CPBS
Center for Pedestrian and Bicyclist Safety

A Tier-1 University Transportation Center

Developing an Urban Quality Metric for Transit Access and Safety

July 2025	A Report From the Center for Pedestrian and Bicyclist Safety

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About the Center for Pedestrian and Bicyclist Safety (CPBS)

The Center for Pedestrian and Bicyclist Safety (CPBS) is a consortium of universities committed to eliminating pedestrian and bicyclist fatalities and injuries through cutting-edge research, workforce development, technology transfer, and education. Consortium members include: The University of New Mexico; San Diego State University; The University of California Berkeley; The University of Tennessee Knoxville; and The University of Wisconsin Milwaukee. More information can be found at: https://pedbikesafety.org

Disclaimer

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16. Abstract

To make a successful transit-oriented community, the walkability and bikeability of the landscape and access to destinations must be addressed alongside the construction of transit services. This research trials a formula using these criteria to produce a Transit Access and Safety Score (TASS), and applies it to San Diego County, California. This study draws on previous research to create a grading metric for public transit stations and their surroundings. Regression analysis using U.S. Census Journey to Work metrics and traffic-related casualty rates is employed to determine the relationship of the walkability/ bikeability aspect of the TASS grades to patterns of human movement and behavior in response to the built environment. The measurement developed in this research equitably, efficiently, and adequately grades the walkability, bikeability, and proximity of destinations to transit stations. The research could not establish a relationship between TASS scores and measures of human activity such as ridership, casualty rates between people and motor vehicles, and commuting patterns. The TASS can assist decision-makers in identifying aspects of the built environment to encourage density and transit use.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

Developing an Urban Quality Metric for Transit Access and Safety

A Center for Pedestrian and Bicyclist Safety Research Report

August 2025

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Acronyms, Abbreviations, and Symbols

AAA – American Automobile Association

APTA – American Public Transportation Association

BLTS – Bicycle Level of Traffic Stress

BRT – Bus Rapid Transit

CPBS – Center for Pedestrian and Bicyclist Safety

dBA – Decibel

EPA – United States Environmental Protection Agency

ESRI – Environmental Systems Research Institute, Inc.

GHG – Greenhouse Gases

GIS – Geographic Information Systems

JB – Journey on Bike

JTW – Journey-to-Work

JW – Journey by Walking

LoTS – Level of Traffic Stress

MTS – San Diego Metropolitan Transit System

NACTO – National Association of City Transportation Officials

NCTD – San Diego North County Transit District

NHTSA – National Highway Traffic Safety Administration

NWI – National Walkability Index

PLTS – Pedestrian Level of Traffic Stress

RAS – Regional Area of Study

SANDAG – San Diego Association of Governments

SCAG – Southern California Association of Governments

SDSU – San Diego State University

SR – State Route

SSWI – Street Smart Walkability Index

TAD – Transit-Adjacent Development

TASS – Transit Access and Safety Score

TIMS – Traffic Injury Management System (University of California Berkely)

TOD – Transit-Oriented Development

UC – Urban Center

UCSD – University of California San Diego

VTA – Santa Clara Valley Transportation Authority

WMATA – Washington Metropolitan Area Transit Authority (Washington DC)

Abstract

To make a successful transit-oriented community, the walkability and bikeability of the landscape and access to destinations must be addressed alongside the construction of transit services. This research trials a formula using these criteria to produce a Transit Access and Safety Score (TASS), and applies it to San Diego County, California. This study draws on previous research to create a grading metric for public transit stations and their surroundings. Regression analysis using U.S. Census Journey to Work metrics and traffic-related casualty rates is employed to determine the relationship of the walkability/bikeability aspect of the TASS grades to patterns of human movement and behavior in response to the built environment. The measurement developed in this research equitably, efficiently, and adequately grades the walkability, bikeability, and proximity of destinations to transit stations. The research could not establish a relationship between TASS scores and measures of human activity such as ridership, casualty rates between people and motor vehicles, and commuting patterns. The TASS can assist decision-makers in identifying aspects of the built environment to encourage density and transit use.

Executive Summary

Addressing the walkability and bikeability landscape standards to transit services is critical for cultivating a transit-oriented environment. Transit services and stations should be safe and accessible to reach your destination. Transit Access and Safety (TASS) measurement establishes grades for the walkability and bikeability within a quarter mile of transit stations for the study area. The physical landscape appearance and accessibility to destinations determine the grades based on the quality of walkability and bikeability. This study gathers research from the mentioned criteria and previous research to identify a formula for calculating the TASS for the 12 station study sites in San Diego County, California. This formula analyzes a common set of variables, intending to improve current and future land use. Ultimately, changes will encourage more walking and biking towards transit stations. The stations are analyzed through place typology and the "best case" and "worst case" for each station. Additionally, three station typologies that were studied: emerging, transitioning, and coordinating. Utilizing information from previous research to adapt to the formula and analysis, this includes commuting patterns, livability, and the development of walk/bike metrics. A regression analysis was done for U.S. Census Journey to Work metrics, and traffic-related casualty rates to determine a relationship between the walkability/bikeability aspect of the TASS grades to the built environment. This research developed a measure based on the built environment that affects various criteria. This involves grading walkability, bikeability, accessibility, safety, and proximity of destinations to transit stations. There was no established relationship between TASS scores and measures of human activity or casualty rates. This demonstrates that outside factors from the built environment such as human activities can have an impact on collision rates. San Diego is a car-centric city, and therefore there was high average annual daily traffic around most stations due to streets with wide lanes exceeding 10 feet or the provision of four or more lanes. Furthermore, future studies and recommendations are dependent on variables. Limits encountered in the study include: inadequate number of spatial analysis data, excess review of Google Street View, to gather findings of sidewalks, bike parking, driveways and more for conversions. Journey to Work data was another limitation because it does not consider trips made for errands such as the grocery store, doctor's office, etc. The TASS metric was applied to San Diego County; however, it can be used in other cities to analyze transit-oriented development for success and improvements. This metric is important for planning and design for transit-oriented development, especially for cities that are looking to expand or change their public transportation. The potential impact of this study showcases the use of TASS score in San Diego County. It is recommended that this score and criteria be replicated to different cities/counties with goals of creating a transit-oriented development.

Introduction

Planners have long assumed that decisions and policy-making around land use will change positively with the introduction of mass transit services. As the saying goes, "If we build it, they will come." This has been a miscalculation in the effort to revitalize and expand public transit (Hurst & West, 2014; Khasnabis, 1998). Some case studies have shown that the presence of transit has not resulted in visual changes or financial investments into land uses that encourage walking and other active transportation modes near stations and corridors (Griffith, 2017; Khasnabis, 1998; Sallis et al., 2004; *Transit Mall Case Studies*, n.d.). To make a successful transit-oriented community, the walkability and bikeability of the landscape must be addressed alongside the construction of transit services (Appleyard et al., 2016; Dittmar & Ohland, 2012; Pucher & Buehler, 2009). For a community to be considered Transit-Oriented instead of just Transit-Adjacent – where the development is next to but insufficiently integrated with transit and features more low-density, single-land uses (Brown et al., 2006) – we need to identify a common set of variables that will allow cities and public agencies to address active transportation in relation to land use around mass transit (Kamruzzaman et al., 2014). This study will identify a formula through the application of a case study in San Diego County, California, evaluating a common set of variables that can be used to inform city planning around transit-oriented development. The outcomes of this study can inform potentially positive changes that can be made to land use that encourage more walking and biking around transit stations through policy.

1) This thesis seeks to identify a consistent set of physical landscape and destination criteria that can be used to evaluate the area around any transit station: station parking availability, major road lane width and quantity, speed limit, sidewalk width, buffer width, AADT, crosswalk access, curb ramps at intersections, crosswalk visibility, stop protection, bike lane access and type, highway ramp "danger lane" conflicts, bike parking availability, highway noise if applicable, and destination access. This study explains the criteria in relation to the walking and biking experience combined with transit usage.
2) This research trials a formula using these criteria to produce a Transit Access and Safety Score (TASS).
3) The TASS generated quantifiably grades the walking and biking experience within half-a-mile of transit stations in the area of study based on physical landscape features as well as destination access and diversity. This will enable decision-makers to efficiently identify aspects of the physical landscape and existing land uses that need to be improved around stations to encourage density and transit use.
4) The research applies the TASS formula to San Diego County, California, analyzing the accessibility and safety of stations based on the collected data. It then issues numerical grades from 1 to 100 for all stations on four primary modes of mass transit in San Diego as well as other significant transit facilities in this study area in relation to safety and accessibility for pedestrians and cyclists.

Literature Review

In this study, a Transit-Oriented Development (TOD) meets the following criteria: a walkable environment that is not only functional but increases the comfort levels of pedestrians; a bike-friendly environment with facilities and routes that are sufficiently protected to reduce stress and risks to cyclists (Furth, 2012; Schneider et al., 2024); and destinations close by or on-site which passengers can either walk or bike to when they disembark at the station or bus stop (Appleyard & Garrett, 2023; Litman, 2013; Özdil et al., 2024). Previous attempts to measure the quality of transit-oriented development have included car ownership rates, vehicle miles traveled (VMT), and proximity of destinations as criteria (Higgins & Kanaroglou, 2016; Lima et al., 2016). The metric in this study improves on the third criterion by analyzing the quality of the walkability and bikeability between the station and destination. The literature to support this study highlights the need for a TOD to provide safe and convenient access to transit, while simultaneously offering a livable and enjoyable experience immediately around the station. It also highlights previous efforts to grade walkability/bikeability and how the TASS metric developed in this study builds from previous research. Studies of commuting patterns, livability, and the development of walk/bike metrics are reviewed.

Commuting Patterns

Studies have identified and graded features around public transit facilities that impact people's commuting patterns. These studies have considered a broad range of variables such as safety (Brown et al., 2006), road design, lighting (O'Sullivan & Parent, 2023), station placement, demographics (Ryan & Frank, 2009), walkability, and the types of nearby destinations (Appleyard et al., 2019; Elkind et al., 2015; Renne & Appleyard, 2019). While these studies have created metrics that can be used to evaluate the accessibility and livability of a TOD, most research has focused on specific geographic regions of the country or on a single transit mode, in particular rail (Park et al., 2018; Zeng et al., 2022). It has been found, however, that bus- or tram-oriented development can also be effective in achieving the broad and subjective goals of TOD (Aston et al., 2016; Kamruzzaman et al., 2014). Other studies analyze local design features such as the quality and width of sidewalks and bike lane class types (Schneider et al., 2024; Speck, 2018). These local conditions are useful criteria for decision-makers analyzing the walking/biking experience around public transit. Ryan and Frank (2009) showed that the more built up an environment is around transit, the more likely there is to be more walking and other non-motorized travel in the immediate area.

Livability

Some researchers highlight "High quality urban design and a sense of place" as principles of TODs (Chen, 2013; Niu et al., 2021). The concept of the 15-Minute City, wherein a person can readily access needs and wants, is an example of current thinking around placemaking (Moreno et al., 2021). The 3D's of the built environment—Density, Diversity, and Design—are also crucial variables to consider when evaluating effective TOD. Both Cervero and Kockelman (1997) and

Ewing and Cervero (2010) for example, show that higher density, diverse land-use, and pedestrian-oriented designs have a statistically significant impact in reducing trip rates and encouraging non-motorized travel. Recent studies also show a constructive relationship between walking/biking and the provision of transit, where 80% of transit trips involve walking to reach a destination (Buehler et al., 2024; Buehler & Pucher, 2024; Gao et al., 2018). Providing walking/biking facilities around transit is insufficient, however, if there are no desirable destinations in the immediate area (Tamakloe et al., 2021). Destinations are a critical component of TODs, as these are what attract people to ride the service(s), disembark, and use the surrounding area. Besides attractive destinations like local retail and event venues, access to essential destinations such as housing, healthy food, education, recreation, and healthcare are crucial components for successful TOD (Appleyard & Garrett, 2023; Litman, 2013).

Safety and the perception of safety–both on the transit service(s) and in the surrounding landscape–are essential to an effective TOD. The perception of safety is aided by a mixture of land uses that provide more "eyes on the street," encouraging business development while reducing the frequency of common street crimes like robbery and assault (Anderson et al., 2012; Jacobs, 1961; Overstreet, 2022; Twinam, 2018). By contrast, when zoned for just one land use – especially non-residential (Stucky & Ottensmann, 2009) – studies suggest urban areas may experience more crime. For instance, Anderson et al. (2012) and Wo (2019) found that lots zoned exclusively for commercial use have a 45%-higher crime rate than those with mixed residential and commercial lots.

Development of Walking/Biking Metrics

Scholars have developed metrics to analyze and grade the walkability/bikeability of urban areas. One of the most popular has been Walk Score®, developed in 2007 to analyze the walkability of any given area with a simple address search. Walk Score® uses access to destinations as the primary factor in its scores. In 2011, the formula was modified to include intersection density and pedestrian friendliness to improve the accuracy of the results, a subsequent calculation referred to as the Street Smart Walk Score or SSWI® (Frank et al., 2021; Simbaqueba, 2018). As of 2014, Walk Score® has been used as a tool for marketing various neighborhoods by the real estate firm Redfin. That same year, the U.S. EPA launched the National Walkability Index or NWI. This tool uses block group data to rank neighborhoods by their walkability based on factors including income levels, intersection density, employment types, and access to transit (Steuteville, 2016; U.S. EPA, 2014).

A pair of metrics that grade the quality of the walking and biking experience in an urban area–Pedestrian Level of Traffic Stress (PLTS) and Bicycle Level of Traffic Stress (BLTS)–measure variables in the built environment that affect people's confidence to walk/bike in that area. Examples of these variables include posted speed limits, sidewalk width, and the presence of traffic calming features such as flashing walk lights and curb extensions (Schneider et al., 2024).

Questions have been raised about the effectiveness of walkability metrics, especially public-facing ones like Walk Score® which seek to quantify and promote the walkability of a given area. Walk Score®, SSWI®, and the NWI have been criticized for weighing the quantity of destinations over the quality of the built environment (Steuteville, 2019). These measures give higher grades to areas simply because they have more of a certain type or group of destinations. They do not consider whether the journey from point A to point B is comfortable or safe to walk/bike (Steuteville, 2019). Other literature has identified physical obstacles that will discourage walking/biking overall but do not analyze overall quality (O'Sullivan & Parent, 2023; Speck, 2018; Wang et al., 2016).

Metrics like PLTS and BLTS overcome the quantitative bias by taking a close look at the quality of the journey rather than the quantity of destinations. However, Schneider et al. (2024) concluded that even these metrics can fall short in determining exactly how people will perceive the route from start to finish. One person may find the walking and biking experience in an area to be more attractive, but others might feel less inclined to use active transportation in that same area. In addition, perceptions of walkability can be based on social factors such as age, race, and gender (Candiracci & Power, 2022; Cusack, 2021).

This study's TASS metric incorporates the measures of Levels of Traffic Stress (LoTS) in relation to transit-access studies. Both Furth and Schneider have also encouraged expanding research respectively on PLTS and BLTS results using human activity measures (Furth, 2012; Schneider et al., 2024). This research seeks to address the human factor in the intersection of active transportation and TOD using regression analysis against the TASS index results. This will account for subjective human perceptions towards safety relating to mobility and livability in a TOD.

Data and Methodology

Regional Area of Study

This research focuses on San Diego County as the Regional Area of Study (RAS). Station location, major roads, and other GIS data were obtained from the San Diego Association of Governments (SANDAG), the regional planning body (SANDAG, 2015). A travel boundary of 0.5 miles was established around public transport facilities analyzed in the RAS (Ryan & Frank, 2009). This was performed using the Buffer Tool in ESRI ArcGIS Pro (Esri, 2021).

Sample Size

Research was conducted primarily for San Diego City, with two other municipalities—Vista and La Mesa—included as secondary locations. In the preliminary academic research for the entire County, data was obtained for 62 light rail, 58 bus rapid transit, 15 hybrid rail, 10 local bus, 8 regional rail, and 3 water transportation stations. Based on the best, worst, and average-scoring results by place type in the preliminary study, a subset of these stations–7 bus rapid transit, 6 light rail, 2 hybrid rail, 1 regional rail, and 1 water transportation–were then extracted for closer inspection. The closer inspection for this study includes additional criteria that were not initially used in the preliminary academic research.

The San Diego stations studied in this research are classified into place types as characterized by Frost et al. (2018). One recent study defines place types as a way to classify the locations outside of the home and workplace where people gather for leisure (Zahnow, 2024). Other studies classify places as the areas where people live and work (Frost et al., 2018). The classifications developed by Frost analyzed GHG emissions based on seven place types in the San Diego, Los Angeles, Sacramento, and Bay Area regions of California. The place types include Urban Centers, Urban Places, Compact Suburban Places, Suburban Places, Employment Centers, Rural Places, and Special Districts. Each of these Place Types is defined in Table 11.

Data Sources

This research incorporates data obtained from the following sources: ESRI ArcGIS Pro software (Esri, 2021), GIS shapefiles from SANDAG (2015), Google Maps (Google, 2025). Journey to Work (JTW) and Census Block GIS data were obtained from the 2022 U.S. Census (U.S. Census Bureau, 2022). Collision data were obtained from UC Berkeley Traffic Injury Management System (TIMS) Database (2025). Public Records Acquisition (PRA) requests for ridership data from the Metropolitan Transit System (MTS), the North County Transit District (NCTD), and the City of Coronado, and ridership data from Amtrak annual reports. The Sound Meter mobile application that measures highest, lowest, and average sound levels for every ten seconds on a graph was used to record decibel levels at stations near highways (rootsApps, 2015).

Score Criteria

Physical Landscape Evaluation

The Physical Landscape analysis is composed of two major components. 1) Pedestrian-related physical landscape features, of which seventeen criteria were evaluated for 2 points each and a total of 34 points; 2) bike-related physical landscape features, of which five criteria were evaluated for 5.2 points each and a total of 26 points. The need to invest in more infrastructure, both around the station as well as on transit property and assets, to accommodate cyclists is the primary justification for separating pedestrian-affecting variables of the physical landscape from the cycling-affecting variables (Edwards, 2021; Kinki Sharyo, 2002). Physical Landscape accounts for 60 out of 100 possible points for the overall score.

The physical landscape analysis involved downloading a combination of GIS shapefiles from SANDAG, estimating features on Google Maps, and conducting site visits to the stations. The site visits included identifying the nearest major road to the transit station and observing the road's physical design. Major roads are identified primarily by SANDAG's GIS Data Warehouse. However, researcher discretion was used where major road classifications did not match physical conditions observed in the field.[1] The 17 pedestrian-related criteria, each worth 2.2 points, are listed in Table 1. Minimum and maximum values are assigned, and the seventeen pedestrian criteria sum to a maximum component score of 37.

The five bicycle-related criteria, each worth five points, include the following in Table 2 (type of and proximity to bike lanes, bike parking, bike lockers, lanes crossing highway on/off-ramps, identified as "danger lanes"[2]). The five biking criteria sum to a maximum component score of 25. Types of bike lanes and points assigned are shown in Table 3 and Figure 1.[3] All bike lanes in the county are shown in Figure 2.

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[1] E.g., Palomar Street in east Chula Vista loses its GIS designation as a major road at the start of the South Bay Rapid dedicated busway. The quantity of accessible destinations and the physical design of the street around the busway largely match those of major roads in other parts of the RAS such as Downtown San Diego.

[2] A danger lane is the term created to describe an unprotected bike lane that crosses a highway on- or offramp with no traffic calming measure to protect cyclists from speeding cars.

[3] Caltrans identifies multiple bike lane configurations and assigns class designations I through IV. In this study, the key consideration is whether the bike lane is protected (classes I and IV) or unprotected (classes II and III). Because a class II lane provides visual identification of the lane (road marking), it is scored in the calculation.

Table 1. Pedestrian Criteria.

Criterion	Eq. #	Notes	Min / Max Values
Station - Parking Lots	2	There should not be a parking lot blocking access between station and sidewalk (Speck, 2018).[4]	$X_{min} = 0$; $X_{max} = 2$
Station - Parking Spaces	2	There should be as few parking spots as possible around the transit station to encourage more walking and cycling and less car usage around the station area (Martin & Hurrell, 2012; Shoup, 2021). The highest scoring station will have no free parking available.	$X_{min} = 0$; $X_{max} = 150$
Station - Highway Noise	2	If the station is on top of a highway, the recorded decibel ratings from the platforms cannot exceed the maximum safe volume of 74 dBA (Corbisier, 2003). Two measurements are taken at each station near a highway. [5]	$X_{min} = 60$ dBA; $X_{max} = 74$ dBA
Proximity to Nearest Crosswalk	2	The nearest crosswalk to the station must not be more than 0.5 miles away (Wang et al., 2021).	$X_{min} = 0$; $X_{max} = 0.6$[6]
Major Roads – Number of Lanes	2	The highest score is assigned for one lane in each direction (NACTO, 2013b).	$X_{min} = 2$; $X_{max} = 4$
Major Roads – Speed Limit	2	Speed limit sign closest to the station displays less than 35 mph (AAA, 2011; Schneider et al., 2024).	$X_{min} = 15$; $X_{max} = 35$
Major Roads – 8ft-Wide Sidewalks	1	The optimal major road has an eight-foot-wide sidewalk on both sides (NACTO, 2013a).	$X_{min} = 0$; $X_{max} = 2$
Major Road – Number of Driveways	2	The major road has a maximum of 15 driveways crossing its sidewalks from the station to the edge of the boundary (City of Los Angeles, 2024; Feldhake, 2019).[7]	$X_{min} = 0$; $X_{max} = 15$
Major Road – Sidewalk Obstructions	2	The sidewalks along the major road from the station to one edge of the boundary have fewer than 10 objects that obstruct walking (Coppola & Marshall, 2021).	$X_{min} = 0$; $X_{max} = 10$
Major Road – Average Lane Width	2	The average travel lane width for the selected major road must not exceed 10 feet (Schneider et al., 2024; Speck, 2018).	$X_{min} = 10$; $X_{max} = 14$

[4] Exemption is applied for parking facilities that do not block pedestrian access to the station.

[5] The highway noise calculation prevents a station in the middle of a highway from scoring higher than one that is not at a highway, else this could give the unintended impression that transit stations should be in the middle of highways.

[6] Since 0.5 miles is still considered accessible, the maximum value is set at 0.6 to state that a crosswalk that is more than 0.5 miles away will not score any points.

[7] Some driveways are exempted from being counted against the Walkability Variable. These are (1) Traffic Signal-Protected Commercial Driveways: pedestrians have some assurance of safety from a crossing light. Drivers must stop before entering/exiting driveway. (2) Single-Family Residential Driveways: low frequency of use by homeowner; lower risk of vehicle collision with pedestrian/cyclist. (3) Emergency Vehicle Driveways: low frequency of use, e.g., at hospitals, fire stations, or police stations. (4) Utility Service Driveways: low frequency of use by utility vehicles (e.g., at electric substations).

Major Road – Buffer Width	1	Any sidewalk buffer, to include both parked cars and street vegetation, should be a minimum of 2 feet on both sides of the street. (NACTO, 2013a)	$X_{min} = 2$; $X_{max} = 10$
Intersection - Crosswalks	2	The nearest intersection to the station must have at least four clearly-marked crosswalks on all four sides (Schneider et al., 2024)[8] [9].	$X_{min} = 0$; $X_{max} = 4$
Intersection – Crossing Visibility	1	The ideal crosswalk design closest to the station will have either flashing warning lights or a flashing strip in the street (Schneider et al., 2024)[10].	$X_{min} = 4$; $X_{max} = 1$
Intersection – Curb Ramps	2	The nearest intersection to the station must have at least four curb ramps into the crosswalks to simplify access for small children, seniors, and people with disabilities (Schneider et al., 2024).	$X_{min} = 0$; $X_{max} = 4$
Intersection – Stop Protection	1	The ideal crosswalk design closest to the station will feature traffic lights in all directions, with signage protecting pedestrians and cyclists from right turns on parallel red lights (Schneider et al., 2024)[11].	$X_{min} = 5$; $X_{max} = 1$

[8] 0 as a categorical number (not a point value) is issued if the nearest intersection has no crosswalks. 4 as a categorical number is issued if the nearest intersection has 4 crosswalks.

[9] A three-way intersection with crosswalks in all three directions will receive a categorical 4 rating to ensure maximum points.

[10] 1 is categorially issued for a white-marked crosswalk with no perpendicular ladder markings. 4 is issued for flashing lights.

[11] 0 is issued for an intersection with no traffic stop measures; 5 is issued for an intersection with an all-way traffic light that includes right-turn-on-red protections.

Table 2. Biking Criteria

Criterion	Notes	Min/Max Values
Type of Bike Lane (see Table 3)	The best scoring bike lane is either a fully protected (Class IV) or grade-separated and/or isolated bike lane (Class I) connecting to the station. A Class II unprotected lane is worth half as many points, while Class III bike routes with little or no markings in the street receiving no points (Caltrans, 2007; Cicchino et al., 2020).	$X_{min} = 0$; $X_{max} = 5$
Number of Bike Parking Spaces	The best scoring station has fifty bike railings or open parking spaces for bikes. The fewer bike railings at the station, the fewer points will be awarded. A station with no bike railings on site will receive no points.	$X_{min} = 0$; $X_{max} = 50$
Number of Bike Lockers	The best scoring station has 25 secure bike storage spaces. Fewer bike lockers or bike parking spaces in a secure storage room at the station means fewer points awarded. A station with no secure bike storage on site will receive no points.[12]	$X_{min} = 0$; $X_{max} = 25$
Proximity to Nearest Bike Lane	The nearest marked bike lane to the station entrance should be no more than 0.5 miles away. For every tenth-of-a-mile that a marked bike lane is from the station, fewer points are awarded. After 0.6 miles, the station receives no points.	$X_{min} = 0$; $X_{max} = 0.6$
Danger Lanes	No more than 4 or more danger lanes can be within the half-mile travel boundary. For every danger lane-style ramp from a highway in the travel boundary, one out of four points will be deducted. The highest scoring station has no danger lanes. The lowest scoring station has four or more danger lanes coming off a highway in its travel boundary.	$X_{min} = 0$; $X_{max} = 4$

[12] For example, SANDAG iCommute bike lockers or dedicated secure space (bike room).

Table 3. Types of bike lanes and points assigned.

Points	Description
0	Class III = No bike lane / sharrows
3.5	Class II = Unprotected bike lane adjacent to road
5	Class I = Fully separated bike path Class IV = Protected on-street / grade-separated bike lane

Figure 1. Four classes of bike lanes. Adapted from graphics in Caltrans Guide to Bike Paths (2017).

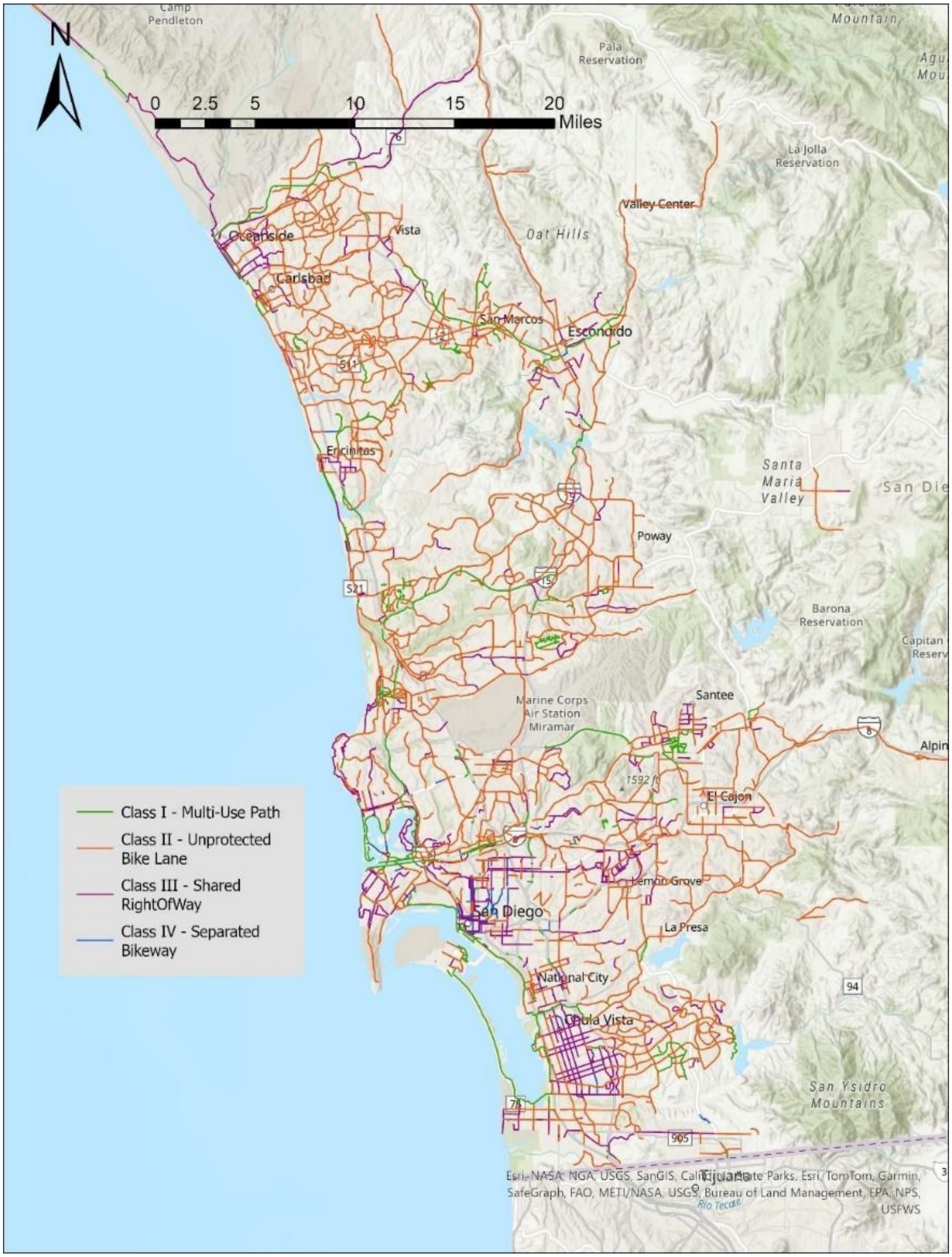

Figure 2. Bike lanes in the RAS.

Note that the easternmost area of the county is not included in the RAS, as there is a lack of significant transit facilities in that portion of the county.

Destinations Access

The other major score criterion evaluates how far the nearest of each of six destination types is from the station. The criteria maxima in the Destinations component are each set at X_{max} = 0.6. This represents the maximum distance in miles that each destination type can be from the station (Appleyard & Garrett, 2023; Litman, 2013; Simbaqueba, 2018). X_{min} = 0 is the best-case scenario, indicating that the destination is right on site at the station. Eq. 1 is used to calculate a positive value from the six destination types for a maximum component score of 40 points. That is, each type is assigned a value of one-sixth or 6.67 points.

Table 4. The six destination types considered essential for TOD.

Destination	Notes	Min/Max Values
Housing	Housing, preferably multi-family due to the lower construction costs and lot size contrasting with the higher affordability and density available (Tesler, 2025).	$X_{max} = 0.6; X_{min} = 0$
Healthy Food	At least one, grocery stores, farmers market, or community gardens	$X_{max} = 0.6; X_{min} = 0$
Healthcare	At least one, hospitals, urgent care, senior care facility, or doctor's offices.	$X_{max} = 0.6; X_{min} = 0$
Recreation	At least one, basketball or tennis court, public park, or hiking spots	$X_{max} = 0.6; X_{min} = 0$
Education	At least one K-12 education, university, college, or technical school	$X_{max} = 0.6; X_{min} = 0$
Commercial activity	At least one people-serving business: e.g. small retail[13], restaurant, service office, entertainment venue, etc.	$X_{max} = 0.6; X_{min} = 0$

[13] Big box retail is excluded from this study because mass and active transportation is not commonly used to access this business type.

Transit Access and Safety Score

After obtaining individual scores for the major components of Walkability, Bikeability, and Destination Access for each station, the component values are summed to assign a cumulative Transit Access and Safety Score (TASS). The TASS maximum is 100 points. The three components for this final calculation (C) are as follows: Walkability – total score out of 34 points; Bikeability – total score out of 26 points; Destinations – total score out of 40 points.

The Physical Landscape component is split such that the fifteen pedestrian elements are weighed greater than the five cyclist elements. While cycling is an important form of active transportation in urban areas, walking is more convenient because no additional equipment is required to complete the last mile (Edwards, 2021). Cycling requires transit operators and cities to make investments in station design, street infrastructure, and transit vehicle interiors to store bikes properly. Some examples of capital investments made for cycling-friendly transit in other cities include:

1) The purchase or refitting of rolling stock with more bike accommodation facilities. For example, modern light rail vehicles purchased in 2002 by the Valley Transportation Authority (VTA) in the Santa Clara Valley. The middle-articulated section of these low-floor rail vehicles is fully fitted with bike locking racks in place of seats (Kinki Sharyo, 2002).
2) The construction of secure storage rooms on or inside station premises. A recent example is the new Potomac Yard station on the Washington DC Metro. This features a dedicated storage room designated as the North Pavilion located next to the ticket hall. According to WMATA (2023), this space has room for up to 49 personal bikes. In addition, Capital Bikes bikeshare has a designated parking area outside.

Photo 1. Bike suspension racks in the middle-articulated section of the current VTA light rail fleet. (Credit: Kinki Sharyo website, 2002)

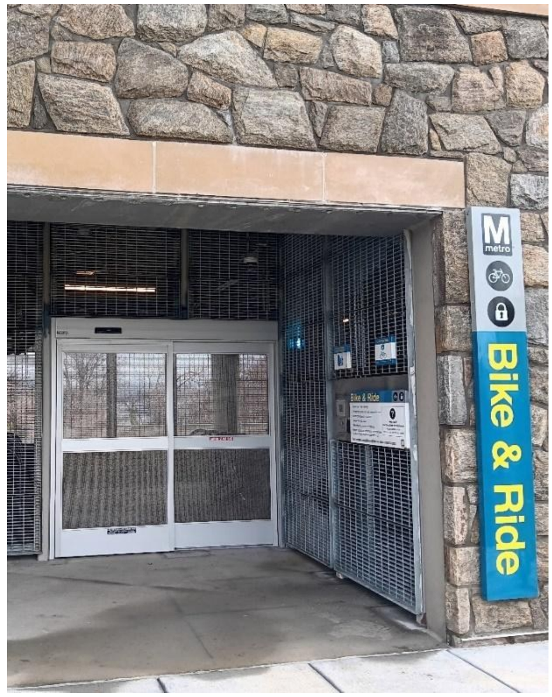

Photo 2. Bike storage room in Potomac Yard station on the Washington Metro.

Walkability requires less capital investment by the transit agency itself and instead requires the individual cities or the regional planning authority broadly to make walking feasible. As evidenced in the redesign of Chula Vista's East Palomar Street in response to the South Bay Rapid's protected busway, bike infrastructure can be made safer and more reliable once the landscape has already been adapted to accommodate more walking, and street calming measures have influenced automobile behavior (Nabors et al., 2008).

TASS Calculation

Values are assigned to the individual criterion, and these are then converted to a number of points contributing to the final score. Variables are defined in Table 5.

Table 5. Variables defined.

Variable	Value
X_{min}	Minimum possible value for the criterion
X_{max}	Maximum possible value for the criterion
A	Station's recorded value for the criterion, between X_{min} and X_{max}
T	Maximum possible points the specified criterion contributes to the cumulative score
C	Number of points awarded to the station for the specified criterion

Two principal equations are employed to evaluate the criteria and produce the TASS. Variables that represent beneficial elements such as bike parking spaces are calculated using Equation 1, where a higher value from the raw data corresponds to a higher overall score. Variables denoted as having a negative impact such as the distance to the nearest crosswalk are calculated with Equation 2, where a higher value from the raw data corresponds to a lower overall score. Equation 1 yields a positive value; Equation 2, a negative value.

Equation 1

$$C = T\left(\frac{(max(A, X_{max}) \; - X_{min})}{(X_{max} - X_{min})}\right) \; \#(Positive\ Value\ Equation)$$

Equation 2

$$C = T\left(1 - \frac{(max(A, X_{max}) \; - X_{min})}{(X_{max} - X_{min})}\right) \#(Negative\ Value\ Equation)$$

Equation 3

$$F_{CAS} = C_1 + C_2 + C_3 \#(Cumulative\ Access\ Score\ Calculation)$$

All station data for each criterion are collated. Scores are calculated using Equations 1 and 2 based on those data and are reported in Table 7. Place typologies as identified by Frost et al., 2018 in Table 6 are assigned to each station.

Table 6. Seven place types.

	Place Type	Description
1	Urban Centers	The largest downtown area(s) in each municipality, such as Central Business Districts
2	Urban Place	City's oldest residential neighborhoods. High integration between housing and jobs on the same lot.
3	Compact Suburban Place	Located adjacent to urban and suburban areas, with a mix of multi-family and single-family housing.
4	Suburban Place	Mostly single-family housing. Low integration between housing and jobs on the same lot.
5	Rural Place	Widely-spaced communities surrounded by otherwise largely undeveloped land.
6	Employment Center Place	A concentration of office, service, entertainment, and/or industrial activity. Typically located outside CBDs and Urban Places.
7	Special District Place	Areas that specialize in a particular activity or have a unique land use.

The research applies regression analysis to compare TASS results to measures of human activity around the stations. These include traffic incidents, specifically collisions between pedestrians or cyclists with motor vehicles.

Casualty Evaluation

After determining the TASS Index results for each station, collision events over the past five years around all stations were analyzed. This study's expectation is that higher scoring stations will have lower collision rates (averaged over five years) than those with lower scores.

Collision data for the State of California was obtained from the UC Berkeley Traffic Injury Management System (TIMS) Database (2025). In this research, a query period of five years was chosen to normalize collision results. Inaccurate results would have been generated from the lack of collision data for some stations in the RAS if the queries were based on annual data. Journey to Work (JTW) rates from the 2022 Census were also obtained for each station's census tract(s).[14] JTW is a measure of commuting and travel patterns by the U.S. Census Bureau that records where people work, how they get there, when they leave home, and how long it takes them to get there (U.S. Census Bureau, 2022).

[14] Some stations were on the borderline between two census tracts. The JTW data for both tracts were combined for these stations.

JTW data used in this study was the number of people choosing to walk, bike, or ride transit from home to work. A spatial join was performed in ArcGIS Pro to determine the number of pedestrian- and cyclist-involved automobile collisions that occurred within each station's travel boundary. The raw number of collisions occurring inside the travel boundary within the last five years was divided by five to get an average casualty rate per year (Y). Given the large numerical size of this data, the JTW totals are divided by 100,000 to make the values more tractable. By scaling the numbers down from the thousands or millions into shorter and more readable numbers, JTW totals can be calculated more efficiently using visually smaller numbers.

The average collisions-per-year is then compared to the JTW rates of walking and transit usage (JW) (Equation 3) and the JTW rates of bicycling and transit usage (JB) (Equation 4).

$$\boldsymbol{Y = \frac{\#\, of\ casualties\ 2019-2023}{5}} \quad \textbf{\# Equation 4}$$

$$\boldsymbol{JW = \frac{2022\ JTW\ Walk + 0.8*(2022\ JTW\ Transit)}{100{,}000}} \quad \textbf{\# Equation 5}$$

$$\boldsymbol{JB = \frac{2022\ JTW\ Bike}{100{,}000}} \quad \textbf{\# Equation 6}$$

$$\boldsymbol{WT = \frac{Y}{JW}} \quad \textbf{\# Equation 7}$$

$$\boldsymbol{BT = 100(\frac{Y}{JB})} \quad \textbf{\# Equation 8}$$

$$\boldsymbol{PCR = 100{,}000(\frac{PC}{Pop*PS})} \quad \textbf{\# Equation 9}$$

The casualty rate is the average number of walkers and cyclists (per 100,000) in the station's census tract who are injured or killed by motor vehicles each year. This casualty rate considers that many of the people choosing to take transit in this area are also walking or biking as part of their travel (Buehler et al., 2024; Buehler & Pucher, 2024; Gao et al., 2018). The casualty rate for each station is shown in Table 7.

Results

Table 7. Final scores for all stations analyzed in the primary research. Ped and bike casualty rates are determined per 100,000 pedestrians per day and per 100,000 cyclists per day respectively.

Transit Station	*Ped Score*	*Bike Score*	*Destination Score*	*Ped Casualties (ann. per walk rates)*	*Bike Casualties (ann. per bike rates)*	CAS	Place Type
SDSU TC	18	21	39	28	99	**78**	Special District
Horton Plaza	20	15	34	265	[No data]	**69**	Urban Center
30th Street	25	17	26	87	124	**68**	Urban Place
Hazard Center	20	15	27	51	[No data]	**62**	Employment Center
Vista Transit Center	21	16	23	102	[No data]	**60**	Compact Suburban
54th Street	18	13	25	59	9	**56**	Urban Place
La Mesa Boulevard	19	12	24	53	[No data]	**55**	Compact Suburban
Camino Ruiz	17	13	23	25	90	**53**	Suburban
University Avenue	23	11	18	117	[No data]	**52**	Urban Place
County Admin. Center	17	15	18	77	407	**50**	Urban Center
Fifth Avenue Landing	20	16	13	148	92	**49**	Urban Center

Mission Valley Center	15	16	14	264	[No data]	**45**	Employment Center
Otay Mesa Transit Center	20	19	4	173	[No data]	**43**	Special District
Middletown	20	12	8	[No data]	[No data]	**40**	Urban Place
Sorrento Valley	14	20	6	43	25	**40**	Employment Center
Civic Center - Vista	13	10	17	136	85	**40**	Compact Suburban
San Ysidro	14	12	13	24	[No data]	**39**	Special District
Rancho Bernardo	13	8	9	[No data]	[No data]	**30**	Suburban

Table 8. JTW rates for all stations analyzed, ordered from highest to lowest scoring.

Transit Station	***JTW Transit*** *(daily per 100,000 riders*	***JTW Walk*** *(daily per 100,000 walkers)*	***JTW Bike*** *(daily per 100,000 cyclists)*	***Ped Casualties*** *(ann. per walk rates)*	***Bike Casualties*** *(ann. per bike rates)*	CAS	Place Type
SDSU TC	4.4	35.2	0.9	28	99	**78**	Special District
Horton Plaza	12	22.5	0	265	[No data]	**69**	Urban Center
30th Street	13.1	4.2	2.1	87	124	**68**	Urban Place
Hazard Center	4	3.6	0	51	[No data]	**62**	Employment Center
Vista Transit Center	2.9	1.5	0	102	[No data]	**60**	Compact Suburban

54th Street	8.5	1.8	8.9	59	9	**56**	Urban Place
La Mesa Boulevard	4.9	3.8	0	53	[No data]	**55**	Compact Suburban
Camino Ruiz	3.7	2.9	0.4	25	90	**53**	Suburban
University Avenue	2.7	6.7	0	117	[No data]	**52**	Urban Place
County Admin. Center	5.2	13.3	0.6	77	407	**50**	Urban Center
Fifth Avenue Landing	4.3	15.5	4.5	148	92	**49**	Urban Center
Mission Valley Center	0.6	1.3	0	264	[No data]	**45**	Employment Center
Otay Mesa Transit Center	3.7	0.6	0	173	[No data]	**43**	Special District
Middletown	7.2	0	0	[No data]	[No data]	**40**	Urban Place
Sorrento Valley	4.8	6.8	4.2	43	25	**40**	Employment Center
Civic Center - Vista	0.6	1.7	0.6	136	85	**40**	Compact Suburban
San Ysidro	5.4	4.9	0	24	[No data]	**39**	Special District
Rancho Bernardo	0	1.5	0	[No data]	[No data]	**30**	Suburban

Summary

Following the generation of TASS results, the stations were sorted from highest score to lowest as shown in Tables 7 and 8. The highest scoring station was SDSU Transit Center on both the MTS Green Line Trolley and MTS Rapid Bus Route 215, with a TASS value of 78. The lowest scoring station was Rancho Bernardo station on the MTS Rapid Bus Routes 235 and 290 Express, with a TASS value of 30. The average score was calculated at 53. The research then used regression analysis to determine relationships between the TASS results and human activity measures, including Journey-to-Work (JTW) and motor vehicle collision rates with pedestrians and cyclists.

Scores by Journey-to-Work

Journey-to-Work rates are presented in the 2022 Census and are calculated for every 100,000 pedestrians (T_{Walk}) and cyclists (T_{Bike}) in the tract area of each station per day.

SDSU station—the station with the top TASS score—had a JTW T_{Walk} rate of 35.2 pedestrian commuters per 100,000 walkers per day, a $T_{Transit}$ rate of 4.4 riders per 100,000 passengers per day, and a T_{Bike} rate of 0.9 cyclists per 100,000 bike riders per day all in the census tract area. This implies that around 35 people per workday walk to work around the SDSU station area; around five people per workday use a bicycle and around 4 people a day use transit on their daily commutes here. Rancho Bernardo—the lowest-scoring station in the county—had a JTW T_{Walk} rate of 1.5 and a JTW T_{Bike} rate of 0. This implies that around 2 people per workday walk to work around the Rancho Bernardo station area, and nobody bikes or takes transit here.

Table 9. Stations with highest/lowest daily JTW Walking and JTW Biking rates.[15]

JTW Rate (Persons per 100,000 people per day)	Station & Mode	TASS
 = **35.2**	SDSU Station (MTS Green Line Trolley & Rapid 215)	**78**
 = **1.5**	Rancho Bernardo (MTS Rapid 235 & 290)	**30**
 = **8.9**	54th Street Station (MTS Rapid 215)	**56**
 = **0.6**	Civic Center-Vista (NCTD Sprinter)	**40**

The highest TASS stations exhibited strong JTW T_{Walk} and T_{Bike} rates, while stations with the lowest TASS held the lowest JTW T_{Walk} rates. SDSU Station held a TASS of 78 and a JTW T_{Walk} Rate of 35.2. There was less of a relationship established between igher scoring stations and higher T_{Bike} rates. 30th Street station was one of the higher-scoring stations in the study (TASS = 68), with a lot of bike- and pedestrian-supporting infrastructure surrounding the station, but a T_{Bike} rate of only 2.1 daily cyclists per 100,000 bicycles. By comparison, 54th Street on the same Rapid Bus line had a higher T_{Bike} rate of 8.9 (approx. 9) daily cyclists per 100,000 cyclists, but a more average TASS result of 56. As such, a relationship could not be strongly determined between these two variables or TASS and casualty rates.

[15] Pedestrian and Bicycle symbols obtained from Wikimedia Commons. Ped symbol credit Lewis737a3nthony, (February 2020). Bike symbol, public domain (Finnish Transport Agency, January 2020).

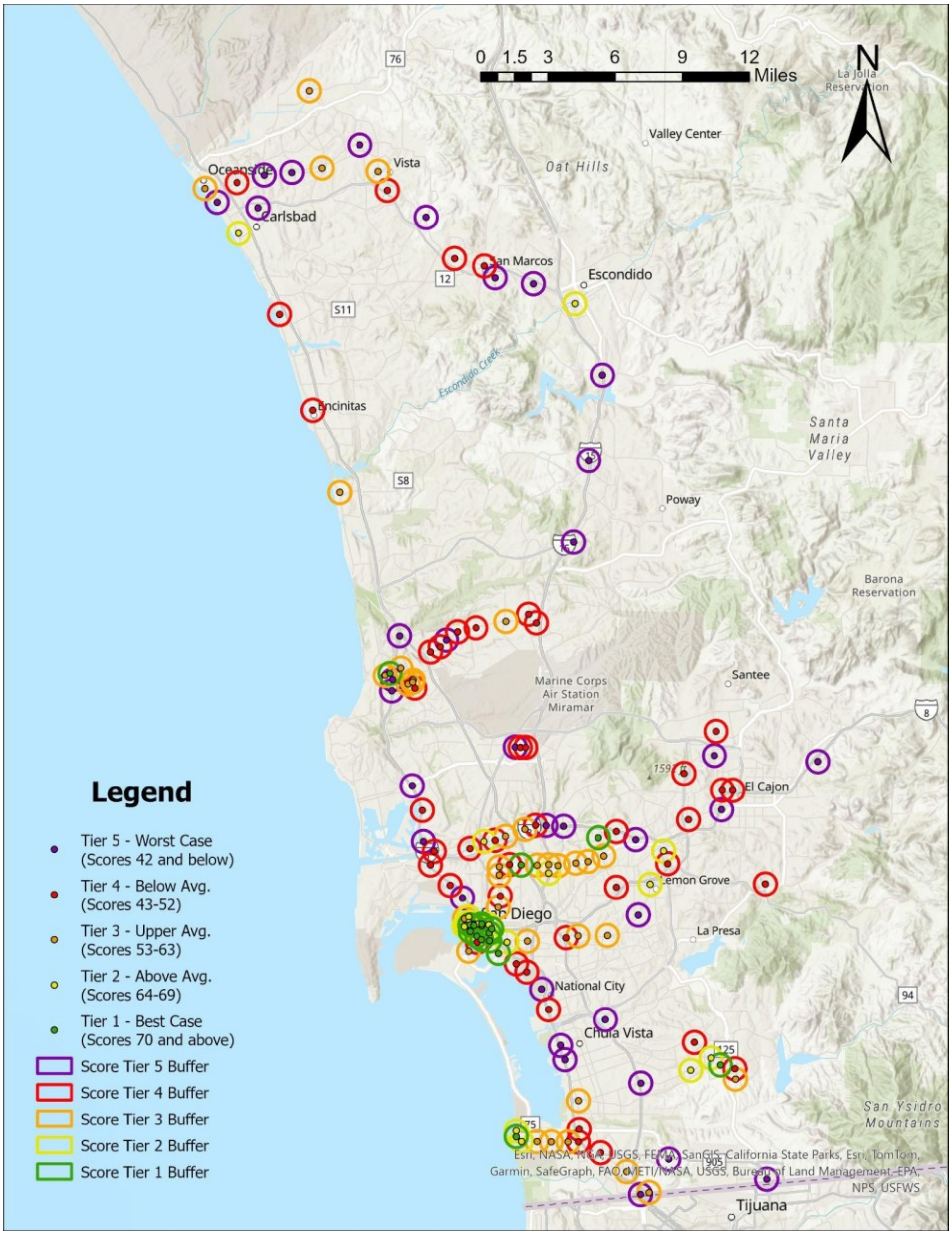

Figure 3. Map of all stations analyzed in the preliminary research across San Diego County, colored-coded by score.

Figures 4 through 7 show the distribution of stations by their TASS scores in relation to the rate of collision events within their travel boundaries. A strong relationship between collision rates and TASS scores will be shown with both a high R2 value of 1 and an array of datapoints sticking closely along the trendline. A marginal relationship will show a less dense cluster of points along the trendline and an R2 value of between 0.5 and 1. And little to no significant relationship will be shown as the data points scattered across the graph and an R2 value below 0.5.

Scores by Walkability

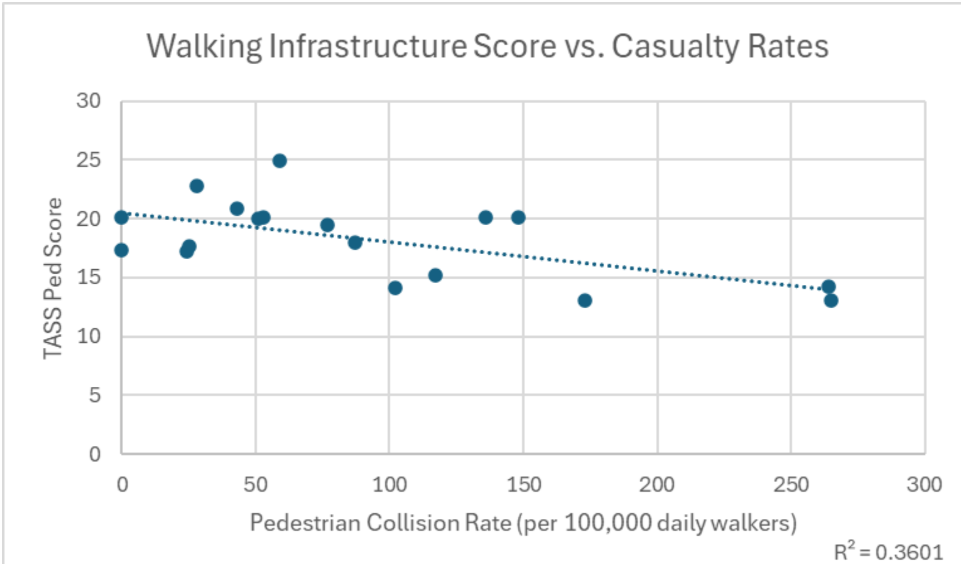

Figure 4. Rate of collision with pedestrians vs. the TASS Pedestrian Component Scores.

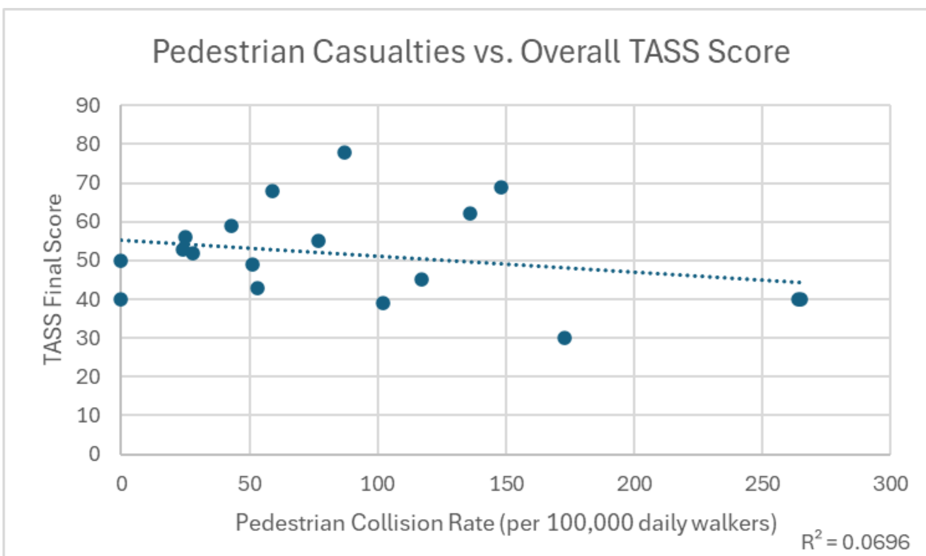

Figure 5. Rate of collisions with pedestrians vs. TASS results.

The R2 value of 0.36 in Figure 4 shows a vague relationship between the walkability component score of TASS and pedestrian casualty rates. Although the trend line is dropping, suggesting a negative relationship in which higher scores result in lower casualty rates, the scattered nature of the datapoints on the chart is not enough to conclude a solid relationship between these two variables. The same is true with Figure 5, where again the trend line angles downward but the R2 value is only 0.07, well below the 0.5 minimum needed to establish a reasonable, marginal relationship between pedestrian casualty rates and overall TASS scores.

Looking at a station with an extremely low JTW T_{Walk} rate and a lower-than-average TASS result offers insight into why transit stations are used less frequently than others. For example, Rancho Bernardo Transit Station's nearest major road is on W Bernardo Drive, which is 5 lanes wide with 4 travel lanes and 1 center turn lane leading up to intersections. The posted speed limit is 40 mph. The transit station is located on the west side of the Interstate 15 Freeway among multiple commercial buildings that interrupt direct access to suburban residential areas half a mile away to the north and south. There are no 8-foot sidewalks on either side of the major road, nor along any roads within a half mile of the station. The JTW T_{Walk} for Rancho Bernardo station (1.5) is significantly lower than the mean (13), showing that walking demand is not high for this area. And its TASS of 30 being well below the mean score (52) indicates that Rancho Bernardo station is surrounded by a pedestrian hostile environment. The urban environment consists of open spaces and cul-de-sacs that close off residents from quick access to the Rancho Bernardo station.

A station that encompasses strong indicators of walkability is SDSU's Transit Center. Located on SDSU's main campus, students and visitors have direct access to the MTS Green Line Trolley, the Rapid 215 Bus, and six local bus lines. The high TASS score signifies a more comfortable environment for pedestrians and cyclists to reach their destination when within half a mile of the station based on physical landscape features. The campus area has a JTW T_{Walk} rate of 35.2 and TASS score of 78, the highest scores among the 17 other stations observed. SDSU's main campus provides walkable spaces for students, faculty, and visitors to access the Trolley and Rapid Bus with little interruption from vehicular traffic.

Scores by Bikeability

The scatterplot in Figure 6 with an R^2 value of 0.01 shows no relationship between JTW T_{Bike} collision rates and the TASS biking infrastructure component scores. The trendline is perfectly horizontal and the datapoints remain clustered right on the y-axis. Figure 7, however, shows a slightly more visible, though still vague, relationship between cyclist casualties and the overall TASS score. Although the trendline angles upward and some datapoints appear across the graph, there is still a cluster of collision rates occurring on the y-axis, showing no relationship between those scores and the casualty rates. The few datapoints that are off the y-axis are scattered and do not cling to the trendline, again showing little relationship.

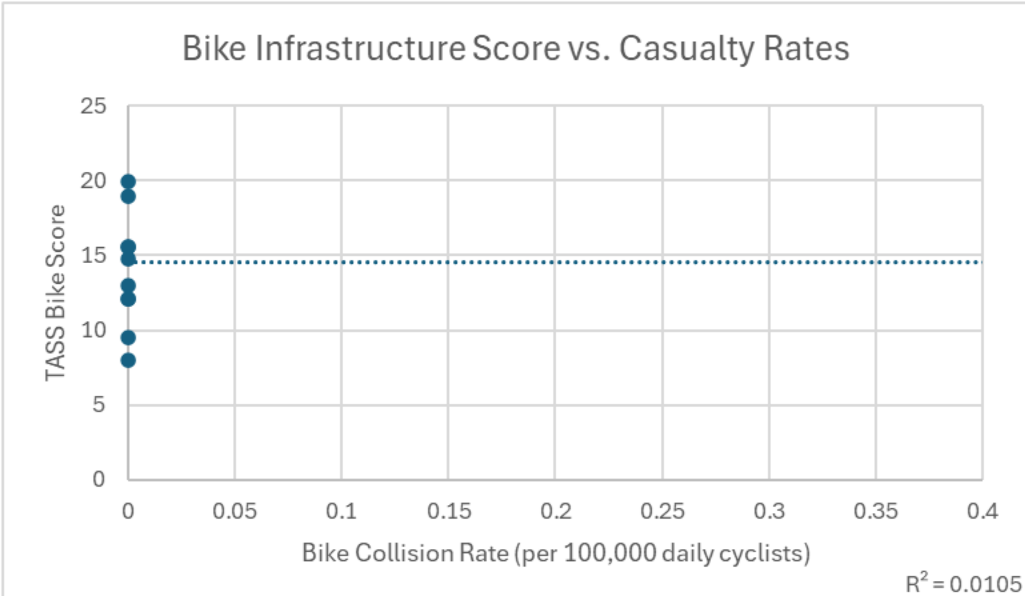

Figure 6. Rate of collisions with cyclists vs. TASS Biking Component Scores.

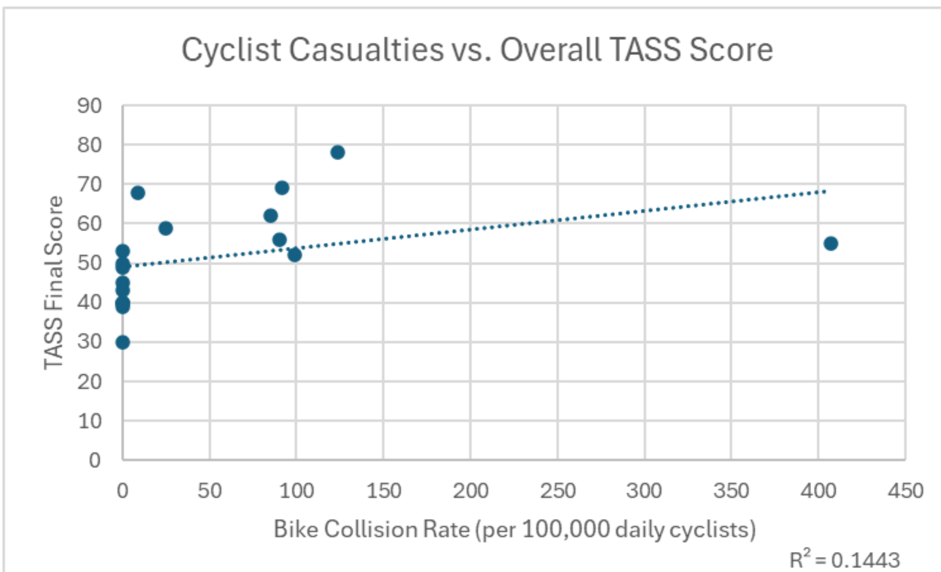

Figure 7. Rate of cyclist casualties vs. overall TASS score.

Looking at a station with an extremely low JTW T_{Bike} rate at 0.6 and a below average TASS score of 40 is Civic-Center Vista (NCTD Sprinter). This station is an example of an area with less bike presence. This station has a pedestrian score of 13, which is below the average walkability component score of 20. However, the bike score of 10 was the second lowest of the studied stations[16] due to the physical landscape and urban design features. The nearest bike lane is 0.4 miles from the station and is a Class II. Civic Center Drive's high speed travel lanes make it extremely hard to travel to and from this station safely on a bicycle.

A station with the highest JTW T_{Bike} rate at 8.9 but an average TASS score of 56 is 54th Street (MTS Rapid 215). This station has a relatively low bike score of 13, compared to 30th Street on the same line which has a higher bike score of 17. 30th Street station includes many desired amenities for a travelling bicyclist. There is a bike lane perpendicular to the station (Class IV), bike parking spaces, and frequent stops and lights. The infrastructure here better supports and protects bicyclists travelling to this station. Despite these features, 30th Street has a low daily JTW cycling rate of 2.1. By comparison, 54th Street only has the basic provision of a Class II unprotected bike lane on 54th Street-Collwood Boulevard. This street is four 12-foot-wide lanes across but has a low speed limit of 25 mph.

Scores by Casualty Rates

From 2019 to 2023, an average of 7 pedestrians and 17 bicyclists per year were hit by motor vehicles within a half mile of each transit station in the RAS. The TASS results for stations with a high volume of collisions between pedestrians and motor vehicles do not show a correlation with casualty rates. For example, 18 pedestrians per year were hit within the half-mile boundaries of SDSU Station (TASS = 81) and Civic Center-Vista (TASS = 45) stations, neither of which scored at the very bottom of the list. Rancho Bernardo, which scored at the bottom with a TASS value of 30 had no motor vehicle collision events with either pedestrians or cyclists. The lack of casualty events around this station may be in part due to the significant lack of destinations nearby and the visibly hostile environment surrounding this station. Horton Plaza station, which scored seventeen points above the average (TASS Ped = 69), has very walkable surroundings such as sidewalks that measure up to 17 feet wide and narrow streets with few lanes to cross. And yet, it was the station with the worst collision rate over the five-year period: 265 pedestrian casualties per 100,000 walkers per day in the census tract area. It can be further inferred by the high ridership of 164,430 boardings and deboardings in 2022 that Horton Plaza faces an increased risk of collision events due to high pedestrian volume. The TIMS data, however, shows that the majority of these incidents were not fatal, suggesting that these collision events did not occur at high speed.

Civic Center-Vista station, on the other hand, is isolated from Vista City's actual civic center by more than a mile. The landscape here is visibly car-centric, with a limited number of traffic light-protected intersections that also have less than four crosswalks near the station and a four-lane major road—Civic Center Drive—with a 35 mph speed limit and an average lane width of 11 feet. Despite the Civic Center itself being more than a mile away, there are destinations such as housing

[16] San Ysidro has a TASS Bike Score of 8, making it the lowest.

and commercial activity less than a tenth-of-a-mile from the station, which will attract more riders to the station area. Although it was one of the Sprinter stations with moderately low ridership in 2022—61,101 boardings and deboardings[17]—the presence of less pedestrian-friendly features in the land use and road design will still increase the risk to walking such that collision rates are still be high: 136 pedestrian casualties per 100,000 daily walkers per day in the census tract area.

In terms of biking, cyclist casualty rates were the inverse of what should have been expected with lower scoring stations getting higher collision rates. One station with a below-average score–the County Admin. Center drop-off stop for the Rapid Express coach buses in Downtown San Diego–had a very high casualty rate of 407 daily cyclist collisions. However, right behind it was a much higher scoring station that a disturbingly high collision rate as well: 30th Street on the Rapid Bus 215 in North Park, with a TASS score of 68 but an average daily collision rate of 124 cyclists per 100,000 bikes in the census area.

In conclusion, TASS is measuring the quality of a TOD’s built environment rather than people activity. Thus, it is difficult to establish a relationship between our scores and actual collision frequencies.

[17] For comparison, the top three stations with the highest 2022 ridership on the Sprinter were Escondido TC (236,279), Vista TC (184,946), and Oceanside TC (173,995). The three lowest-ridership stations in the same year on the Sprinter were Nordahl Road (51,154), Coast Highway (49,019), and Rancho Del Oro (40,023).

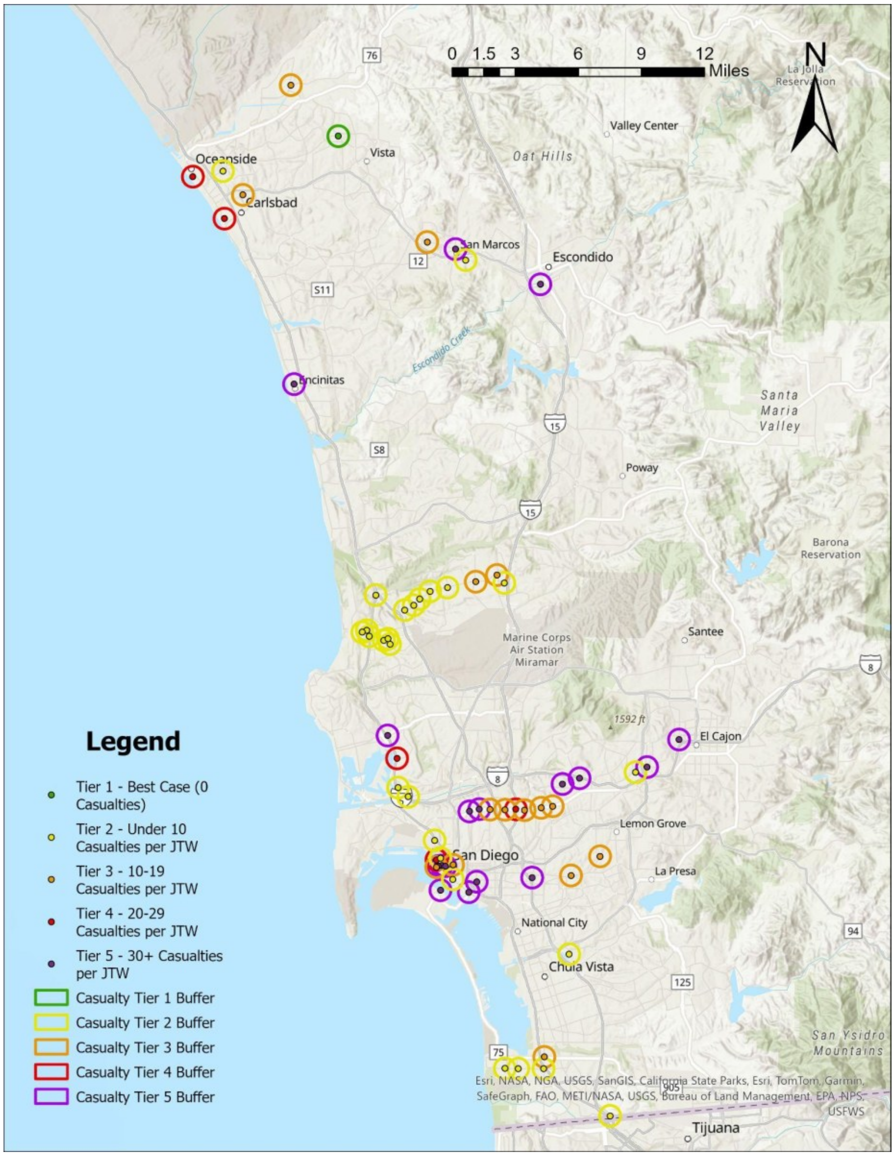

Figure 8. Map of all stations in San Diego County analyzed in the preliminary research, color-coded by number of pedestrian collisions from 2019-2023.

Scores by Destination Access

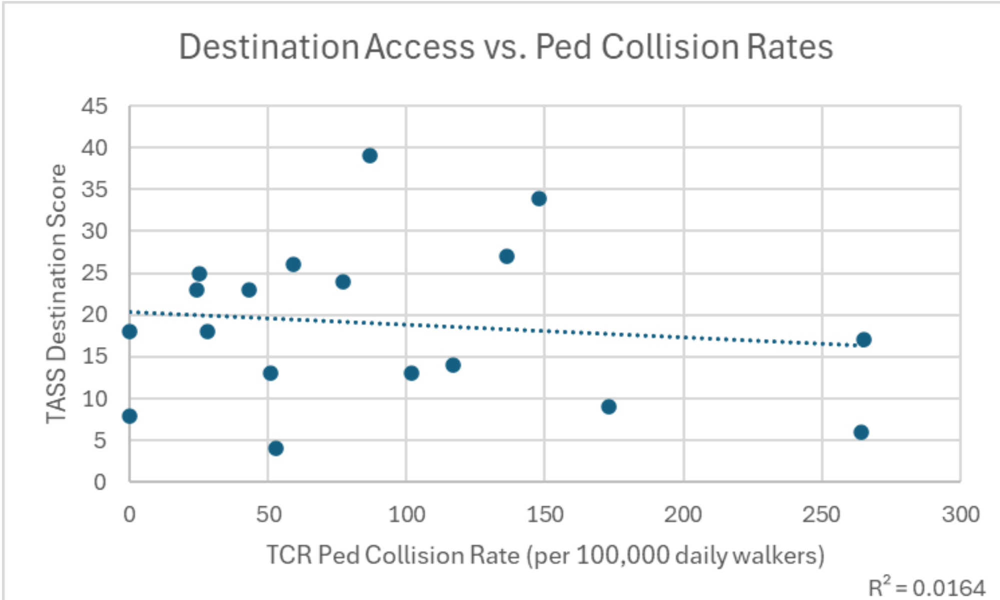

Figure 9. Pedestrian collision rates near transit in relation to destination accessibility.

Destinations showed a similar lack of significant relation to casualty rates, as both Figures 9 and 10 illustrate with R2 values below 0.5. The datapoints in Figures 9 and 10 show the rate of pedestrian and cyclist collision events with motor vehicles respectively within the five-year-query, in relation to their destination component scores.

Figure 9's trendline is relatively straight, with only a partial downward angle to signify a vague negative relationship between pedestrian collision rates and TASS destination component scores. The significantly low R2 value of 0.02 suggests that any relationship between these two variables is so vague that it is practically nonexistent. This is further exhibited by the scattered appearance of the datapoints across the graph, whereas a significant relationship would be exhibited by a more organized array of datapoints along the line.

The upward direction of the trendline and R2 value of 0.2 in Figure 10 suggests the barest possibility of a relationship between cyclist collision rates and destination access, but most of the datapoints are on the y-axis proper. This shows that there were significantly few stations that had a statistically significant rate of cyclist collision events occurring within the five-year-query. With only a few stations in the dataset showing a statistically significant rate of collision events with cyclists in the query period, there is not enough data to show more cyclists are getting hit by motor vehicles near these stations. More stations are needed from across the San Diego County RAS to increase the sample size, which will create a greater number of stations and scores to compare against local collision rates (Cooksy et al., 2025).

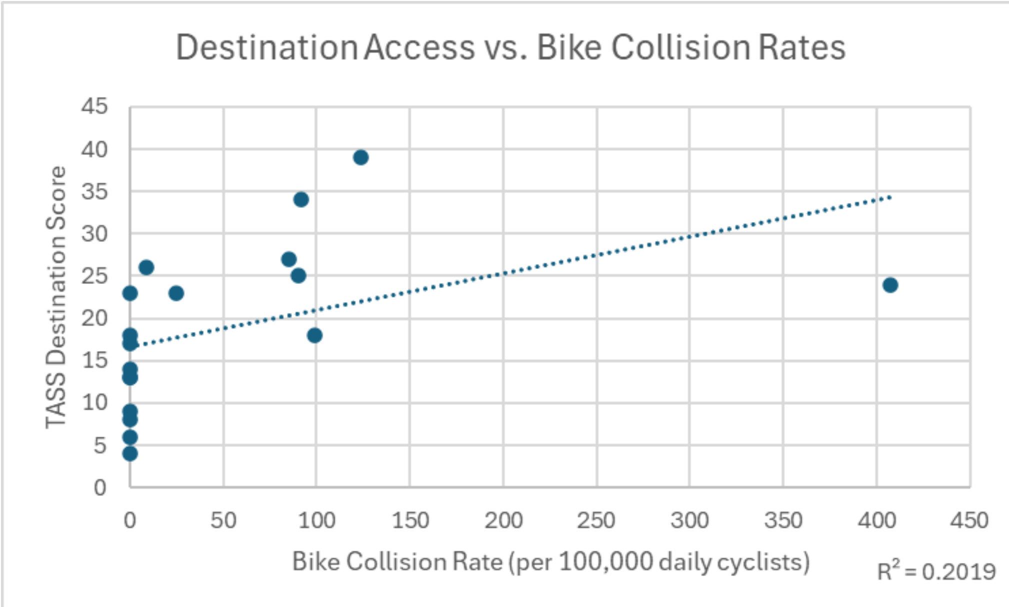

Figure 10. Bicyclist collision rates near transit in relation to destination accessibility.

Scores by Place and Station Type

A distribution analysis from a previously broader academic application of this research which looked at 146 stations over the entire San Diego County region used means and standard deviations, shown in Table 11 (Cooksy et al., 2025). This helped better understand the distribution of scores within and between each of the six evaluated place typologies, and helped further validate our selection of stations to be analyzed in this continued research.

In the previous thesis, the average TASS of 46.2 for Employment Center stations and 47.1 for Suburban Place stations were lower than the scores of other typologies. The Urban Center stations, meanwhile, had significantly higher scores than the other place types, with an average TASS of 64.1 and a standard deviation of 7.6. This distinction is shown in Figures 11 and 12, which illustrates the distribution of scores divided out by the six different typologies, assuming pure normal distributions based on the mean and standard deviation values in Table 11. Much overlap was shown between the curves for the Suburban, Urban, Compact Suburban, and Special District typologies in Table 10. The greatest difference in mean values, for the Employment Center and Urban Center place types, gave these two distributions the least overlap, as shown in Figure 12.

Table 10. Definitions of each place type.

Place Type	Definition
Compact Suburban	Older and more dense than traditional suburban places Located adjacent to urban and suburban areas Mix of multi-family and single-family housing
Employment Center	Typically located outside UCs and Urban Places A concentration of office, service, entertainment, and/or industrial activity
Rural Place	Widely spaced communities Separated by farms, vineyards, orchards, etc. Largely undeveloped land Low density
Special District	Specialize in a particular activity Unique land use in the area
Suburban Place	Mostly single-family housing Low integration between housing and jobs/retail/services Minimal transit access and high car dependency
Urban Center	The commercial, civic, and cultural center of the city. Contains mixed land uses and extensive pedestrian access. High transit access.
Urban Place	Typically a city's oldest residential neighborhoods. Majority multi-family housing and mixed land use. High transit access.

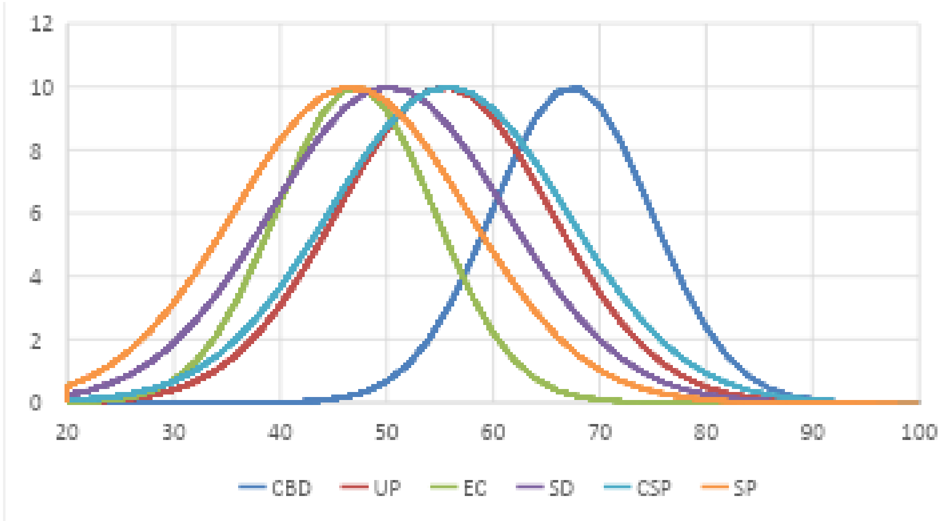

Figure 11. Distribution of scores separated by place types. Employment Center in the apple green and CBD in the dark blue are furthest apart, while the other typologies including Suburban Place (shown in orange) largely overlap with each other.

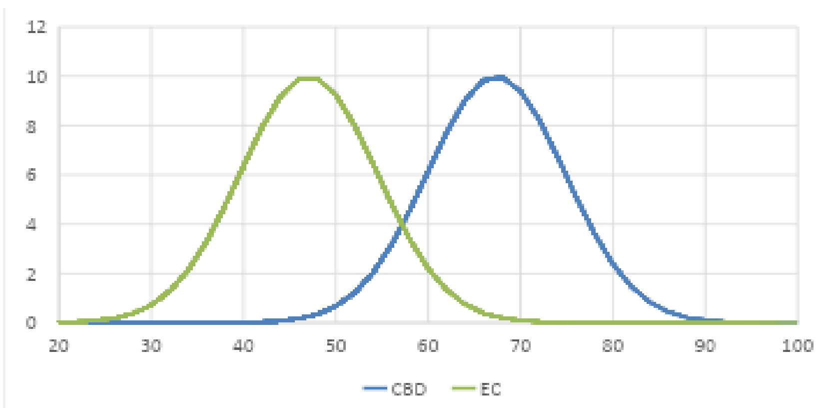

Figure 12. Distribution of scores separated by place types, showing specifically the curves for Employment Center and CBD, the average scores of which are separated by more than two standard deviations.

The student t-test comparison of scores for the Urban Centers and Urban Places gave a p-value of 0.020, which was only slightly less than the threshold value of 0.05 typically used to indicate a statistically significant difference. However, comparison of UCs to all other place types yielded p-values of $3{\times}10^{-4}$ (for Compact Suburban Places) down to as little as $9{\times}10^{-8}$ (for Suburban Place stations), indicating that the UC stations scored higher than other place types to a statistically significant degree. At the low scoring end, the Suburban Place and Employment Center typologies overlapped significantly with each other (p-value = 0.62) but differed significantly from other typologies. A similar student t-test was also performed on the distribution of scores between station typologies. The resulting p-values were vastly below 0.05, showing significant differences between the scores for emerging, transitioning, and coordinating station area types.

The difference in average scores between San Diego's Downtown and Employment Center stations showed a clear relationship between the TASS scores and the place type categories. Stations in Employment Centers in San Diego County are more likely to score lower while stations in UCs are more likely to score higher. This would imply that San Diego's Employment Centers need several overall improvements to their physical landscapes to become transit oriented. Downtown San Diego, like the Urban Centers of other metropolitan areas, is largely transit-oriented: its stations provide closer, safer, and more efficient access to destinations. Efforts should instead be focused on improving social factors around stations in Downtown San Diego: the riders' perceptions of safety and comfort around the station as well as frequency of service.

The small standard deviation of 6.7 among stations in Employment Centers meant there was less scatter in those TASS results than in other place types. This suggests that most of the stations in this place type deal with similar hindrances to walkability and bikeability, or that they are consistently lacking in convenient access to the same destination types. Therefore, improvements that would benefit one station in an Employment Center area are likely to apply to other stations in this place category. The two features that were the most inhibiting to the walkability and bikeability around San Diego's Employment Center stations were high speed limits on the major roads (average of 42 mph posted speed) and too many commercial and service driveways on the sidewalks (average of 21) (Cooksy et al., 2025).

In contrast, the standard deviation of 11.2 for Urban Places was almost twice that of Employment Centers, meaning that the range of scores for stations in this category were more spread out in the previous research (Cooksy et al., 2025). This indicates that no one physical landscape feature is consistently impeding the walkability or bikeability around a station in an Urban Place. These stations are more likely to require case-by-case analysis for improvement.

This study and its previous academic research also identified the level of transit activity and development based on research by Appleyard et al. in 2019. These include three Station Typologies that we will use to define how connected to transit the station is, and how developed the surrounding area is (Appleyard et al., 2019). These are defined in Table 12 below from the previous thesis (Cooksy et al., 2025). A comparison of average TASS results for stations in the three station typologies clearly shows a relationship similar to that of the TASS with place types, shown in Figure 13.

Table 11. Station typologies with mean and standard deviations of TASS results.

Station Typology	Definition	Mean	St. Dev.
Emerging	Infrequent transit, limited transport connectivity, and segregated/low intensity land uses	48.0	6.5
Transitioning	Moderate transit frequency, moderate street connectivity, moderate-to-high intensities, and some mixes of uses	55.8	9.0
Coordinating	High transit frequency, high connectivity, moderate-to-high intensity, and a mix of complementary uses)	64.5	6.6

Table 12. The number of stations by mode appearing in each station type.

Place Type	SD Trolley	Rapid Bus	Coaster	Sprinter	Local Bus	Coronado Ferry	Total
Emerging	1	2	1	1	0	1	6
Transitioning	1	1	0	0	0	0	2
Coordinating	1	2	1	0	0	1	5
Total	3	5	2	1	0	2	13

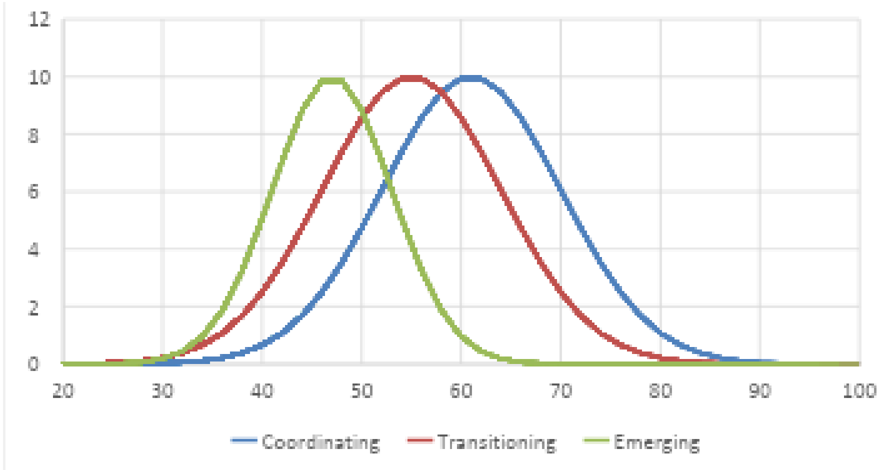

Table 13. Distribution of scores by Station Area Typology. Note the clear difference between Coordinating (developed) and Emerging (underdeveloped) areas in San Diego. Transitioning areas have more overlap with the other two.

The average TASS result in a Coordinating typology was more than two standard deviations from the average result for an Emerging typology, as shown in Table 12. The average TASS for a station in a Transitioning typology was one standard deviation above the Emerging typology group and one standard deviation below the Coordinating station type group.

A two-tailed t-test performed in the earlier thesis confirmed a strong correlation between the TASS results and both the place and station area type designations (Cooksy et al., 2025; Pfanzagl & Sheynin, 1996). The mostly low p-values ($p < 0.05$) showed a statistically clear distinction between TASS results for stations sorted into the six place types, and a stronger distinction when sorted into the three station typology categories. The average TASS result in the Urban Center was generally higher than the other five place types, as shown in Figure 11, while San Diego's Suburban and Employment Center places had the lowest average scores across the study. The average TASS result in an Emerging station area type in San Diego was significantly lower than either the Coordinating or Transitioning areas of the RAS as shown in Figure 13. The null hypothesis that there is no relationship between TASS results and either place or station typologies was thus rejected.

Discussion

This study identified a formula through the application of a case study in San Diego County, California, and evaluated a common set of variables that can be used to inform city planning around transit-oriented development. The outcomes of this study can inform potentially positive changes that can be made to land use to encourage more walking and biking around transit stations through policy.

Given the overall results of our analysis, the TASS metric and its criteria for walkability and bikeability around transit are effective in accurately grading the visual lay of the land. Like Walk Score®, however, this metric and its criteria cannot accurately measure human activity in response to physical landscape features and destination access. There was no strong relationship observed between higher TASS scores and higher JTW commuting rates, even though a vague trend was noted in the scatterplots. The same was true for TASS scores and casualty rates involving active transit users and motor vehicles.

Common Problems and Solutions

According to GIS data obtained from the U.S. Fatality Analysis Reporting System (FARS), out of 6,268 transit stations and bus stops in San Diego County, 252 (4% overall) had at least one fatal collision within 0.2 miles of the stop in 2022. 17 of these 62 pedestrian fatalities near transit stops in San Diego (27%) took place during the day, and another 39 (63%) occurred at night. 12 of those 39 evening collisions occurred in areas where there was no light (NHTSA, 2025).

Due to San Diego being a car-centric city, AADT rates were very high around most stations. This was often due to the nearest major roads having either wide lanes or at least four lanes. Our data shows that stations with less than three lanes often have AADT volumes under the maximum 10,000 cars-per-day ceiling that was established for the research. Stations with more than four lanes always had AADT volumes over 10,000. Almost every station's nearest major road also had an average lane width exceeding 10 feet, which provides more space for cars to maneuver and drive at excess speeds. A relationship could not be shown between wider lane widths and higher AADT, however. All but one station had a major road where the lane width was more than 10 feet. The most frequently occurring was 11 feet. Fifth Avenue Landing was the exception, where the average lane width of East Harbor Drive was 10 feet, and yet the most recently recorded AADT volume near the station was 20,689 cars in 2016. Narrowing all major road lanes to 10 feet when passing next to transit stops on major modes like rail and BRT or major city bus transit centers will reduce vehicular speeds and may even decrease the amount of traffic that passes by the station. This would in turn provide more space for wider sidewalks and bike lane upgrades to Class IV protection.

Although it was not a common trend spotted in our current 12-station sample size, parking lots are a challenge for pedestrian and bike access to transit. Some of these parking lots are tucked in areas where they don't directly conflict with active transit access and they often have under 100 parking spaces. Those with larger parking lots essentially surrounding the station, like Rancho Bernardo and Sorrento Valley, often had more than 100 parking spaces and were among the lowest scoring stations in our study and the previous academic research. The surrounding areas were also very car-centric in their design, with almost no major business activity or other destinations next to either of these stations, although the AADT rates were not necessarily the highest around these stations. Nonetheless, significantly reducing the size of parking lots, and thus the number of parking spaces, around the station often contributes to lower rates of driving (Haque, 2023).

A common trend observed around transit stations throughout San Diego County was the bare minimum accommodation of Class II bike lanes, which do not provide meaningful protection for cyclists. These are merely demarcated white lines or colored narrow lanes on the side of the street and are easily crossed into by paralleling motor vehicles. Upgrading all Class II unprotected bike lanes within half-a-mile of transit stations into Class IV protected lanes will better protect cyclists from car traffic and has the potential to increase cyclist activity near the station and in the surrounding area (CALBIKE & SCAG, n.d.). This can also calm traffic speeds by narrowing the adjacent lanes of the street (Hamidi & Ewing, 2023; Schneider et al., 2024).

For streets next to transit stations, another solution to consider is the application of a road diet. This would involve transforming a four lane street into two lanes of bidirectional traffic and creating a center lane for turning traffic, once again providing more space for a Class IV bike lane on both sides of the street (FHWA, 2025). taking additional actions when applying road diets to streets with an AADT over 17,000 cars as drivers will start to deviate from the main route. With streets above this AADT, people should also consider installing traffic calming measures on the side streets (Appleyard, 2021). This will mitigate the effects of car spillage into the surrounding neighborhoods caused by restricted space on high traffic roads, which would only spread out motor vehicle disturbances and hazards to pedestrians. In our study, six of the twelve stations surveyed have a nearby major road where the AADT volume is under 17,000. Two of these stations' selected major roads are already down to two lanes, nullifying the need for road diets at these locations. The remaining six stations in our study had AADT volumes exceeding 17,000, requiring added mitigation infrastructure in the surrounding neighborhoods to control the spillage of cars into nearby streets once a road diet is applied.

Complications and Suggestions

Transit stops are built with the intention to provide useful stops for riders to access their destinations. Some stations in the San Diego area were built to address walkability or bikeability needs, or built as a response to a development to encourage walkability for residents. While transit stops are supposed to connect riders to useful locations, some fall flat due to an inconvenient location. A few stations from San Diego were used as examples to understand where some stations missed the mark, serving as lessons on how to create successful stations.

The Sprinter Line's concept plans dedicated 1.7 miles of tracks dedicated to serve Cal State San Marcos University students and faculty, eventually leading to the CSUSM Sprinter Station to officially open to the public in 2008 (CSUSM, 2008). In comparison to SDSU or UCSD Central Campus stations, which are located within the university campuses, CSU San Marcos' Sprinter station is located about a mile off-site from campus facilities and nearby apartments. Walking from the campus to the Sprinter station is an indirect walk through San Marcos' commercial area, also requiring students living on-campus to walk on the side of a road overlooking the State Route 78 Parkway. More so, a large portion of the university's student body are commuters, bringing to question why easier access to the campus was not prioritized through the San Marcos' Sprinter station development plans.

The opening of trolley stations between America Plaza and City College is another case that was reviewed. The C Street corridor was one of the decisions made to jumpstart the revitalization of the commercial corridor of C Street in Downtown San Diego. Since the original Civic Center, Fifth Avenue, and City College stations opened in 1981, only some new developments have opened on the eastern edge of the corridor. Some improvement was noted in field observations of the western C Street area near America Plaza station, which opened in 1991. These include more office buildings and cleaner, wider sidewalks measuring 36 to 22 feet on the first two blocks east of the station on C Street. Otherwise, few improvements to the physical layout have occurred that contribute to the anticipated revitalization of commercial activity along the trolley lines serving the corridor (Hernandez, 2007; Urban Land Institute, 2023). The lack of effort on the part of surrounding property owners to adjust their land uses to support rail transit services is another case study exemplifying the independent nature of transit and zoning.

The last example of a station not effectively developed to serve the public is Gillespie Field Trolley station, serving Gillespie Field Airport in northern El Cajon. This station was constructed in preparation for new housing developments intended to be built near the airport that never materialized (Elkind et al., 2015; Morlan, 2015). This is now the trolley station with the lowest ridership, giving riders no key destinations to access other than the parking lot.

These three examples illustrate that transit stations do not automatically spur housing or mixed-use development and that work is needed to adjust zoning and road designs around transit in order to support more ridership. For the Sprinter, the off-site location from CSUSM's campus does not attract as many students and faculty to utilize the transit services. A suggestion to ensure transit is accessible for students and faculty is to provide free shuttle services to the station from different campus facilities. Similarly, the C Street Trolley stretching 1 mile between the America Plaza and City College stations did not bring as much success due to its surrounding environment not warranting people to utilize the transit. The mile-long stretch is currently home to law offices, a few eateries, and some new housing developments. The significant lack of business activity, especially surrounding the abandoned California Theater near the Fifth Avenue station, and the abundance of anti-homeless measures on many buildings (e.g. fencing, warning signs, lack of benches, bird spikes) discourages most walking and biking activity on this stretch. The C Street corridor does have potential, evidenced by the presence of a couple new housing developments around the City College station, some additional street-level business activity to the eastern edge of the corridor, and sidewalks measuring thirteen feet wide with an added seven feet of buffer space in the form of trees and planters. Thus, with high Trolley frequency and more pedestrian-friendly infrastructure already present in some places, the responsibility now hinges on commercial landowners to adapt their properties to encourage more people to walk, bike, or take transit on the corridor. The Gillespie Field trolley stop offers a key lesson when constructing transit stops. With the initial plans for housing near Gillespie being abandoned but efforts to jump start new development still running into obstacles (Elkind et al., 2015; Morlan, 2015), a future note for transit station development would be to ensure that development proceeds forward first before the station is constructed. This ensures that there will be at least something destination-worthy that justifies people using the station.

Coordinating with property owners who own lots near a transit station will ensure that development (proactively and retroactively) is coordinated in tandem with the station's construction. The implications of successful coordination between transit and property owners means higher ridership at stations and the transit service overall, creates a diversity in land uses and businesses that increases competition and tax revenue for the city (Hughes-Cromwick, 2020), and demands greater focus towards improving sidewalk and bike lane designs to better accommodate non-motor vehicle users. Comparisons can be drawn between the above three case studies to more successful developments built in tandem with transit in the San Diego area, from which strategies can be applied to improve the accessibility, physical safety, and attractiveness of less successful TOD. For instance, SDSU station being in the middle of the main campus area and serving immediately adjacent apartments, businesses, and entertainment centers such as the Student Union. Another successful example are Heritage and Santa Venetia stations on the South Bay Rapid Corridor. Compared to the C Street Trolley corridor, these two stations were built in tandem with the redevelopment of Chula Vista's Otay Ranch neighborhood in the late-2010s (KUSI News, 2019). As a result, the road design was appropriately adapted to restrict car volume to one lane in each direction and speed to 25 mph, while giving more space and protection on the sidewalks for pedestrians and cyclists in the form of 7 to 15-foot-wide sidewalks, Class I bike paths, and combined planter and parked-car buffers of up to 24 feet. Additionally, business activity had already been designed as smaller street-facing establishments that serve people walking by or taking transit to the area.

Conclusions and Recommendations

Limitation of Study

The primary limitation to the study is an inadequate number of spatial analysis data that can be compiled to perform a quick analysis of an area. Extensive review of Google Maps, including street views of the major roads helped fill in gaps. Capturing quantitative findings (sidewalks, driveways, bike parking types at stations, etc.) and converting these into GIS data format will improve future studies.

Relying on Journey-to-Work (JTW) as the primary means of tracking human activity in relation to the built environment also has limitations. By its very definition, JTW tracks only the trips made to work and home by the mode in question (in this case walking, cycling, or taking transit). JTW does not consider trips made for grocery shopping, visiting the doctor's office, going to school, or traveling to a destination for entertainment (Buehler & Pucher, 2024). Additional metrics or interview surveys are needed to quantify trips that are not considered a journey to work and verify travel patterns in an area.

Although data for all major roads in each travel boundary were gathered, this research only looked at the nearest major road to the station in its Physical Landscape analysis. This presented a challenge especially for the BRT mode category, where two major roads often intersect in front of a bus stop. Since the initial study could only analyze one major road at a time, a single street had to be chosen. A more comprehensive score should include the data on all the major roads to paint a more accurate picture of that area.

The essential destinations considered in the TASS include housing, healthy food, healthcare, education, recreation, and commercial activity; it did not explicitly include work destinations (Appleyard & Garrett, 2023; Litman, 2013). This needs to be incorporated into the next iteration of TASS methodology. For example, the San Diego County Administration Center in Downtown is directly served by the Rapid Express coach buses at peak hours and is a block away from the County Center/Little Italy Trolley station. By including work as destination criteria, a more accurate TASS measurement can be made. Including work as destination criteria also prevents issuance of poor TASS grades to stations in Employment Centers and Special Districts, where specialized land uses may encourage high transit ridership, but other essential destinations are not present. This component of the study is dependent on the diversity of destinations around a station, meaning that stations in the Urban Center and small-town centers like La Mesa are more likely to score higher than stations in Employment Centers and Special Districts. The formula also didn't consider single-family residences when evaluating the housing criterion. The research looked only at multi-family lots because of the lower upfront construction costs and their higher affordability compared to single-family units (Tesler, 2025). Despite the affordability and popularity of multi-family housing near transit, single-family housing should be considered in order to reflect higher income populations who may still rely on transit for work or social experiences. The scores need to be scaled to reflect these inherent biases (Appleyard et al., 2019).

Research Application and Conclusion

The TASS metric developed in this study has significant value in the planning and design of successful TOD. The metric was applied to San Diego County, California and efficiently provided clear and equitable measures of the built environment around a transit station regardless of the mode, place type, geography, or demographics. Thus, the TASS metric can be effectively implemented in other cities to evaluate the success and needed improvements of transit-oriented development. Although not dependent on geography, demographics, or the level of existing transit service, TASS would be best applied in cities and counties where there are efforts to expand transit usage and service reach.

The Physical Landscape component criteria will help inform planners and decision makers on what is needed to make TOD more walkable and bikeable. The Physical Landscape component also includes a tolerance for car-centric criteria such that planners can still accommodate motor vehicle users without compromising active transportation access to areas around transit. Example tolerances include a street width under four lanes, a speed limit under 35 mph, and a maximum number of parking spaces at the station if trying to draw riders from sprawl areas not yet served.

This research can be used in both proactive and retroactive applications. In retroactive applications, the TASS metric can help determine how best to improve the area around existing stations. This is useful for cities that want to improve or redesign their transit systems to accommodate higher population growth, encourage less car usage, and bridge economic and racial gaps (Sanchez, 1999). In the proactive sense, the TASS metric helps planners identify what is needed when developing a new transit station. This is useful for new transit projects that are either still in the planning stages or have already broken ground (Kolko, 2011).

Integrating transit with neighborhoods is another crucial priority. When designed correctly, mass transit such as public bus or rail can be incorporated into a community with less risk of damage to existing structures, displacement of residents, or economic and environmental impacts compared to roads and highways (Aiello et al., 2024; Sanchez, 1999). The TASS metric can be useful in identifying solutions that are compatible with place type, demographic, or geographic area considerations. This ensures that the transit mode will properly serve both locals in that neighborhood as well as transit riders.

In this study, the TASS metric has been applied to grade existing transit stations across four primary modes of mass transit in San Diego County. The TASS can also be used proactively with SANDAG's new Regional Transportation Plan, which seeks to expand bus corridors, provide additional Rapid bus routes, and build new rail lines such as the Purple Line. For example, TASS can be used by SANDAG to evaluate areas where new Purple Line stations are planned. By issuing a cumulative score for each station, individual Purple Line stops can be singled out and prioritized for improvements to encourage walking and biking.

The TASS equation also supports analyses of Pedestrian and Bicyclist Level of Traffic Stress (PLTS/BLTS) specific to major roads around public transit, identifying problematic streets near stations. Combined with surveys and observational data, the TASS calculation may help assign a Level of Traffic Stress (LoTS) rating for a specific street near transit.

In conclusion, the presence of public transit alone does not guarantee that an area will automatically become more walkable or bikeable. Rather than developing the area after-the-fact as was the case with the Trolley on C Street, public transit and land use changes need to be planned and constructed in tandem with each other like they were with the South Bay Rapid. While the research could not ascertain a strong relationship between TASS scores and people's actual travel patterns, it clearly identifies features that need to be modified to create a more walkable and bikeable experience around individual transit stations. Examples include wider sidewalks, protected bike lanes, fewer travel lanes on streets, closer access to crosswalks, little-to-no station parking, no conflict zones at highway on/offramps, and essential destinations that encourage use of mass transit and active modes.

This study draws upon previous research efforts to create a grading metric for public transit stations and their surroundings to make TOD more successful. The findings will streamline the process of planning both improvements to transit itself and TOD in the San Diego area. The TASS formula and the criteria used to grade the stations can also be applied to other cities with any type of transit mode, not just rail transit. By having a clear list of features that improve the walking and bicycling experience around transit, planners and decision makers can develop safer routes between transit and destinations. This will in turn promote stronger connectivity within larger metropolitan regions.

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