

The Effect of Park-n-Rides on Greenhouse Gas Emissions

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ABSTRACT

Over the past decade, rising greenhouse gas emissions (GHG emissions) have put public transit in the forefront of sustainable transportation. To improve transit accessibility and attract riders, Park-n-Ride (PnR) facilities have been built on the periphery of cities. By providing convenient parking facilities, agencies encourage drivers to shift modes in their single occupancy vehicle (SOV) and complete their journey by transit.

While PnRs are intended to facilitate more transit riders, the facilities may also carry paradoxical consequences. Do PnRs actually reduce the distance traveled by SOVs? Does a multi-modal trip offset emissions from a theoretical SOV drive-only trip? Critics have challenged the environmental efficiency of PnRs, claiming the magnitude of the modal shift may not necessarily be reflected in GHG emissions. Drivers may still make long trips by car to reach the PnR.

This study evaluates the magnitude of GHG emissions saved from transit ridership, based on SOV PnR users in the Denver metro area. By comparing the multi-modal trip against a theoretical SOV drive-only trip, the effects from GHG emissions are weighed. Theoretically, the further a person drives to reach a PnR, the less of an impact transit has on reducing GHG emissions.

Results showed that PnRs located at inner-corridor stations are less effective at reducing GHG emissions than end of line stations. PnRs near downtown provide an incentive for longer SOV drives. Consequently, drivers who make long transit access trips can outweigh the benefits of transit usage due to increased vehicle emissions.

TABLE OF CONTENTS

CHAPTER

I. INTRODUCTION	1
II. BACKGROUND AND LITERATURE REVIEW	2
III. STUDY OVERVIEW.....	4
Data	4
Methodology.....	5
Calculating vehicle and transit mileage.....	5
Calculating GHG emissions.....	7
Carbon dioxide ratio: Multi-modal trip vs. SOV trip.....	8
IV. RESULTS.....	8
V. DISCUSSION.....	11
Parking fees.....	12
Parking demand.....	13
VI. CONCLUSION.....	13
REFERENCES.....	16

LIST OF TABLES

Table

Table 1: PnR parking availability and station typology.....	8
Table 2: Greenhouse Gas Impacts from RTD LRT System, 2009.....	7
Table 3: Average distances for Multi-Modal and Theoretical SOV trip	8
Table 4: GHG emission summary and CO ₂ -equivalent ratio	9

LIST OF FIGURES

FIGURE

Figure 1: Origin and destination summary for Nine Mile Station PnR	4
Figure 2: Multi-modal trip	6
Figure 3: SOV drive-only trip	6
Figure 4: Average CO ₂ -equivalent ratio by station.....	11
Figure 5: PnR Transit Alternative Question.....	12

CHAPTER 1: INTRODUCTION

Concerns about environmental sustainability have led to an increased consciousness in seeking more sustainable transportation. A good portion of the carbon footprint derives from transport activities, making it more important than ever to reduce single occupancy vehicles (SOVs), utilize alternative modes of transportation, and reduce vehicular emissions. In cities with congested urban corridors and limited parking capacity, park-n-ride (PnR) facilities have become a popular measure toward increasing transit ridership. Serving as a magnet to draw more drivers out of their cars and into public transit, PnRs can improve the accessibility of transit.

While there are several studies that discuss the effects of public transit on environmental sustainability, there is little literature that explores the link between PnR and greenhouse gas emissions (GHG emissions). In theory, vehicle emissions should decrease as drivers shift their mode to public transit. Public transit has been touted as one of the most effective means in reducing GHG emissions from SOVs because shifting modes from private vehicles to public transit creates displaced car trip that correspond with displaced vehicle miles traveled (VMT).

Although PnRs are designed to facilitate maximum transit usage, they may also carry paradoxical environmental consequences. The magnitude of the modal shift may not necessarily be reflected in significant GHG emissions reductions as drivers could be driving a long portion of the trip by car. In other words, a driver's individual choices may not necessarily be in the best interests of the environment. Placed against driving, a rational individual might only use a PnR if its generalized cost is lower than the one for the drive-only trip (J. Holguin-Veras et al., 2012). In the context of individualized costs, a driver is more likely to use a free PnR when the drive-only trip carries parking fees. In fact, drivers may go out of their way to access a PnR facility if

doing so results in a significant savings in parking costs. These challenges, amongst others, make the environmental effects from PnRs multi-faceted and in need of further study.

This report will seek to better understand the relationship between PnRs and GHG emissions through a case study of Denver, Colorado. Using data from the Regional Transportation District (RTD) of Denver and the Denver Regional Council of Governments (DRCOG), the study will analyze trip patterns for SOV PnR light rail users across metro Denver. Trip distances will be determined for a multi-modal trip, including a SOV transit access portion and a light rail portion, as well as the hypothetical SOV drive-only trip distance. Using these distances, the study estimates the GHG emissions saved by riders using PnRs and light rail transit with respect to their relative effect on the overall commute. Because carbon dioxide (CO₂) is the primary element in transport-based GHG emissions, CO₂ equivalents will be used to measure the environmental effects of each mode. Theoretically, riders create the most environmental benefits when the transit access trip is shorter than the light rail trip, reducing vehicular emissions from an SOV drive-only trip while still providing convenient access to the PnR facility. In a broader scope, this study will add to the larger library of literature examining how public transportation usage can affect the environment.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

PnRs are a popular gateway to increasing transit ridership, but there are limited publications that explore the sustainability effects from these facilities. Do PnR facilities reduce the miles driven by SOVs? The impacts on the environment are rather uncertain. Several arguments challenge the environmental efficiency of these facilities. First, the magnitude of the modal shift may not necessarily reflect on GHG emissions; a potentially long part of the trip can still be made by car (Gantele, 2008). Transit access trips are generally longer than the trip leg

between the PnR location and the urban center (Parkhurst, 2000, Meet et al., 2008b). PnRs may induce unexpected and counterproductive effects, such as commuters who reach the train station by car instead of walking or biking. Additionally, by facilitating accessibility, PnR facilities may potentially attract new driving trips, thus having a negative effect on vehicle emissions. Finally, the long term effects of PnRs may help proliferate urban sprawl by creating more vehicle accessibility outside the city center (Gantele, 2008). Paradoxically, each of these potential impacts raises challenges for PnRs in fulfilling their sustainable purpose.

A study from the Swiss Federal Office of Energy (Guillaume-Gentil et al., 2004) reported mixed results for Swiss PnRs in regard to environmental efficiency. Notably, PnRs located near city centers turn out to be counterproductive, while PnRs along regional transport networks showed better energy efficiency. Overall, the results of the Swiss study were inconclusive. The methods used for the study in Switzerland encompass several aspects that affect environmental sustainability, including the cost efficiency, the effects on roadway congestion, and the availability of long-term parking in metro areas. While the study covers multiple issues, it is difficult to determine any true findings as many of the factors were inconclusive. For this study, the primary focus will be to highlight GHG emissions in terms of CO₂-equivalents.

More recently, a research study from the Netherlands found that PnRs may create unintended effects, which not only limit transit usage, but may even increase vehicle travel in the metro area. The primary consequence was “*abstraction from public transport,*” where individuals shifted to driving from transit that had been previously been making the entire trip via public transit before the PnR was introduced (Mingardo, 2013). While the Dutch study provides interesting insights for European PnRs at rail-based stations, there is a lack of literature studying the environmental effects from American-based PnRs.

CHAPTER 3: STUDY OVERVIEW

Data

In 2008, RTD conducted an on-board survey of its riders in the Denver metro area. Riders were surveyed for the immediate one-way trip. Surveyors were asked to provide information about their transit access trip, mode of access, origin and destination, and transit route. According to NuStats, samples from all major bus and light rail routes are at the 95% confidence level.

The 2008 RTD on-board survey provided a total of 2,019 surveyors who accessed PnR facilities by SOV and rode light rail for a portion of the commute. Results for transit-access trip distance varied across the region; for end-of-the-line stations (such as Nine Mile and Lincoln), drivers tended to be from more geographically scattered areas. Figure 1 shows a map with the origin and destination of surveyors accessing Nine Mile PnR.

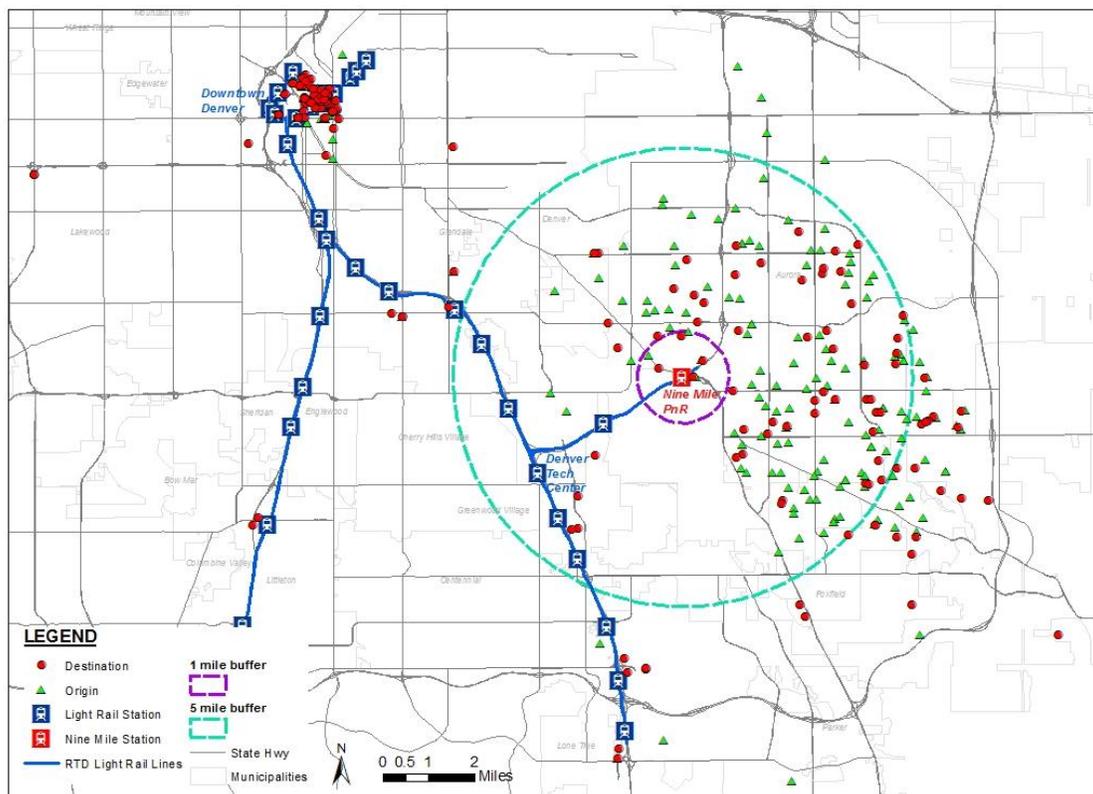


Figure 1: Origin and destination summary for Nine Mile Station PnR

Methodology

Calculating vehicle and transit mileage

In order to obtain an applicable set of data, several filters were applied to the original set of 23,865 surveys. Using the truncated data, calculations were made to determine the approximate distance riders traveled during their commute. The car-based portion of the trip is referred to as a 'transit access trip'. The transit portion of the trip is referred to as 'transit miles traveled'. The following procedure was used to determine the mileage of each trip:

1. Transit access trip mileage was provided by the surveyors and verified through Google Maps.
2. Transit miles traveled was determined as the distance between boarding station (PnR) and alighting station (destination). This is also referred to as the light rail trip.
3. SOV mileage for the theoretical drive-only trip is estimated by entering the origin and destination addresses in Google Maps. The Google Maps program calculates the best routes based upon shortest distance and shortest drive time.

As shown below, Figure 2 illustrates an example of a rider's transit access trip and light rail trip (steps 1 and 2 in procedure). Figure 3 provides an example using the same rider's data for the theoretical SOV drive-only trip.

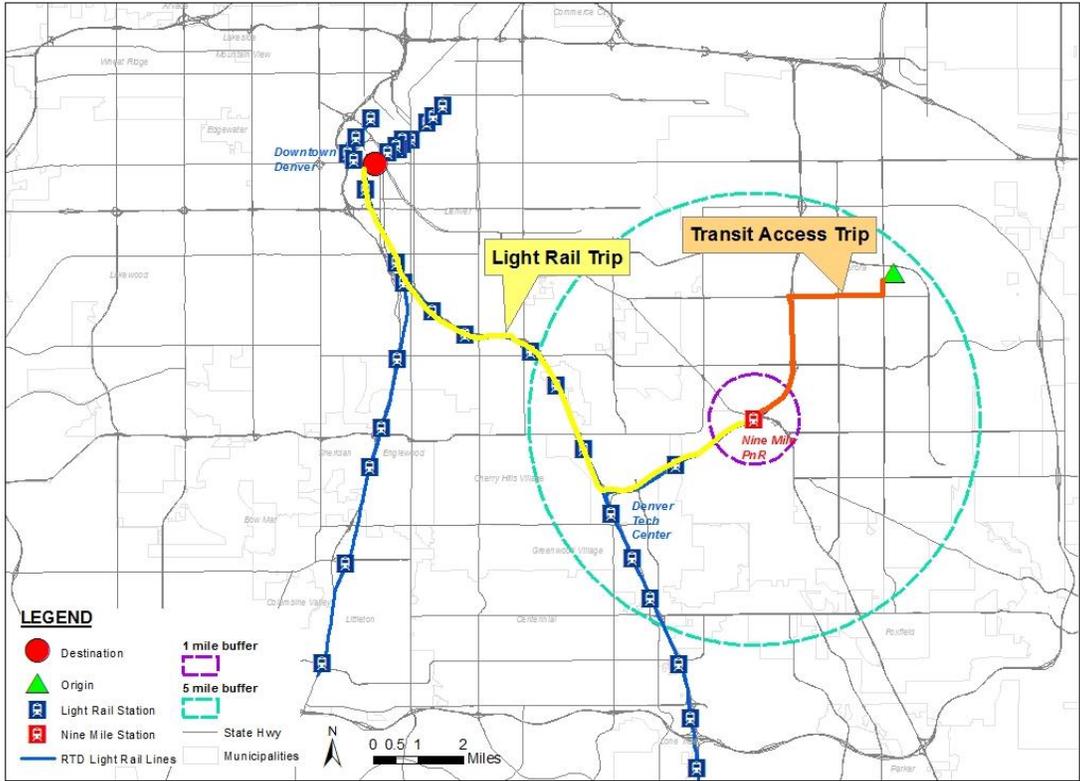


Figure 2: Multi-modal trip

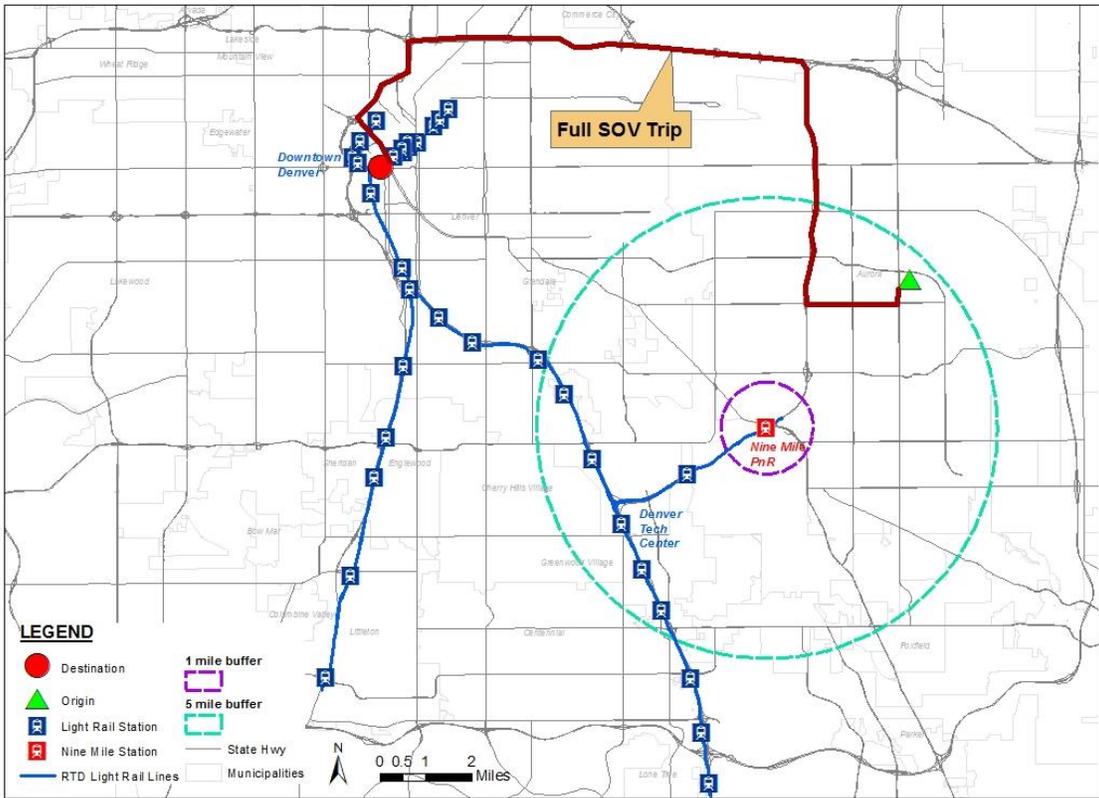


Figure 3: SOV drive-only trip

Calculating GHG emissions

Vehicle emissions from the transit-access trip and theoretical drive-only SOV trip are calculated by using the American Public Transportation Association (APTA)'s methodology for quantifying GHG emissions from transit. The national default value for fleet fuel economy is 20.2 miles per gallon, as reported by the EPA in *Light-Duty Automotive Technology and Fuel Economy Trends: 1973 through 2007*.

$$\text{Average Fuel Economy} = \text{VMT} \div 20.2 \text{ miles per gallon} \quad (\text{Equation 1})$$

From the average fuel economy, carbon dioxide emissions are obtained by using the national default values for GHG emissions, as reported from *The Climate Registry General Reporting Protocol v. 1.0*, Tables 13.1 and 13.4. Carbon dioxide is the primary GHG emitted through human-based transportation activities; thus, carbon dioxide emissions will be the primary GHG emission measured in this study. The default value for carbon dioxide emissions is:

$$\text{CO}_2 \text{ vehicle emissions} = \frac{\text{Average Fuel Economy}}{8.81 \text{ kg CO}_2 \text{ per gallon of gasoline}} \quad (\text{Equation 2})$$

Environmental impacts from transit are determined from the 2009 RTD Sustainability Survey. GHG impacts for light rail are based upon electricity usage (kilowatts) used for the traction power supply system (TPSS). Table 2 provides a summary of the LRT system's GHG impact, as well as the carbon dioxide equivalent per passenger mile.

Table 2: Greenhouse Gas Impacts from RTD LRT System, 2009

LRT System Component	Electricity Usage (kWh)	CO ₂ -Equivalent (kg CO ₂)
Traction power system supply	43,766,810	32,695,000
Communication signal house	1,450,420	1,023,000
LRT station power usage	8,817,095	6,221,000
LRT station lighting	44,509	31,000
<i>Total CO₂-Equivalent from LRT system</i>		39,970,000
Annual LRT Passenger Miles (2009)		129,248,691
<i>CO₂-equivalent per Passenger Mile (CO₂ Equiv. per Passenger Mi)</i>		0.3092

The CO₂ equivalent per passenger mile in Denver was calculated to be 0.3092. The carbon dioxide equivalent per passenger mile is used to determine how the actual transit miles traveled impacts the environment, as calculated in equation 3:

$$CO_2 \text{ transit} = (CO_2 \text{ Equiv. per Passenger Mi}) \times \text{Transit Miles} \quad (\text{Equation 3})$$

Carbon dioxide ratio: Multi-modal trip vs. SOV trip

By using the GHG emission calculations for vehicles and transit, a ratio of the CO₂ emissions from a multi-modal trip to a SOV trip is determined. This ratio calculates the effect of using light rail relative to a fully SOV drive-only trip. A ratio that is less than 1.0 indicates that the multi-modal trip emits fewer GHG emissions. As the ratio value approaches 1.0, the lesser the effect transit has on emissions.

$$CO_2 \text{ ratio} = \frac{(CO_2 \text{ transit access}) + (CO_2 \text{ transit})}{(CO_2 \text{ SOV drive-only trip})} \quad (\text{Equation 4})$$

CHAPTER 4: RESULTS

Using survey data from the 2008 RTD on board survey, travel patterns were analyzed for 2,019 SOV drivers who used PnRs in the Denver metro region. Trip patterns were determined for both the multi-modal trip, including a SOV transit-access portion and a light rail portion, as well as for the theoretical SOV drive-only trip. A summary of average distances for trips is shown in Table 3.

Table 3: Average distances for Multi-Modal and Hypothetical SOV trip

Light Rail Station	Multi-modal trip		Hypothetical SOV drive-only (mi)
	Transit access trip (mi)	Transit miles traveled (mi)	
30th & Downing	5.6	3.8	9.3
Orchard	3.4	11.7	15.1
Belleview	2.8	12.0	14.8
Evans	2.9	5.7	8.6

Light Rail Station	Multi-modal trip		Hypothetical SOV drive-only (mi)
	Transit access trip (mi)	Transit miles traveled (mi)	
Yale	3.4	8.0	11.4
Dry Creek	3.6	15.0	18.6
Dayton	7.3	13.0	20.3
Alameda	5.6	8.1	13.8
County Line	7.8	16.5	24.3
Littleton-Downtown	4.0	10.0	14.0
Colorado	3.5	7.6	11.1
University	4.4	5.6	10.0
Southmoor	4.2	9.4	13.5
Arapahoe at Village Center	5.2	14.0	19.1
Englewood	6.0	7.5	13.5
Nine Mile	5.4	13.9	19.3
Littleton-Mineral	5.0	11.9	16.9
I-25 & Broadway	7.3	5.0	12.3
Lincoln	6.7	16.4	23.1

Based upon the distance of the trips, a carbon dioxide (CO₂) equivalent was calculated for each mode as described in the methodology. Table 4 provides results of the GHG emission analysis, including the average of emissions for each station and the CO₂-equivalent ratio.

Table 4: GHG emission summary and CO₂-equivalent ratio

Light rail station	Transit access emissions (kg CO ₂)	Light rail impact (kg CO ₂)	SOV drive-only emissions (kg CO ₂)	CO ₂ Ratio
30th & Downing	2.4230	1.1681	4.0706	0.88
Orchard	1.4762	3.6153	6.5756	0.77
Belleview	1.2176	3.7104	6.4512	0.76
Evans	1.2783	1.7592	3.7598	0.81
Yale	1.4992	2.4736	4.9883	0.80
Dry Creek	1.5860	4.6380	8.1280	0.77
Dayton	3.2009	4.0196	8.8707	0.81
Alameda	2.4601	2.5074	5.9969	0.83
County Line	3.3993	5.0927	10.5828	0.80
Littleton-Downtown	1.7290	3.0920	6.0904	0.79
Colorado	1.5192	2.3551	4.8411	0.80
University	1.9113	1.7233	4.3421	0.84
Southmoor	1.8211	2.8967	5.9070	0.80
Arapahoe at Village Center	2.2565	4.3154	8.3435	0.79
Englewood	2.6297	2.3249	5.9090	0.84
Nine Mile	2.3613	4.3043	8.4327	0.79
Littleton-Mineral	2.1656	3.6920	7.3732	0.79
I-25 & Broadway	3.1763	1.5554	5.3702	0.88
Lincoln	2.9166	5.0657	10.0619	0.79

The closer a CO₂-equivalent ratio is to 1.0, the lesser the benefit transit has on the environment. Conversely, stations with lower ratios would have a greater environmental benefit from transit. In theory, drivers who make longer transit access trips may be negating the positive environmental effects from transit usage, due to the greater SOV usage over longer distances. From the ratios, it is observed that some stations have a disproportionately higher amount of SOV transit-access miles. Many of the drivers who parked at 30th & Downing station did not originate from nearby neighborhoods. Because this station provides free parking and is located within two miles of the downtown central business district (CBD), it lures drivers who would otherwise make a fully car-based trip into downtown. In this scenario, the PnR serves primarily to save the driver on costs of parking downtown. The graph in Figure 4 provides a graphical analysis of the CO₂ ratios, organized in ascending order of parking spaces provided.

Of the stations with highest ratios, 30th & Downing and I-25 & Broadway station are among the closest PnRs to downtown Denver. Parking fees provide a disincentive for drivers to park downtown, while still maximizing the utility of driving as close as possible to a free parking lot. In this sense, the PnR does not serve a purpose of encouraging sustainable transit ridership. Instead, the PnR facility actually induces driving to the closest free parking possible. These effects are contrary to the overall intent of PnRs. Although these lots are intended to provide better access to public transit, drivers may still make long trips to reach the PnR facility and therefore negate the environmental benefits of using transit.

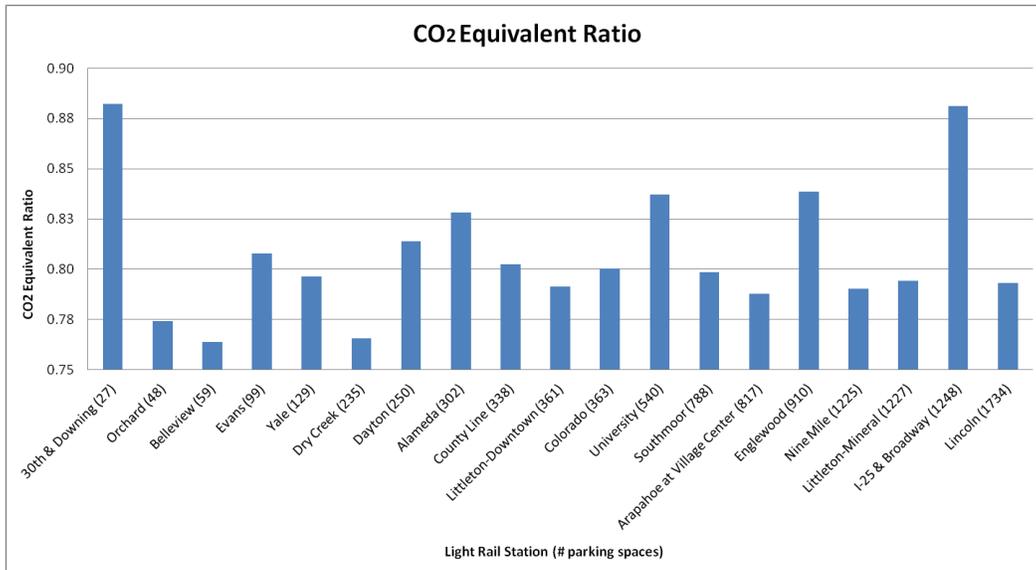


Figure 4: Average CO₂-equivalent ratio by station

CHAPTER 5: DISCUSSION

Do PnR facilities increase transit ridership? The 2008 RTD on-board survey asked riders how they would have made their trip if transit was not available. Out of the 2019 drivers who used the PnR, over 88% claimed that they would have otherwise driven alone for the full trip, shown in Figure 5. Thus, it would be fair to assume that because a PnR facility was available, this made public transit more accessible to drivers. Most of these individuals fit into the ‘choice rider’ category- individuals who have access to a private vehicle, but have chosen to switch modes in favor of public transit. What makes these riders significant is that alternatively, these same individuals would have been driving the roads in a lone-occupant vehicle. Not only would this increase congestion to roadway networks, but GHG emissions from transportation would also rise.

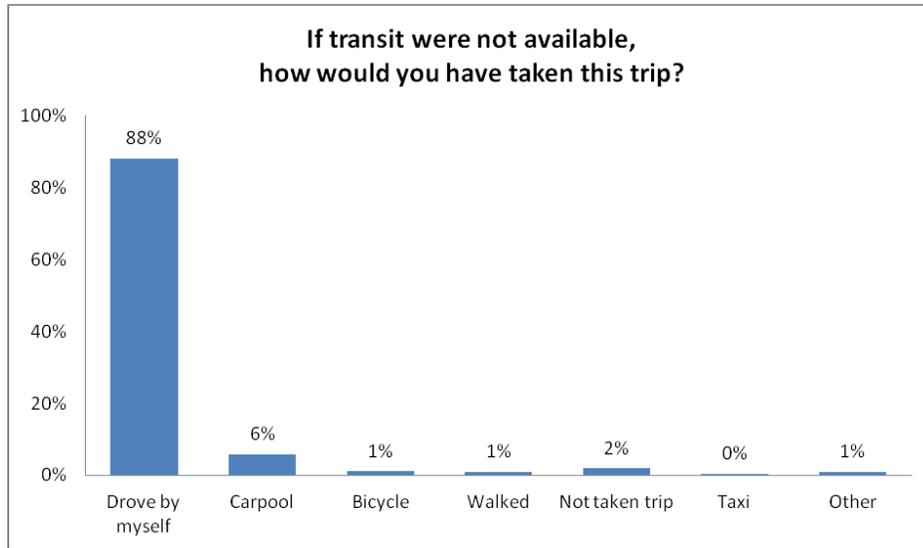


Figure 5: PnR Transit Alternative Question

Parking fees

Parking fees can influence where a driver parks or which mode a rider chooses to take. In the downtown Denver central business district, parking is priced at premium, averaging \$16 per day (Denver Business Journal). This incentivizes commuters traveling into the downtown Denver CBD to seek alternative modes and/or free periphery parking. The other large employment center in the Denver metro region is the Denver Tech Center, located south of I-25 and I-225. Although the southeast corridor caters to riders commuting through the DTC, there is a disparity in transit ridership because of free parking. Because parking within the DTC is free of charge, employees have less incentive to leave their vehicles behind and commute by transit. A survey of Denver businesses within one mile of light rail stations found that more than 80% of businesses outside the downtown CBD had free parking right next to their building (DRCOG). The abundance of free parking outside of downtown adds to the disincentive of riding transit.

A notable observation from this study is the parking patterns of Castle Rock drivers. Castle Rock, located 31 miles south of downtown Denver, is not within the RTD district. Because its residents do not pay RTD taxes, riders from Castle Rock must pay to park at all

times. Without the first 24 hours free, like other RTD in-district residents enjoy, Castle Rock residents may feel an incentive to find free neighborhood or street-side parking. The closest RTD light rail station with direct street-side parking is at Belleview Station. Belleview is located six miles from Lincoln Station, meaning that drivers are willing to commute an extra 12 miles a day roundtrip in order to save on the \$2 per day parking fee.

Planning implications

The only station on the Southeast corridor without a PnR is at Louisiana-Pearl Station. Transit planners had designed this location to provide walk-up service at a neighborhood-based station. Despite the lack of parking provided, ridership at Louisiana/Pearl station is consistently high and has made the station one of the busiest stops outside of central downtown. The distance to the next closest PnR facility from Louisiana-Pearl is I-25/Broadway Station, located 0.8 miles away. The close proximity of these light rail stations to one another lends to the broader topic of station typology and station planning. Planners should be weary of placing a PnR facility at every station along the corridor for the sake of providing parking; in the larger scope of TOD planning and development, mixed-developments may struggle if parking is over-abundant

CHAPTER 6: CONCLUSION

PnR facilities are intended to increase transit ridership by providing convenient, free parking access to suburban commuters. However, PnRs may also produce unintended consequences. As shown by the results of this study, drivers can still make long trips to reach the PnR, commuting up to 30 miles to reach a lot. The vehicular emissions from these long, SOV transit access trips may negate the environmental benefits from using public transit.

Illustrated by the CO₂-equivalent ratio, multi-modal trips that include a long SOV drive portion actually emit almost as many GHG emissions as a SOV drive-only trip. Thus, when a commuter makes a long drive to reach the PnR facility, the positive environmental effects of using light rail are nominal. On the other end of the driving spectrum, PnR facilities may also induce additional driving trips. As observed in analysis, up to 46% of PnR users drove less than two miles to reach the parking facility. Shorter drives of less than two miles could be substituted with walking and biking. Using an active mode of transport produces zero-emissions, and allows for the overall trip to become even more sustainable more the environment. However, when parking is over-abundant, users become less inclined to walk and bike to the stations, and instead, make a short driving trip, which is counterproductive in to the overall goal of a sustainable environment.

On a regional level, when drivers shift modes to incorporate transit into their commute, the community should benefit from a net reduction in greenhouse gas emissions. From the analysis CO₂ equivalent ratios, the results of this study found that end of line stations were amongst the more sustainable locations for PnRs. The geographic locations of these PnRs allow commuters to ride a longer distance on the light rail than if they were to drive closer into downtown. Nine Mile, Lincoln, and Littleton-Mineral stations are all end of line points for their respective corridors, and each station had a CO₂ equivalent ratio of 0.79. In comparison, 30th & Downing and I-25 & Broadway had a CO₂ equivalent ratio of 0.88. The higher ratio indicates that stations near downtown are less effective in facilitating sustainable habits. Providing free, convenient parking near downtown can be counteractive, such that drivers are provided an incentive to make a longer drive by car and shorter trip by transit. In order to promote the most sustainable transportation system possible, transit agencies should heavily consider the implications of parking supply and parking demand in station design. Furthermore, the cost of

parking should be factored into the management of PnRs; providing free parking encourages drivers to disregard added miles and emissions to the trip. PnRs need to foster sustainable transportation, and currently, some lots may be underpriced for the market.

There is still much more work to be done in advancing sustainable transportation and offsetting GHG emissions by transport. Looking forward, the role of PnRs in transit corridors should be one that complements sustainable transportation patterns. Instead of placing a PnR facility at each station, planners and stakeholders should consider a strategy that focuses on how PnRs can be most effective. Inner-corridor stations, particularly those closest to the downtown area, should be wary of creating induced traffic with parking facilities. End of line stations may be more effective in funneling suburban riders and maximizing their distance on transit. When used effectively, these facilities can provide a valuable tool to increase ridership and reduce GHG emissions. PnR facilities have played an important role in attracting choice riders from suburban areas, and allowing them a means to incorporate transit within their commute patterns. As more people become comfortable in using alternative transportation, the transport patterns of society will begin to shift, leading to a more sustainable tomorrow.

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