 10 for jobs and 20 for population to move from Transitioning to Coordinating. These thresholds appear to also work in light of Renne and Ewing's modest bar for mixture of use—"Not having 100% of land uses as either residential or commercial = 1 point (p. 10)."

Answering the call by Renne and Ewing to help distinguish between commercial and residential areas, the study calculated thresholds for retail jobs density (retail employees/acre), as well as health care and access to culture & arts. We ultimately did not use these variables as thresholds during this phase of our research as they did not seem more important or distinct enough from retail employment – we wanted to keep the use of these thresholds as simple as possible. In some cases, these measures were also not as consistent across the stations studied to be reliable thresholds. We plan to re-evaluate the use of this measure in the future.

3.5.2. Design (intersections per square mile)

Instead of using Renne and Ewing's (2013) walkability measure of "Average block size", we use the more common measure of intersection density per square mile, broadly recognized for its association with route directness and street network connectivity, both important components to walkability (Appleyard, 2015, 2012; Ewing and Cervero, 2010). In determining the threshold between Transitioning and Coordinating stations, we reflect Renne and Ewing's (2013) walkability threshold of "Average block size less than 6.5 acres" we use the equivalent measure of 100 4-legged intersections per mile. For the threshold going from Emerging to Transitioning, we chose 64 4-legged intersections per mile, which is roughly equivalent to 10-acre sized blocks. This intersection density threshold can be found in historically Mormon grid-patterns, such as found in downtown Salt Lake City, UT and parts of Burbank, CA. While these both are considered "urban" environments, this block scale does not readily support walkability. Therefore, using 64 4-legged intersections as the threshold marker between the lowest performing, Emerging, station areas, and the mid-range performance of Transitioning station areas, seems appropriate.

3.5.3. Destination (jobs) accessibility

In addition to the other improvements outlined above using various built environment indicator thresholds, such as density, mixed use (diversity), and design, we add the use of additional "D" variables, such as destination/regional (mostly job) accessibility, as well as distance to transit, to more fully capture regional and local access to opportunities (Cervero and Kockelman, 1997; Ewing and Cervero, 2010, 2001).

First, we add a measure of destination/regional (jobs) accessibility, which Ewing and Cervero found in their seminal reviews of travel behavior and the built environment studies to have the strongest association with lower VMT and auto trip rates (Ewing and Cervero, 2001, 2010). Including such a variable makes a significant contribution toward understanding the difference between two station areas that may appear to be similarly designed, at the local perspective, yet could be actually located in vastly different parts of a region, and hence provide significantly different opportunities for auto-independence, based on Ewing and Cervero's findings related to regional job (destination) accessibility (Ewing and Cervero, 2010).

3.5.4. Distance to transit

Transit frequency is used as a measure of distance to transit, as well as TOD supportive investments and coordination, as per one of the six HUD/USDOT/EPA "Livability Principles", "Coordinate and leverage federal policies and investment". It is also a useful measure of the degree to which people have transportation choice, as well as their ability to free themselves from auto-dependency.

Both metrics were derived from Smart Location Database Version 2.0 (EPA, 2013). Transit jobs accessibility metric involved the preparation for five different Origin-Destination matrices. Transit service coverage metric is calculated by dividing aggregated frequency of transit service per hour during evening peak period by total land acreage (census block groups) then converting to units per square mile.

3.6. Determining a station's place-type

Once the thresholds were defined, we sorted the stations into their respective typology categories. For example, to achieve Coordinating status, a station had to achieve measures above all thresholds in Table 2 from "Transitioning to Coordinating". If a station was above in some thresholds, but not in others, but still above all "Emerging to Transitioning" thresholds, the station was classified as Transitioning. Our approach is beneficial as it moves us toward the development of a composite, continuous variable for transportation/land use coordination (TLC) which can be used for future statistical modeling.

The validity of this typological framework was then tested through an analysis of variance (ANOVA) difference of means test, first checking the integration for livability metric scores, and then the validity of livability potential by examining key quality of life proxy measures, as shown in Tables 4 and 5, respectively.

4. Analysis and discussion

Through the station typology developed herein, we can gain a better understanding of how transportation and land use co-ordination (TLC) in these station areas can affect access to livability opportunities, and ultimately chances for improved quality of life (QOL) by all members of the public using these areas.

Table 3

Transit stations categorized by transportation, land use integration and livability metrics.

Typology Scale	2010	
	Number of LRT Station	Percentage of Stations
Emerging	48	13.4%
Transitioning	258	72.3%
Coordinating	51	14.3%
All Stations	357	100%

Table 4

Light-rail station typology results.

Metric	Mean Values by Light Rail Station Type						
	Emerging	Transitioning	Coordinating	CBD	F Value	ANOVA Sig. F-Test	Degrees of Freedom (Between, within)
Transit jobs accessibility	6,980	16,437	47,095	48,379	72.771	.000	(3, 295)
Transit service coverage (aggregate frequency of transit service per square mile)	153	752	3,797	4,600	62.37	.000	(3, 307)
Jobs density (employees/acre)	7.66	11.97	55.76	60.52	68.431	.000	(3, 363)
Entertainment jobs density (entertainment employees/acre)	0.55	1.19	5.87	6.12	76.122	.000	(3, 363)
Retail jobs density (retail employees/acre)	0.50	0.59	2.68	1.87	114.87	.000	(3, 363)
Population density (population/acre)	4.96	9.70	15.60	21.4	33.74	.000	(3, 363)
Pedestrian environment (intersections per sq. mile)	50.7	99.2	174.0	187	69.74	.000	(3, 363)

Table 5

Analysis of variance (ANOVA) results comparing coordinating and emerging average proxy QOL indicator scores for light rail transit stations, outside of CBDs.

Proxy QOL Outcome Indicators	Mean Values for LRT Station Types (Outside of CBD)						
	Emerging	Coordinating	Difference	% Difference	F-Values	ANOVA Sig. F-Test	Degrees of Freedom (Between, within)
Journey to Work (ACS, 2014)							
Drove Alone	69.45%	49.55%	−19.90%	−28.65%	49.65	.000	(2, 193)
Public Transportation (excluding taxicab)	7.48%	13.97%	6.49%	86.76%	19.42	.000	(2, 193)
Bicycle	1.71%	4.35%	2.64%	154.39%	13.34	.000	(2, 193)
Walked	3.83%	18.05%	14.22%	371.28%	130.93	.000	(2, 193)
VMT, Auto Ownership, Household (HH) Expense (HUD, 2013), and Housing (Zillow, 2016)							
Household* Annual Vehicle Miles Traveled	23,028	17,239	−5,789	- 25.13%	65.69	.000	(2, 354)
Auto Ownership Per HH*	1.97	1.62	−0.35	−21.60%	36.82	.000	(2, 354)
HH* Transportation Costs % of M Income	19.08%	15.34%	−3.74	- 19.60%	38.83	.000	(2, 354)
HH* Housing & Transportation Costs % of M Income	46.48%	41.51%	−4.97	−10.69%	21.54	.000	(2, 354)
Median Square Foot Sale 2010	$158.8	$219.2	+60.4	+38.03%	10.17	.000	(2, 354)
Civic Engagement (Census, 2012), Carbon Footprint (Jones and Kammen, 2014) & Health (CDC, 2014)							
Opportunity for Civic Involvement (# of civic, social, religious, political & business organizations per 10,000 people)	6.05	7.20	+1.15	+19.00%	7.085	.002	(2, 354)
Access to Cultural, Arts, and Entertainment Institutions (# of institutions per 10,000 people)	0.69	1.06	+0.36	+52.01%	11.545	.000	(2, 354)
Household Carbon Footprint from Transport (MtCO2e/yr)	14.05	10.21	−3.84	−27.33%	18.53	.000	(2, 354)
Total Household Carbon Footprint (MtCO2e/yr)	42.70	34.53	−8.17	−19.13%	16.19	.000	(2, 354)
Obesity Rates**	23.52%	22.79%	−0.73	−3.10%	2.04	.112	(1, 307)

*Household of 2 adults and 2 children **Emerging & Transitioning Stations vs. Coordinating Stations.

4.1. Characteristics of transportation land use integration for livability light rail station typology

Based on methodology explained in the previous section, Table 3 shows that 13.4 percent of LRT stations were *Emerging*, 72.3% were *Transitioning* and 14.3% were *Coordinating* for the 12 metro areas. The typology analysis reveals how more than 85% of LRT station in this study did not meet the *Coordinating* criteria for TLC for livability, validating the difficulty of improving transportation

and land use imbalances and thereby the limited realization of land use/transportation integration in the United States.

4.2. Validation of the LRT typology for TLC, livability, and quality of life outcomes

Once the iterative process of classifying the light rail stations to the TLC for livability typology was complete, average metric scores and ANOVA tests of significance between the means were calculated for each typology category. As shown in Table 4, the LRT station types yielded interpretable results, with *Coordinating* having the best metric average scores, followed by *Transitioning* LRT stations, and then *Emerging* station areas. These preliminary results provide initial validation of the typology as measuring both aspects of transportation and land use integration, accessible livability opportunities, and ultimately the potential for quality of life satisfaction outcomes.

4.3. Comparing LRT station quality of life proxy measure outcomes

To further validate the connection of this typology to transit corridor livability, a variety of proxy quality of life (QOL) variables related to transport, economic opportunity, environmental sustainability, and health were gathered and used to compare outcomes between the various LRT station types. Specifically, we focus on the differences between the higher performing (*Coordinating*) LRT stations and the lower performing (*Emerging*) ones.

In theory transit stations with the highest transportation/land use integration and livability should also provide the greatest number of economic opportunities within easy access, which, by extension, should lead to a higher potential for QOL. Several QOL proxy travel outcome indicators were used to test the hypothesis that people in *Coordinating* station areas appear to realize higher levels of auto-independence and destination accessibility, and by extension, have a greater potential to achieve a higher level of potential QOL, than people in *Emerging* station areas.

Therefore, in terms of transportation-related QOL proxies, the travel patterns of *Coordinating* station residents should be relatively short, should use non-auto modes for a significant share of their trips, and should have low household transportation expenditures compared to *Emerging* station areas.

Analysis of a collection of travel behavior outcome (Proxy QOL) indicators supports these hypotheses (see Table 5).

For example,

- *Coordinating* LRT stations lead to more walking, bicycling, and transit ridership, while lowering the overall amount of driving.
- According to data from the ACS (2014), people walk to work 14.22 percentage points more in *Coordinating* LRT stations areas versus *Emerging* ones, while biking to work is 2.64 percentage points more frequent in *Coordinating* LRT stations areas versus *Emerging* ones.
- Workers in *Coordinating* stations drive to work 19.9 percent less than workers in Emerging LRT station areas, while taking about 6.49 percent more transit trips to work (ACS, 2014).
- According to data from HUD (2013), *Coordinating* station households travel over 5,789 fewer vehicle miles per year, than households in *Emerging* LRT stations.
- *Coordinating* station households own fewer cars (1.62 per HH) *vs. Emerging* LRT station areas (1.97 per HH).
- Households of two adults and two children also pay more for transportation in *Emerging vs. Coordinating* LRT stations spending 19.1% vs. 15.3% of Household Median Income (HUD, 2013).
- All of this leads to important benefits for our climate and air quality, as greenhouse gas emissions (GHG) are lower for households living in *Coordinating* LRT stations with annual total household carbon footprint at 42.70 tCO2e in *Emerging* vs. 34.53 tCO2e in *Coordinating* LRT stations, a reduction of GHG emissions by roughly 8.17 tCO2e per year. This is mostly attributed to higher transportation emissions, where residents in *Emerging* LRT station are estimated to account for 14.05 tCO2e while 10.21 tCO2e for *Coordinating* LRT, which equate to saving of about 3.84 tons of GHG per year (Jones and Kammen, 2014)

While the data show considerable household budget savings, it is worth noting that when comparing housing cost per square foot from Zillow (2010), homes in *Coordinating* LRT station areas are selling for about $60.4 more per square foot higher than *Emerging* LRT station areas. This makes sense as livability opportunity measures are capturing the value of conveniences, amenities, services, and place-making. These paradoxical results on cost and affordability are also consistent with a recent paper by Renne et al. (2016). More research should be done to confirm, however, whether people living in *Coordinating* LRT stations are living in physically smaller households, as these findings suggest.

4.4. Additional QOL proxy measures findings

Several additional QOL proxy measures were evaluated from a variety of sources (see Table 5), providing further evidence that *Coordinating* LRT stations provide greater livability and QOL potential than *Emerging* stations. Specifically, *Coordinating* stations are found to yield additional benefits to households in those areas.

For example, analyzing data from HUD (2013), we found that households in *Coordinating* LRT station areas pay significantly less for transportation than households in *Emerging* LRT station areas. Specifically, households in *Emerging* LRT station area pay a factor of 20% more for transportation compared to *Coordinating* LRT station areas.

When looking at housing and transportation (H + T), we also find the differences great with households in *Coordinating* LRT

station areas paying about a factor of 10.6% less of their household budget for housing and transportation. Part of this is likely associated with the ability to avoid the burden of car-ownership - 1.6 per household in *Coordinating* station area, and 2 per household in *Emerging* - and the fewer vehicle miles travelled per year, as discussed earlier.

According to data from Census (2012) people living in *Coordinating* LRT station have twice the access to cultural, arts, and entertainment institutions while 19% more opportunities for civic involvement via civic, social, religious, political and business organization compared to *Emerging* LRT station areas.

Finally, higher transportation land use coordination also provides positive health benefits. The obesity rate (BMI > 30) is a factor of 3.1% less in *Coordinating* LRT station areas compared to *Emerging* stations (CDC, 2014). Although the significance is relatively weak, most likely due to a lack of granularity in the dataset, the difference merits further investigation to study health outcomes between the two different station typologies in California.

Coordinating LRT station areas also have higher walking and biking rate compared to *Emerging* LRT station areas. A recent U.S. survey conducted in both English and Spanish found that 79 percent of Americans believe they should walk more, but 40 percent do not walk within their neighborhoods because it lacks nearby service, shops, schools, and workplaces (Tuckel and Milczarski, 2015). As coordinating transportation and land use increases, the likelihood of residents engaging in more sustainable and healthy non-motorized transportation activities increases–helping people realize positive health outcomes.

4.5. LRT typologies and health outcomes – California case study

Analyzing the most recent data from California Office of Statewide Health Planning and Development (OSHPD), University of California Los Angeles (UCLA) and American Community Survey (2014) around three LRT systems in California – Sacramento, San Diego and San Jose - many public health benefits are revealed. This is likely due to better granularity – at the census track and ZIP code - of the data. As shown in Table 6, there is a difference of 5.5 percentage points in obesity rate or a factor of 21% less obesity for those who live around *Coordinating* LRT stations than *Emerging/Transitioning* stations. While the rate of cardiovascular disease is 25% lower and incidence of asthma is 31% lower in *Coordinating* LRT stations area compared to *Emerging/Transitioning* stations.

4.6. LRT typologies and social vulnerability and exclusion – California case study

While we have many indications that people are realizing higher quality of life (QOL) outcomes around *Coordinating* stations, these stations, at least in the California context, do not seem to be providing livability opportunities equitably; while *Coordinating* stations in this study are diverse from a transportation and land use perspective, they are not diverse with respect to socio-economic status. For example, education levels, poverty, race/ethnicity, and linguistic isolation in the *Emerging/Coordinating* station areas are all about a quarter to a half the rate of those in station areas that are integrated from a transportation/land use perspective.

This brings up at least two fundamental issues. First, this socio-economic disparity limits strong conclusions regarding the causal relationships between transportation/land use integration and quality of life public health outcomes. More research is needed to understand these causal relationships. Second, this represents a violation of our earlier livability ethics arguments for equitable access to livability opportunities for better quality of life (Appleyard et al., 2014). Based on guidance provided by the Handbook for Building Livable Transit Corridors (Ferrell et al., 2016), policies for greater social equity and inclusion are needed such as the construction of affordable housing, low income housing tax credits, inclusionary housing strategies to encourage more family-size apartments and townhouses, more public elementary schools, parks and recreational facilities, while increasing allowable densities and reducing minimum parking requirements.

5. Caveats and limitations

As with any study we recognize limitations, omissions and potential biases. For one, it is important to recognize that some of these outcomes may actually be a result of self-selection bias—that is, people and their individual capacity, actions, and preferences are the major drivers of healthy and sustainable behaviors, not the environment in which they live (Cao et al., 2009). For example, while our finding that cardiovascular disease and asthma rates are much lower in higher performing, *Coordinating* TODs than *Emerging* LRT stations is important, this could be due to self-selection biases driven by wealth, age, and the preference for walkable communities. to address this in the future, surveys can be conducted of people who work and live around these stations, in combination with statistical modeling techniques such as confirmatory factor and path analysis, to help sort through the causal mechanisms of these associations.

Another caveat of this study is that it may not look enough at the downsides of living near TODs, such as traffic, noise, etc. Indeed, not everyone may agree that lower auto-use necessarily supports high quality of life, at least from an individual perspective. But our focus should be on *Livability Ethics and Equity,* which asks us to think more broadly about societal livability by prioritizing the needs of vulnerable populations – and that we be prepared to mediate between livability pursuits in conflict in order to facilitate the pursuits of the less powerful to have the freedom to improve their lives (Appleyard et al., 2014). Finally, by quantifying walkability, transit access, and job accessibility as key determinants of lowering auto-dependency (Ewing and Cervero, 2010), we are also capturing important components of sustainable travel outcomes.

6. Conclusion & next steps

This paper provides an approach that defines *transportation land use coordination (TLC) for livability (TLC4L)* by measuring urban

Table 6
ANOVA results comparing emerging and transitioning vs. coordinating average proxy QOL outcome scores for SJ/SD/SAC light rail transit stations, outside of CBDs.

Proxy QOL Outcome Indicators	Mean Values for CA LRT Station Types (Outside of CBD)				F-Values	ANOVA Sig. F-Test	Degrees of Freedom (Between, within)
	Emerging & Transitioning (N80)	Coordinating (N8)	Difference	% Difference			
Obesity Rate – above 30% BMI for workers over 18 years old (2014) (UCLA 2014)	26.28%	20.78%	−5.5	−20.92%	5.17	.025	(1, 86)
Cardiovascular Disease – spatially modeled, age-adjusted rate of emergency department visits for AMI per 10,000 (OSHPD, averaged over 2011–2013)	7.92	5.87	−2.05	−25.88%	8.00	.006	(1, 87)
Asthma – spatially modeled, age-adjusted rate of emergency department visits for asthma per 10,000 (OSHPD, averaged over 2011–2013)	58.45	39.90	−18.55	−31.73%	3.30	.073	(1, 87)
Unemployment – percent of the population over the age of 16 that is unemployed and eligible for the labor force. Excludes retires, students, homemakers, institutionalized persons except prisoners, those not looking for work, and military personnel on activity duty (ACS, 2014)	12.03%	6.87%	−5.16	−42.89%	7.93	.006	(1, 87)
Measures of Social Vulnerability and Exclusion							
Education – percent of the population over 25 with less than a high school education (ACS, 2014)	16.64%	8.98%	−7.66	−46.03%	3.04	.083	(1, 87)
Poverty – percent of the population living below two times the federal poverty level (ACS, 2014)	40.40%	28%	−12.4	−30.69%	4.096	.046	(1, 87)
Linguistic Isolation – percentage of households in which no one age 14 and over speaks English "very well" or speaks English only (ACS, 2014)	10.12%	5.79%	−4.33	−42.78%	3.32	.073	(1, 87)
Race/Ethnicity – Percent of population that is not White (non-Hispanic) (Census, 2010)	58.40%	43.52%	−14.88	−25.47%	3.77	.055	(1, 87)
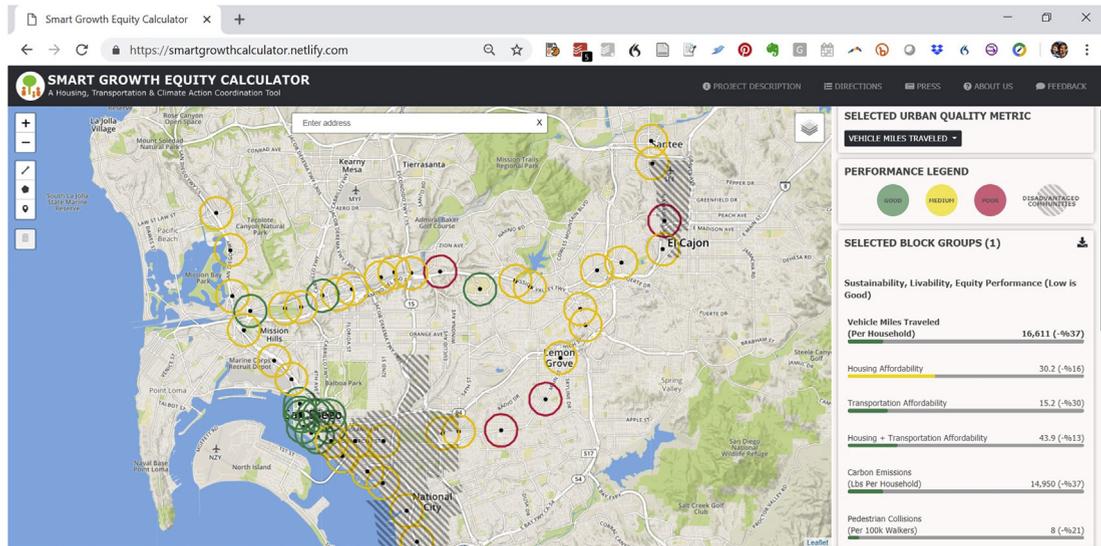
Fig. 3. Shows the performance of light rail stations in San Diego, California, as provided by the new online *Smart Growth Equity Calculator*, and according to the Smart Growth & Transportation/Land Use Coordination (TLC) performance typology outlined in this paper: Red = Emerging; Yellow = Transitioning; Green = Coordinating. The indicators on the right show the performance of a sample Coordinating station, with lower regional averages for household *Vehicle Miles Traveled, Carbon Emissions, Transportation Expenditures,* but challenged in terms of affordability because of paradoxically higher housing costs. The hatched areas on the map locate California designated disadvantaged communities deserving protection from forces of displacement via targeted policies. For more information, see https://smartgrowthcalculator.netlify.com/ or http://bit.ly/ SmartGrowthEquity (Appleyard et al., 2018). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

quality and access to livability opportunities, and then examines the associated quality of life outcomes for health, wellness and equity for 357 LRT stations in 12 Metro areas throughout the US. These findings can allow planners to systematically identify transportation and land use coordination needs by comparing the metric scores for a particular LRT station area of interest to similar station areas from across the U.S. The research this paper builds on previous work (Appleyard et al., 2014; Appleyard et al., 2016b; Ferrell & Appleyard et al., 2016), which is operationalized using the *Livability Calculator for the Handbook for Building Livable Transit Corridors: Methods, Metrics and Strategies*, and related handbook (Appleyard et al., 2016a; Ferrell & Appleyard et al., 2016) also allows planners to first assess, then address these needs using a host of implementation strategies and actions that cross jurisdictional and disciplinary boundaries. Similar livability opportunity assessments can now be found in the new online *Smart Growth Equity Calculator* (See Fig. 3). Importantly, the research provides an operational framework for understanding livability and guidance for achieving transportation and land use coordination (TLC). Therefore, it is intended that these findings not merely serve as an academic exercise, but as the foundation for building a series of practical applications for use by transit corridor and station area stakeholders.

While TLC is often associated with urban quality resulting from best planning, urban design, and engineering practices, this is one of the first studies to establish empirically-based methods to understand how the connection between TLC and improving access to livability opportunities is associated with people's potential to achieve greater quality of life (QOL) outcomes – particularly around LRT stations.

For example, the study finds high levels of TLC and access to livability opportunities to be associated with less driving and more walking, bicycling and transit ridership. Furthermore, *Coordinating* station areas are places where people spend less on transportation, live healthier lives with lower obesity rates, and help save our climate by emitting significantly lower amounts of greenhouse gases.

Unfortunately, while we have many indications that people are realizing higher QOL outcomes around *Coordinating* stations, these stations, at least in the California context, do not seem to be providing livability opportunities equitably; while *Coordinating* stations in this study are diverse from a transportation and land use perspective, they are not diverse from a socio-economic one. As this condition violates key tenants of *livability ethics*, namely providing equitable access to livability opportunities for the less powerful to achieve a better quality of life (Appleyard et al., 2014), policies are needed for greater social equity and inclusion around these stations, such as the construction of affordable housing, low income housing tax credits, inclusionary zoning. For further guidance for these policies and associated analysis are provided in the new online *Smart Growth Equity Calculator,* the *Livability Calculator for the Handbook for Building Livable Transit Corridors* and the associated handbook (Appleyard et al., 2016a; Ferrell & Appleyard et al., 2016).

In closing, this paper describes effective methods for measuring and understanding smart growth & transportation/land use coordination (TLC), and places these associated approaches firmly within the context of best-practices in planning, engineering, and urban design. Results conclude that effective smart growth and livability measurably benefit people's ability to access opportunities to improve and/or maintain their quality of life. More work is needed, however, to make sure this access is equitable.

Put simply, *livability opportunity access analysis,* combined with "livability ethics" (Appleyard et al., 2014) provides an effective

organizing framework for guiding transportation and land use coordination (TLC) strategies toward providing people equitable and comfortable access to opportunities that will allow them to achieve their desired quality of life outcomes, such as increasing walking and bicycling which is associated with lowering obesity, auto-dependency, household transportation budget burdens, and greenhouse gas emissions.

Nevertheless, more analysis is needed to further validate these initial findings. For example, surveys should be conducted of corridor and station area users to further validate proxy measures to determine what aspects of a station or corridor are leading to higher levels of QOL satisfaction and controlling for such things as self-selection bias. To address this, we are exploring the use of social media (Twitter) data to dynamically capture peoples' sentiments about their respective station areas. This research provides direction on how and where such surveys should be conducted.

We should also recognize the need to control for such things as self-selection bias and the absence of random sampling in light of the clustered nature of the data collected along each transit system, both of which could be addressed through mixed-model and hierarchical linear statistical approaches.

Future research can also seek to understand obstacles encountered by metropolitan planning organizations (MPOs) and local stakeholders on the path to station and corridor-level visioning, planning, and implementation, such as with best practices for gathering information, evaluating scenarios, and communicating strategies that enable decision makers to move from vision to action, and overcome the institutional obstacles presented by the "transportation land use imbalance" mentioned in the beginning of this paper. While the federal SCP's Livability Principles offer a solid framework for considering livability in the context of urban quality, their interpretation may, at times, need to account for local conditions and values. Future adjustments for local variability can be addressed through refinements to the methods and proposed policies outlined in this paper.

Finally, building on this exploratory study, future research should further review these typologies and their measurements, develop conceptual and empirical evidence for all the elements that may be left out, then test the new typologies against various outcomes (as we have done here). All along the way, we need to continually assess whether all the new metrics are worth the effort.

7. Closing remarks

This paper and the research that it describes represent a "first salvo" in the effort to address livability through transportation and land use coordination. The online *Smart Growth Equity Calculator*, the *Livability Calculator for the Handbook for Building Livable Transit Corridors,* and the associated handbook (Appleyard et al., 2018; B Appleyard et al., 2016; Ferrell et al., 2016) provides a dynamic assessment and policy guidance for strategies that can effectively address common challenges and target implementation. Strategies for corridors and their station areas also span the spectrum of livability needs – to name a few: affordable housing programs, pedestrian network improvements, traffic calming, access to recreation, and health care services. Strategies also include governance tools. For example, case study research shows that TOD guidelines have become a common practice among MPOs to help address factors associated with physical form and urban design. At the local level, station area plans are also common.

Finally, it is important to recognize that MPOs, transit agencies, and local land-use decisions need coordination and integration to make significant advancements toward overcoming TLU imbalances inhibiting livability access and optimization. The advancement of transit station areas and corridors toward higher levels of *livability opportunity access* relies on both transit system investments AND local and regional progress toward *coordinating* land use and urban design approaches to TOD. Livability performance remains relatively low when activities only focus on transit system investments *or* local progress (in the form of land use, connectivity, development character, etc.). The Transportation/Land Use Coordination for Livability (TLC4L) approach described herein can be a vehicle for initiating and sustaining initiatives in this regard, as it focuses holistically on LRT catchment area livability and squarely on people's equitable and comfortable access to opportunity.

As our study controls for areas within a ½ mile, straight-line distance, to light rail transit, it provides a useful evaluation of urban quality performance related to the often elusive concepts of TOD, Transportation Land-use Coordination (TLC), "Smart Growth" and "New Urbanism. All station areas in this study have roughly equivalent access, at least in terms of straight-line distance, but they perform along a continuum of low to high Transportation Land-use Coordination (TLC)/Smart Growth quality — the core determinants, as discussed in this paper, are a) how much "Livability Opportunity Access" is provided? and, b) how well are people able to derive beneficial quality of life outcomes from this access? And our findings present concerning implications for the less powerful and more vulnerable in our society in this regard.

Based on our findings, the poorer and less powerful seem to have diminished access to opportunities they can access to realize key quality of life outcomes, such as lower rates of obesity, cardiovascular disease, asthma, and even lower poverty and unemployment rates. Furthermore, our findings have direct implications for society as a whole as the inequitable exclusivity of these high-performing stations providing robust rates of access to livability opportunities so people who live around them can improve their quality of life also means the less powerful and more vulnerable may experience increasingly lower opportunities to be free from driving, or the chance to walk, bicycle, and/or ride transit—even though these are all transit stations. In light of discourses to raise gas and congestion charges to mitigate greenhouse gas emissions in response to climate change, this could leave the poorer and less powerful vulnerable to the regressive nature of higher gas taxes and congestion charges–we need only look to the recent "Yellow-Vest" protests in France to see how auto-dependent groups can revolt against gas tax increases designed to fight climate change, likely fueled by their lack of access to housing in areas that can free them from having to drive – core basic concept of Livability provided by USDOT Secretary Ray La Hood when he presented the Six Livability Principles of the USDOT/HUD/EPA Sustainable Communities Partnership in 2009 (Appleyard et al., 2014, 2016).

In sum, the short answer asked in the title of our paper is, unfortunately, no – all stations are not equal, let alone equitable or

inclusive. And this should be of great concern to us all.

In response, we recommend transportation and land use agencies work together to combine livability-opportunity-access-assessments with *livability ethics* to *measure, understand,* and the *realize* the coordination of transportation/land-use in research and policy, with the overarching goal of providing equitable access to opportunities for all people so they can freely pursue sustainability, livability, health, and equity outcomes for themselves, those who they care about, and society as a whole.

In closing, we offer this *livability ethics & equity* maxim to help guide us toward these objectives:

As stewards of the built environment, planners, designers and engineers should seek to coordinate transportation and land use to provide all people easy and equitable access to opportunities to improve and maintain their desired quality of life, prioritizing the needs of society's less powerful and most vulnerable, and placing highest value on people's humanity, at rest and in motion.

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