Livable Streets, Livable Arterials?
Characteristics of Commercial Arterial Roads Associated with Neighborhood Livability

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Problem, research strategy, and findings: Planners and engineers traditionally consolidate motorized traffic onto arterial roads that pose challenges for surrounding neighborhoods. We investigated the positive and negative impacts of commercial arterials with nodes of activity on the livability of surrounding neighborhoods. We examined 10 arterials in Denver, Colorado, and surveyed respondents in adjacent neighborhoods asking how they viewed those arterials. We employed factor analysis to create a typology of neighbors' perceptions of these arterials. Neighbors like arterials that they perceive as (1) Vibrant with good transit access, and (2) Quiet and clean; they dislike arterials that they perceive as (3) Unpleasant, and (4) Sketchy. Vibrant arterials contributed to the perceived livability of the surrounding neighborhoods, while Sketchy arterials were negatively associated with livability—but the same arterials were often simultaneously Vibrant and Sketchy. Residents clearly value the social functions that arterials provide and seem less aware of traffic volumes; some low volume arterials were not more livable than those with higher traffic volumes. Our findings are limited by the small sample size; we did not try to validate objective measures of livability with residents' perceptions.

Takeaway for practice: Arterials can be good places for surrounding neighborhoods while still serving as major traffic corridors; accessibility and mobility do not always conflict. Planners should develop economic development plans for affected neighborhoods and enhance neighborhood livability by encouraging active land uses on arterials, maintaining the safety and cleanliness of arterials, and enhancing the pedestrian environment along those arterials.

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Introduction

Growing cities must enhance public transit, create bicycle and pedestrian networks, and revitalize neighborhoods. Planners often assume that *arterials*, or major roads, are obstacles to achieving these goals because arterials aggregate local traffic to move it efficiently across cities and regions. Many arterials are therefore unsuited to walking, cycling, and accessing transit. Planners often assume that arterials reduce *livability* and quality of life—that is the extent to which residents are happy to live where they live—in the neighborhoods surrounding arterials.

Some researchers have questioned whether arterials necessarily reduce livability. We believe that some arterials can be livable despite heavy traffic, but we have little empirical evidence about what characteristics are required for livability, especially from the perspective of people living nearby. This is a problem because growing cities need streets that are both livable and useful for transportation (Cherry et al., 2006; Mejias & Deakin, 2005), but we do not yet know what factors contribute to their livability. Planners cannot work to create livable arterials without this knowledge.

We investigated *commercial arterials* to address this gap and focused on commercial arterials with *nodes*, intersections where multiple streets come together clustering commercial land uses like restaurants, bars, and shops. We surveyed residents living near commercial arterials in Denver, Colorado, to find out how happy they were with their neighborhoods (livability) and how they perceived the characteristics of nearby arterials. Our goal was to answer the following question: What resident-perceived factors distinguish livable arterials from non-livable arterials?

To answer this question, we determined the characteristics of arterials that are important to residents; then, we determined whether these characteristics statistically related to perceived livability. This perspective on the livability of arterials builds on the neighborhood livability literature by focusing on streets, and by distinguishing between different scales of streets in a neighborhood (i.e., residential and arterial). We review existing research on arterials and livability in the first two sections of this article. We then describe how we collected data and the statistical methods we used in our study. We present our results in four sections: first, we identify the factors that neighbors use to describe nearby describe arterials and reveal how these factors are related to livability; second, we explore our novel findings related to one interesting type of arterial: “Vibrant–Sketchy” arterials; third, we recommend policy and practice improvements; fourth, we present additional results that may be of interest to scholars and practitioners.

We found that neighbors perceive arterials in ways that we categorize in four categories: (a) Vibrant, (b) Quiet and Calm, (c) Socially Sketchy, and (d) Unpleasant. Arterials can fall into more than one category; we found that Vibrant and Sketchy characteristics, for example, often occur on the same streets. The Vibrant nature of these arterials confers livability benefits, while their Sketchy nature constrains livability. We believe that three types of interventions could help minimize sketchiness and maximize vibrancy on these arterials: (1) encourage nodes of active land uses, such as restaurants, that serve nearby residents; (2) control litter and prevent minor incivilities; and (3) enhance the pedestrian environment, particularly supporting transit access and reducing exposure to traffic hazards. These interventions require integrated land use and transportation planning as well as partnerships beyond the transportation sector.

What We Know about Arterials

Arterials play a special role in transportation networks. They support through trips by carrying high volumes of fast traffic across regions. Arterials are more like freeways than local roads (U.S. FHWA, 2013). Arterials in practice, however, often provide more access to pedestrians and cyclists than the theory would ideally allow. They support local trips, serve transit routes, and facilitate goods distribution. These multiple—and often conflicting—uses of the road persist because arterials are the typical location of drive-through restaurants, gas stations, auto repair shops, dollar stores, and other commercial establishments. Motorists and pedestrians alike must be able to access these commercial centers, but design standards based on the original concept of an arterial force tradeoffs between providing safe, multimodal access to these places, for example by adding wider sidewalks and timing traffic signals with longer walk phases, and maintaining mobility for automobiles and other motorized traffic (Gillem, 2008; Macdonald, 2007). Planners do not typically approach arterials considering both multimodal access and enhanced motorized mobility.

Different types of arterial roads handle traffic and access in different ways. Planners limit commercial land use along arterials in some places to avoid the problem of access and to reduce traffic congestion (U.S. FHWA, 2003). Conversely, some arterials, like the ones in our study, double as neighborhood main streets. These neighborhood arterials still allow for relatively high traffic volumes but serve the dual demand for travel and leisure activities (e.g., eating out, window shopping). Such arterials support a vibrant street life and can have bicycle lanes, sidewalks, and well-designed transit stops to serve multiple travel modes. Arterials that serve this dual demand are critical in places where arterials are the workhorse of the regional transportation system, carrying a significant share of total traffic while also providing important functions in the local context.

The important physical characteristics of arterials include traffic volumes, traffic speed, noise levels, the potential to support transit, and the design and attractiveness of the streetscape (Alameda County Transportation Commission, 2016; Gillem, 2008; McAndrews et al., 2006;

Mejias & Deakin 2005; Seto et al., 2007; ULI, 2016). Figure 1 presents examples of a range of arterial designs from Denver, Colorado. The arterials in (a) and (b) both carry more than 25,000 vehicles per day, but the design of (b) includes one edge with a pedestrian-focused design that uses parking and trees to create a buffer between the traffic lanes and sidewalk. A similar contrast exists for smaller scale arterials too. Examples (c) and (d) carry only about 13,000 vehicles per day, but (d) does not have building setbacks and includes a bus stop with street furniture. Arterial (f) carries only about one-tenth the amount of traffic carried by Arterial (c)—about 60,000 vehicles per day—although (f) is officially designated an arterial by the City of Denver. The smaller arterial (f) functions as a neighborhood main street, while the larger one (c) links to the interstate freeway.

[Figure 1 here]

Arterial roads can be neighborhood cultural assets and social places, in addition to their role as travel corridors (Bosselmann et al., 1999; Loukaitou-Sideris, 1997, 2002; Loukaitou-Sideris, 2000; McAndrews & Marcus, 2014; McAndrews et al., 2006). Arterials are places that nearby residents use with some frequency, despite their traffic and related hazards. For example, residents use *boulevards*—a type of arterial designed with a landscaped median and travel lanes that separate faster through traffic from slower local traffic—for walking, jogging, and bicycling, and as parks where they can walk dogs, interact, or sit and watch the activity (Bosselmann et al., 1999; Jacobs et al., 2002).

Arterial roads can also reflect social and economic challenges. Churches, theaters, memorials, and libraries may be located on main streets because they are "the ideal setting for speeches, parades, and celebrations" (Liebs, 1985: 8). These downtown arterials, however, lost traffic and business declined when cities built freeway bypasses. Urban arterials faced the dual impact of decline and urban renewal as development occurred in suburbs, leaving many urban arterial roads and their commercial strips empty, boarded up, and decaying (Liebs, 1985; Loukaitou-Sideris, 1997, 2000, 2002). Development today has revitalized some of these arterial strips, but the vast majority continue to serve primarily as traffic and fast-food corridors (Hurvitz et al., 2009; Loukaitou-Sideris, 1997, 2000, 2002).

Some research has shown that residents perceive an association between social problems and arterial roads in inner cities and older suburbs that have commercial strip development (McAndrews et al., 2006). Surveys of nearby residents, business owners, and developers have been a main source for data about the social characteristics of arterials. Survey respondents and focus group participants highlight gangs, drug dealing, and prostitution as well as needles, graffiti, litter, and a lack of maintenance as typical problems that negatively affect their neighborhoods (Loukaitou-Sideris, 1997, 2000; McAndrews et al., 2006; Mejias & Deakin, 2005). Business owners call attention to surrounding poverty as a challenge (Loukaitou-Sideris, 2000). These social issues could negatively affect livability in the neighborhoods surrounding arterials.

The transportation system includes arterials with different characteristics depending on when the area developed, the design standards that applied at the time, and the current social, economic, and demographic context. We focus on commercial arterial roads located in central Denver, which includes arterials that were early streetcar lines, and that could currently function as main streets. Our study does not include arterials in Denver's newer suburbs, which have a different mix of social and design characteristics. Nor does our study include Denver's historic, residential boulevards.

Arterials and Livability

There is a decades-long tradition of research related to managing the negative effects of motorized traffic (Buchanan, 1963; Godschalk, 2004). The negative, “unlivable” characteristics of urban arterial roads, such as a lack of traffic safety, have been documented in planning, engineering, urban design, and public health literatures (Dowling et al., 2008; Dumbaugh & Gattis, 2005; Dumbaugh & Rae, 2009; Hebbert, 2005; Mindell & Karlsen, 2012; Miles-Doan & Thompson, 1999). Research consistently finds that high volumes of motorized traffic, combined with a lack of pedestrian-oriented design, have a negative effect on livability. Poor pedestrian environments can limit access to jobs, housing, schools, and neighborhood amenities because streets designed for motorized traffic alone function as barriers to other types of users (Hur & Morrow-Jones, 2008; U.S. FHWA, 2013). Streets with high traffic volumes are also sources of noise and other health hazards (Seto at al., 2007; Urban & Máca, 2013). Such health hazards include higher self-reported stress and depressive symptoms (Matthews & Yang, 2010; Yang & Matthews, 2010); injury (Miles-Doan & Thompson, 1999; Dumbaugh & Gattis, 2005); and higher risk of cancer, respiratory disease, and poor birth outcomes (Landrigran, 2017). Planners, urban designers, and traffic engineers have therefore developed strategies to protect residents from the problems that cars create including noise, pollution, and speed.

Researchers recognize today that traffic can make certain streets dynamic and interesting, despite being noisy and polluted. Researchers in the 1970’s like Appleyard (1972, 1973) began to consider the idea that, just as streets with heavy traffic could take away from livability, they could also contribute to livability through their design. Contemporary researchers agree that there is a conflict between traffic and livability, but they are not mutually exclusive (Bosselmann et al., 1999; Jacobs, 1993; Jacobs et al., 2002).

There are rich practical and research literatures about what makes a neighborhood livable, as well as what indicators represent this livability (Basolo & Strong, 2002; Greenberg et al., 2010; Mast, 2010; Sawicki & Flynn, 1996). Research about residents' perceptions of livability indicates that key factors include an aesthetically pleasing environment that is safe from crime and traffic and the presence of nearby parks and other amenities (Hale et al., 2011; Lee et al., 2017; Litt et al., 2011). This literature, however, does not distinguish the unique ways that arterial roads—as distinct from residential streets or other elements of the built environment—can influence neighborhood livability. Our study begins to address this gap in the literature.

Existing research identifies several ways that arterials can differ from one another in their street design and traffic operations (Marshall & McAndrews, 2017), social and economic activity (Mejias & Deakin, 2005), land use mix (ULI, 2016), presence of multi-modal transportation amenities (Cherry et al., 2006), and urban design (Gillem, 2008; Macdonald, 2007). Researchers have not yet examined, to our knowledge, how these characteristics influence resident-perceived livability in neighborhoods surrounding commercial arterials. Therefore, we used these characteristics taken from the literature as the variables in our study to determine how, if at all, they influenced livability from residents' perspectives.

Measuring the Relationship between Arterials and Livability

We analyzed a cross-section of 10 commercial arterial roads in Denver, Colorado, each with a node of clustered retail but with different amounts of traffic, street designs, and levels of activity. Our goal in site selection was to capture a range of potentially good and bad qualities of commercial arterials, such as traffic volumes, tree canopy, and presence of sidewalks, so we could determine which of these objective characteristics, in combination with perceived characteristics, contributed most to livability. We chose only commercial arterials in central Denver with surrounding residential neighborhoods so that the arterials we chose were comparable. Each of our 10 sites is a "case" that includes the segment of the arterial road, the retail node, and the surrounding residential area.

Our site selection process proceeded in several stages. In stage one, we identified all of the street segments in central Denver officially designated as arterials using Denver's geographic information systems street layer. We identified arterials that also had commercial nodes using a combination of parcel-level land use data, visual inspection using Google Maps, and site visits. We narrowed down our list of potential sites by excluding those that were dominated by hospitals, schools, or industrial land uses. We made field visits to the remaining 34 sites and narrowed the list to 19 sites, choosing only those where the retail nodes were in the center of a residential district, rather than functioning as the edge of a neighborhood.

In stage two, we gathered publicly available, administrative data on six variables for these 19 sites. We determined (1) the number of lanes, (2) curb-to-curb width, (3) percentage of the street covered by tree canopy, and (4) average annual daily traffic (AADT). We determined (5) the socioeconomic context surrounding each potential site using U.S. Census data for each adjacent or intersecting block group.

We used environmental data collection to construct (6) the urban design score, using a method developed by Ewing and Clemente (2013). This method breaks urban design into five categories: imageability, enclosure, human scale, transparency, and complexity. Each category has several specific measurements that contribute to its category score. One measurement that contributes to the category score of imageability, for example, is a count of the courtyards, plazas, and parks along both sides of a block. (See the Technical Appendix for a description of the operationalized metrics that result in the urban design score.) The method combines all of the category scores into an overall urban design score, where higher values indicate better urban design. We chose to examine the overall urban design score because prior research suggests that good urban design on an arterial can buffer the negative effects of heavy traffic, whereas poor urban design can exacerbate its effects (see Hebbert, 2005). Table 1 presents information about the physical characteristics of the sites.

In stage three, we used the data gathered from our short list of 19 sites to select 10 sites for our study. Our goal in narrowing down the list was to arrive at a selection of sites that, taken together, had diversity in the traffic volumes on the arterial itself, income levels in surrounding neighborhoods, and the quality of urban design. We organized the secondary data about the arterials into three groups: traffic (the AADT, dichotomized into *high* and *low* categories), urban design (the urban design score, dichotomized into *high* and *low* categories), and socioeconomic status (U.S. Census median household income for surrounding block groups; again defined as *high* or *low*). Figure 2 illustrates the rubric we develop to identify all eight possible combinations of these categories. We chose one arterial site for each of the eight possible combinations from among our 19 candidate sites. We assigned eight sites to the rubric, and then included two remaining sites whose neighborhoods had high-, medium-, and low-traffic residential streets, for a total of 10 sites. We excluded the remainder of the sites because their surrounding neighborhoods lacked residential streets that had heterogeneous traffic volumes.

[Figure 2 here]

We selected, for each of the 10 final sites, three nearby residential streets on which to administer a residential survey, for a total of 30 residential streets (we did not administer the survey to residents living on the arterial itself). We conducted our own 24-hour traffic counts of prospective nearby streets and selected our cases to ensure a range of residential traffic volumes (high: 5,000–27,500 veh/24hr, medium: 1,700–8,500 veh/24hr, and low: < 850 veh/24hr).

We developed and administered a door-to-door residential survey (*n administered* = 1,849, *n responses* = 723) during the summer of 2014 to learn about how livable residents find their neighborhoods, residential streets, and local arterial roads. We pre-tested the survey instrument with a convenience sample of university students. Graduate research assistants conducted the door-to-door interviews and manually entered the survey data into an electronic form. We audited ten percent of the coded surveys to ensure data quality. Our university's Institutional Review Board reviewed and approved our study.

Table 2 presents demographic data for the sample, including the distribution of respondents across the 10 arterial sites. We adapted the questions that we included in the survey from questions created by Appleyard to investigate livable streets, which Bosselmann et al. (1999) also used. The survey included 33 questions; 20 questions asked about the residents' perceptions of their residential street (5 questions), neighborhood (8 questions), and nearby arterial (7 questions); the remaining 13 questions asked about residents' individual and household characteristics (see the Technical Appendix for survey questions and response categories). We asked residents, for example, whether they thought their neighborhood arterial had good lighting and sidewalks, whether it was good for bicycling, and whether traffic on the arterial moved too fast. We also investigated how neighbors used their arterials by asking, for example, whether they went to restaurants on the arterial and whether they walk to destinations on the arterial.

We administered the survey to all residential units that were (a) located on one of the 30 streets and (b) within 0.5 miles of the nearby arterial road. For the first visit, a team of survey interviewers placed a door hanger at the residence to announce the survey and inform residents that interviewers would be coming to their neighborhood on a specified day. For the second visit, teams of two interviewers rang doorbells and attempted to administer the survey at that moment. If residents agreed, then they filled in the survey while the interviewers waited. If a resident came to the door, they were also given the option of taking the survey privately and having it picked-up later in the afternoon, or taking the survey privately and returning it by mail in a pre-paid envelope. If a resident did not answer, interviewers placed a different door hanger at their door with a “we missed you” message and additional dates when the survey interviewers would be returning, as well as a contact number to schedule a visit, if preferred. Those who called for appointments ($n = 15$) were interviewed within one week. Monolingual Spanish speakers received an informational flyer about the survey in Spanish with the contact number of a bilingual interviewer. Interviewers recorded the address in notes so that the bilingual interviewer could return during the next round with a Spanish-language survey. We dropped off only four surveys in Spanish, and we received none back.

During the third and final visit, interviewer teams visited all of the units that had not answered the door. If a resident came to the door, they had the same options as before (i.e., complete in the moment, complete for pick-up, mail-in, or refuse). If no one responded at the door, survey interviewers left a cover letter, survey, return envelope and slip giving the option of receiving the incentive by e-mail. We offered survey respondents a five-dollar gift card for participating.

We visited a total of 1,849 housing units and received 723 completed surveys. Of these, 319 (44%) were returned by mail and 401 (56%) were conducted in person while the interviewers waited. The overall response rate was 39%. Our lowest response rate for a street was 12%.

Our research questions asked about (a) the characteristics of arterials and (b) if and how these characteristics were associated with livability. We conducted two analyses to address these issues. We first conducted an exploratory factor analysis (EFA) to reduce our 33 survey questions to concrete factors related to livability to explore the characteristics of arterials. EFA is a statistical technique used to determine whether survey items naturally group into categories, or "factors", based on the response trend among participants. We asked residents, for example, whether their arterials were good for walking, and, whether the arterials had good sidewalks. These are two separate questions strictly speaking, but we would expect them to relate statistically—residents are likely to perceive streets that have good sidewalks as being better for walking. EFA is a way of identifying groupings like this, revealing the overall factors that make up livability.

We next conducted statistical analysis to determine whether and how each of the factors derived from the EFA analysis contributed to perceived livability (using a technique called "ordinal logistic regression"; see the Technical Appendix for more detail). Our goal was to find out whether our independent variables of interest—the arterial factors—were related to our measures of perceived livability (the dependent variables) when controlling for personal characteristics and characteristics of the residential street that might also influence perceived livability. The three measures of perceived livability were (1) how happy residents are living on their street (on a scale of 1 to 5); (2) how highly residents rated the overall quality of their residential street (on a scale of 1 to 10); and (3) how highly residents rated the overall quality of their neighborhood (on a scale of 1 to 10). We selected control variables for the statistical analysis using a purposive approach based on theoretical relationships, prior empirical research, bivariate relationships between the dependent variable and potential covariates, and the Akaike Information Criterion as a measure of model fit (see Technical Appendix).

Arterial Characteristics Important to Residents

Our survey asked residents to rate 15 positive and 15 negative characteristics of nearby arterials in terms of how positive or how negative they thought those characteristics were. We divided these items into positive and negative categories based on previous research findings on their association with livability. This strategy limits our ability to identify cases where traditionally positive factors, like lighting, might seem negative, for example if there is too much light. Traditionally negative factors, like noise, conversely might be positive at certain low levels; some noise might give a feeling of liveliness and be better than dead silence. We conducted two EFA analyses using the positive and negative items on the survey. One EFA determined how the 15 positive items grouped into factors, and another determined how the 15 negative items grouped into factors. We identified two positive factors— (1) Quiet and Calm, and (2) Vibrant with Transportation—and two negative factors— (1) Unpleasant Environment, and (2) Socially Sketchy. These four factors capture the distinct features of arterials that are important to residents (see the Technical Appendix for full EFA results with factor loadings). Table 3 shows the variables that constitute these four factors. Figure 3 shows the distribution of our 10 sites in terms of the four factors. Two arterials (South Broadway and the Bonnie Brae node) had high scores for both of the positive factors, indicating the residents perceive them as simultaneously Vibrant and Quiet and Clean. Yet, these two arterials were not ideal, and had certain negative factors according to residents. Residents perceived South Broadway as Socially Sketchy, and the Bonnie Brae node had an Unpleasant Environment.

[Table 3 here]

[Figure 3 here]

Note that we supplied the names for the factors identified in the EFA analysis. Note also that the EFA does not imply external relationships between items within each factor. The Quiet and Calm factor includes streets that are perceived as bike-friendly and with trees, but this does not imply that all bike-friendly streets have trees. Our results show, rather, that respondents in our study who perceived their local arterials as bike-friendly were statistically more likely to also say that the arterials had trees (and vice versa).

We describe our four factors from the EFA analysis as:

1. *Quiet and Calm*: Neighbors perceive these arterials as quiet, bike friendly, with a clean environment characterized by trees. In our sample for example, 23rd Avenue, a high-income neighborhood arterial not frequented by long-distance commuters, was Quiet and Calm.
2. *Vibrant with Transportation:* Neighbors perceive Vibrant arterials as having restaurants, bars, retail, and transportation facilities and services such as sidewalks and transit access. South Broadway, a trendy commercial arterial with dedicated bike and bus lanes, has the highest score for this factor.
3. *Unpleasant Environment:* Neighbors perceive these arterials as noisy and dominated by traffic, lacking sidewalks, trees, and amenities for non-motorized transport. Colorado Boulevard (an eight-lane arterial with the highest traffic-volume in the sample) had the most unpleasant environment.

4. *Socially Sketchy:* Neighbors perceive these arterials as having litter on the street and many people whom residents perceive as being unsafe. East Colfax, a street well known for its low-rent motels and crime, was the most Sketchy arterial.

We tested the statistical relationship between these factors and perceived livability using multivariate regression. We present the results of the regression analysis in the next section. (See the Technical Appendix for descriptive statistics related to livability variables.)

Vibrant–Sketchy Arterials

We found that the most and least livable characteristics tend to coexist on the same streets. Our regression analysis showed that Vibrant arterials were positively associated with livability: residents who live near Vibrant streets are more likely than those on non-Vibrant streets to rate their streets and neighborhoods positively. Sketchy arterials were negatively associated with livability: residents who live near Sketchy streets are more likely than others to rate their streets and neighborhoods negatively. These results hold even when controlling for other factors. (Unpleasant Environment and Quiet and Calm factors were not significantly associated with livability; see the Technical Appendix for model results and significance values.)

It is striking, however, that three of the four Vibrant arterials in our study also qualify as Sketchy-- no other combination of the four factors had such a systematic relationship. We wondered how to characterize Vibrant-Sketchy arterials and what this tells us about the perceived livability of neighborhoods.

First, Vibrant-Sketchy arterials are more likely than other types of arterials to be places where neighbors report engaging in nightlife. Sixty-seven percent of respondents living near Vibrant-Sketchy arterials went to bars on the arterial, compared with only 32% on the other arterials ($p < 0.001$). Ninety-three percent of respondents living near Vibrant-Sketchy arterials went to restaurants on the arterial, compared with 87% of respondents on other arterials (p = 0.027).

Second, neighbors perceive Vibrant-Sketchy arterials as having problems of excessive litter and scarce parking, which may reflect the fact that they frequently use such arterials and are familiar with these issues. Fifty-five percent of residents living close to Vibrant-Sketchy arterials report litter as a problem, compared with only 34% of neighbors living close to other arterials ($p < 0.001$). Forty-five percent of people living close to a Vibrant-Sketchy arterial report that parking is a problem; the comparable figure for other arterials is only 28% ($p < 0.001$).

Third, Vibrant-Sketchy arterials have higher average 24-hour traffic counts than other arterials (35,000 vehicles per day vs. 25,000, respectively) showing that arterials can be active places while also accommodating substantial traffic. Vibrant-Sketchy arterials are relatively walkable places despite their high traffic volumes. Neighbors consider Vibrant-Sketchy arterials at least as good for walking as arterials with lower traffic volumes.

Our study is subject to certain limitations that readers should take into account. First, we cannot interpret our statistical associations as causal, particularly since residents have usually selected dwellings, streets, and neighborhoods that satisfy them. Second, we do not present data on gender, ethnic, or other differences; it is likely that various characteristics of arterials appeal to various groups, so there is room for further research on these issues. Third, we do not account for traffic safety statistics in our analysis, so all characteristics related to arterials' safety are from the perception of neighbors. This is perhaps not a serious limitation, since our primary goal was to find out how residents perceived their neighborhood arterials and why, rather than to link their perceptions to objective data. As mentioned, our strategy for separating characteristics into positive and negative categories based on existing research may introduce an inability to capture nuanced relationships between livability and characteristics that may be either positive or negative. Finally, our small sample of 10 purposively chosen streets in Denver, Colorado does not imply generalizability to any other streets or cities, so more research is necessary to confirm our findings.

Arterials and Livability in Policy and Practice

We originally asked: What resident-perceived factors distinguish livable arterials from non-livable arterials? Our research shows that residents perceive the characteristics of arterials to fall into four broad categories, which we call: Quiet and Calm, Vibrant, Unpleasant, and Sketchy. We found that arterials perceived as Vibrant are positively associated with livability and those perceived as Sketchy are negatively associated with livability. It is interesting that these two qualities commonly occur on the very same streets. We conclude therefore that livable arterials are those with commercial establishments that residents like to frequent, and those that residents perceive as accessible to public transportation, bicycles, and pedestrians. Non-livable arterials are those that residents perceive as crime-ridden, littered, and overcrowded with people. These relationships hold true even when accounting for personal characteristics and the characteristics of the respondents own residential street, both which might also influence perceived livability.

We believe that planners can improve livability, especially along arterials that neighbors perceive as both Vibrant *and* Sketchy. Planners can attempt to increase the vibrancy and decrease sketchiness along urban arterials, allowing arterials to provide their transportation function—especially as cities like Denver grow and traffic volumes increase—without destroying the positive sense of place that these commercial arterials confer. We look at some specific ways below that the arterial typology and livability data presented here could help improve livability along arterials in growing urban areas. We illustrate the possibility of approaching arterials with flexible, evidence-based strategies that support the positive contributions they make to neighborhood livability. Planners and engineers, in contrast, often try to minimize amenities that limit the traffic capacity of major arterials. Our data show that this may be the wrong approach, since even high-volume arterials can, if they contain the combination of characteristics that make a neighborhood Vibrant, actually increase livability in adjacent neighborhoods. Arterials can be interesting, useful, and exciting places that attract people and simultaneously support high traffic volumes.

The “low traffic” arterials in our study in contrast—arterials with about 12,000 vehicles per day—were not necessarily associated with more livable neighborhoods than their higher-traffic counterparts. A “low traffic” arterial with fast-moving traffic, which does not offer much in terms of pedestrian-oriented design or useful establishments, begins to feel dominated by traffic. Our study revealed that people may not perceive differences in traffic volumes. They notice, however, pedestrian-oriented design elements, commercial establishments, the cleanliness they see, and the comfort they feel along the arterial.

We question whether there is or should be a strict division between mobility and access on arterial roads. Our research suggests three specific types of interventions that could enhance the livability of arterials in ways that matter to adjacent neighbors: (1) encourage active land uses, such as restaurants and other commercial establishments, that serve nearby residents; (2) maintain the arterials effectively, control litter and graffiti, and reduce neighborhood neglect and decay; and (3) enhance the pedestrian environment in ways that support transit access and reduce exposure to traffic hazards. Each of these interventions is a departure from the traditional approach to arterial planning because none focuses on motorized traffic, *per se*, although each links to traffic in important ways.

Creating streets that support neighborhood-serving retail and nightlife is a common goal of urban revitalization strategies that our research supports. The demand for retail and nightlife along certain arterials, however, may be low, which explains the prevalence of lower rent uses like dollar stores in those areas. We suggest that urban revitalization policies should seek to stabilize surrounding residential neighborhoods and implement pedestrian-oriented design, and litter control and maintenance programs.

Planners should extend a focus on pedestrian design from the revitalization context into mainstream transportation planning for arterial roads. Preventing neglect and decay should be part of maintaining larger arterials; planners should develop an economic development plan for arterials and surrounding neighborhoods to ensure that they are livable.

Our three suggested planning interventions face other challenges: they may be outside the ordinary scope of "transportation" projects because they require interventions in land use, urban design, social factors, and everyday maintenance. Our planning recommendations require broad partnerships that extend into areas such as crime and litter control. *Blueprint Denver*, the city's integrated transportation and land use plan (adopted in 2000 as a supplement to the City's Comprehensive Plan), recognizes the need to address multi-modal travel, traffic management, and land use on arterial corridors. The plan, however, does not comprehensively address litter control, sidewalk repair, roadway reconstruction, or the kinds of urban design that would make arterials vibrant places.

The concept of a "livable arterial" represents an uneasy compromise between designing streets for both mobility and access because it does not completely disavow motorized traffic; it accepts both the transportation function and the place function of the commercial arterial road, particularly at commercial nodes. We think that openness to motorized traffic at appropriate speeds is necessary for negotiating the various competing claims that people make of these roads. A next step for future research is to use experimental research designs to evaluate the causal effects of livability interventions on arterials to better understand the interdependence of the quantity and quality of traffic, the social features of arterials, and the experience various road users.

Arterials operate as part of the larger set of social and environmental factors that make certain places appealing. Arterial roads are an important element in both transportation systems and vibrant neighborhoods in large measure because of the traffic they carry, not just in spite of that traffic. It is time to balance both access and mobility along the major arterials that are the lifeblood of many urban areas.

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Technical Appendix

Urban Design Score

We assessed the urban design of the arterials with an extensive process set forth by Ewing and Clemente (2013). They asked a panel of 10 design experts to rate 588 street segments. Then they used the expert assessments to develop and validate a quantitative measurement system of urban design quality. They translated the measurement system into a scoring sheet for analysts to use in the field. The scoring includes numerous categories and subcategories. In Table A1, we outline the category *Imagibility* in full, and list the remaining categories for brevity.

[Table A1 Here]

Survey Questions and Response Categories

Table A2 presents the complete survey instrument, including categories, questions, and response scales.

[Table A2 Here]

Additional Methodological Information

We conducted exploratory factor analysis using a varimax rotation. The Kaiser measure of sampling adequacy (MSA) for the analysis of positive attributes was 0.80, and the MSA score for the analysis of negative attributes was 0.70; both were sufficiently high to indicate the viability of factor analysis. We selected factors based on scree plots and interpretability. In addition, we estimated factor scores and used these as explanatory variables in regression analyses. Table A3 presents the factor loadings from the analysis. We included in each factor all items that loaded to that factor and that factor only with a loading $>|0.40|$. Table A4 presents the average factor scores for each arterial.

[Table A3 here]

[Table A4 here]

For ordinal logistic regression, we analyzed separately three dependent variables that capture different dimensions of perceived livability: (1) whether one is happy living on their street (1=strongly disagree, 5=strongly agree); (2) one's perception of the overall quality of their residential street (1=lowest, 10=highest); and (3) one's perception of the overall quality of their neighborhood (1=lowest, 10=highest). These ordinal categorical variables rank respondents' perceptions of quality, but the true intervals representing perceived quality are unknown. All three variables skew toward higher scores: happy to live on one's street (mean = 4.1, median = 4.0); quality of one's residential street (mean = 7.2, median = 7.0); neighborhood quality (mean = 7.8, median = 8.0).

All three models—one for each measure of residential satisfaction—include four categories of explanatory variables representing: (1) the socio-demographic characteristics of respondents and their households; (2) respondents' perceptions of their residential streets (composite variables created with the factor analysis); (3) respondents' perceptions of their arterial roads (the composite variables created with the factor analysis); and (4) objective measures of features of the arterial roads.

Following previous studies of livability, we estimated models for each of the outcome variables by sequentially adding categories of explanatory variables (i.e., socio-demographic, residential quality factors, arterial quality factors, built environment characteristics) (Lovejoy et al., 2010; Lu, 1999). We made decisions about model specification based on bivariate relationships between explanatory and outcome variables, AIC, and the interpretability of the model results.

We carried out all analysis in SAS 9.4.

Regression Model Results

Table A5 presents the results of the regression model.

Of the four factor variables representing respondents' perceptions of their local arterial roads—Vibrant, Quiet, Unpleasant, and Sketchy—Vibrant has a moderate, positive association with all three dependent variables. This relationship holds when controlling for characteristics of the residential streets and socio-demographic characteristics of respondents. Living close to a Vibrant arterial has a relatively stronger (but, in absolute terms, still moderate-strength) statistical association with the dependent variables that capture broad satisfaction, such as being happy to live on one's street ($\hat{\beta}$ = 0.52, p < 0.001) and the overall quality of the neighborhood ($\hat{\beta}$= 0.37, p = 0.003), compared to the dependent variable that focuses on the quality of the residential street ($\hat{\beta}$ = 0.20, p < 0.112).

The arterial factor variable representing perceived incivilities (i.e., Sketchy) has a moderate, negative association with residential satisfaction ($\hat{\beta}$ = -0.22, p = 0.090 for overall quality of residential street; $\hat{\beta}$ = -0.028, p = 0.030 for overall quality of neighborhood). This variable has a nonsignificant (p > 0.10) statistical association with respondents' happiness to live on their street.

The built environment characteristics of the arterial roads are also statistically associated with residential satisfaction, but only for the variable expressing respondents' perception of the overall quality of their neighborhood. Having a high proportion of tree canopy is a positive feature ($\hat{\beta}$ = 0.81, p < 0.001). The urban design score also has an association with neighborhood quality that approaches significance, but its sign is negative and its effect size is small ($\hat{\beta}$ = -0.04, p = 0.053).

Arterials that residents perceive as Quiet and Clean and as Unpleasant do not have statistically significant associations with any of the three outcome variables.

[Table A5 here]