UNIFIED CORRIDOR INVESTMENT STUDY

AUTOMATED TRANSIT NETWORK ALTERNATIVE

CONCEPTUAL EVALUATION

INTRODUCTION

“The objective of the Unified Corridor Investment Study (UCS) is to identify multimodal transportation investments that provide the most effective use of Highway 1, Soquel Ave/Soquel Dr/Freedom Blvd, and the Santa Cruz Branch Rail Line to serve the community’s transportation needs.”[1] The UCS considered bus transit, rail transit, auto, bike/ped and rail freight modes. It also considered automated vehicles/connected vehicles even though those modes are still emerging. Despite this multi-modal approach, the study completely ignores a mode that has been operating in public service since 1975. This mode is called automated transit networks (ATN – an umbrella term for personal and group rapid transit - PRT & GRT). ATN suppliers such as Vectus, Ultra, Modutram and 2getthere have had ATN systems in continuous public service since 1999[2]. ATN systems have completed over 200 million injury-free passenger miles.

The purpose of this paper is to document why the UCS should add ATN to the modes considered. This is accomplished by addressing each of the performance measures used in the UCS in turn, with emphasis being placed on comparison with Scenario B, understood to be the likely preferred scenario.

Vectus

Ultra

2getthere

2getthere

Modutram

Figure 1. ATN Systems in Public Service

[1] SCCRTC’s Unified Corridor Investment Study, Step 2 Analysis Results, Draft, September 2018, by Kimley Horn
[2] Video clip of ATN systems in operation: https://www.youtube.com/watch?v=8IM5299tXcw&

AUTOMATED TRANSIT NETWORKS

DEFINITION AND DESCRIPTION

Automated transit networks (ATN) is an umbrella term for two concepts that are now merging into one. These are personal rapid transit (PRT) and group rapid transit (GRT). PRT was conceived to use small (2 – 6 seated passengers) driverless vehicles carrying individuals or parties travelling together nonstop from origin to destination and not sharing rides with strangers. GRT uses large driverless vehicles (up to 20 or even 30 seated and/or standing passengers) which often wait before departing to encourage ride sharing and stop at intermediate stations if necessary. Modern PRT systems generally have 4 to 6 seats, encourage ride sharing and may make an intermediate stop or two. Other terms for these systems include Podcars (commonly used in Sweden) and Pod Taxis (commonly used in India). This study refers to these systems as PRT, GRT or ATN as appropriate.

ATN systems provide a very high level of service and passengers have no need to know routes, schedules or transfer points. All they need to know is the name of their destination station.

Table 1 on the following page provides a comparison of PRT with cars and conventional transit.

ATN DEFINITION

- Small driverless vehicles
- Exclusive guideways
- Offline stations
- On-board switching

ATN CHARACTERISTICS

- Short wait times
- On-demand service
- Mostly nonstop
- Seated travel
- High reliability
- Very safe

ATN systems proven in public service have capacities ranging from 2,000 to 10,000 passengers per hour per direction (pphpd) and maximum speeds ranging from 25 to 43 miles per hour. Higher capacities and speeds up to 20,000 pphpd and 60 mph are under development now that the American Society of Civil Engineers has agreed to adapt their Automated People Mover Standards to better apply to ATN systems. The maximum speed assumed in this study is 40 mph while the maximum capacity assumed is 5,000 pphpd.

TABLE 1. COMPARISON BETWEEN TRANSIT, CAR AND PRT (Source: PRT Consulting)

Attribute	Transit		Car		PRT	
Technology Level	Mature	✓	Mature	✓	Emerging	●
Total Trip Time	Poor	✗	Depends on traffic	●	Acceptable	●
Operating Cost/Passenger	Poor	✗	Poor	✗	Acceptable	●
Infrastructure Capital Cost/Passenger	Poor	✗	Poor	✗	Acceptable	●
Accident Potential and Cost Savings	Acceptable	●	Poor	✗	Good	✓
On-Demand 24/7	No	✗	Yes	✓	Feasible	✓
Transfers	Yes	✗	No	✓	No	✓
Seated Travel	Yes, with limits	●	Yes	✓	Yes	✓
Private	No	✗	Yes	✓	Yes	✓
Non-Stop Travel	No	✗	No	✗	Yes	✓
Short waiting time	No	✗	Yes	✓	Less than 1 min	✓
ADA Compliant	Acceptable	●	No	✗	Yes	✓
Safe and Secure	Acceptable	●	No	✗	Yes	✓
User Friendly	Acceptable	●	Acceptable	●	Yes	✓
Snow & Ice	Varies	●	Poor	✗	Mostly	●
Minimal Walking	Not Often	✗	Yes	✓	Mostly	●
Environmentally Friendly	Somewhat	●	No	✗	Yes	✓
Energy Efficient	Somewhat	●	Somewhat	●	Yes	✓
Visually Appealing	Acceptable	●	Acceptable	●	Acceptable	●
Operates inside buildings	No	✗	No	✗	Possible	●

Legend: Poor ✗ **Acceptable** ● **Good** ✓

SOLUTIONS PROVEN IN PUBLIC SERVICE

The Ultra PRT System

The Ultra system is rubber-tired, battery-powered, and runs on an open guideway. The front wheels are steerable, and the vehicle keeps itself on the guideway without any physical lateral guidance (using lasers), simplifying switching, which is accomplished by steering. This system has been in operation at London's Heathrow International Airport since April 2011. The commitment to using off-the-shelf technology, wherever possible, coupled with a rigorous testing and development program, has allowed the Ultra system to be the first modern PRT system to win a commercial contract. Heathrow Airport has expressed its satisfaction with the system by including significant expansion in its budget. However, it is understood that construction of a new runway may obliterate the existing system and alter the plans for expansion.

Figure 2. Ultra PRT Vehicle on Elevated Guideway

The Ultra vehicle was designed for four adults, plus luggage. However, Heathrow has opted to replace the bucket seats with bench seats, allowing the vehicle to carry a family of six. Commuter versions of this vehicle are anticipated to include two jump seats allowing six adults to be accommodated.

Open guideway PRT, such as that used by Ultra and 2getthere, tends to be more economical, but the rubber/guideway interface can be problematic during inclement weather conditions. Ultra has plans to address this issue, by using a glass fiber reinforced plastic grating as the riding surface. Preliminary testing by PRT Consulting in the winters of 2006 and 2007 has shown this solution to be very successful in mitigating the effects of Colorado snowfall.

Ultra PRT Ltd. is under new ownership that is aggressively marketing the system in Asia. They are reducing costs by implementing vehicle manufacture in India and other means. They are also developing a next-generation control system to allow higher speeds and shorter headways intended to increase capacity while reducing costs.

Figure 3. 2getthere's Third-Generation GRT Vehicle

The 2getthere GRT System

2getthere, a Dutch company, has been operating an automated GRT-like shuttle bus system, in cooperation with Frog Navigation Systems in Rotterdam, Holland, since 1999. They are delivering their second GRT system using third-generation vehicles in Dubai in the United Arab Emirates. This system will have 25 vehicles and a capacity up to 5,000 pphpd. A third system is being delivered to Brussels Airport. The vehicles are capable of speeds up to 37 mph. Operation in mixed traffic is possible with top speeds up to about 30 mph.

Figure 4. 2getthere PRT Vehicles in Station

The 2getthere PRT System

2getthere's true PRT system was the first of its kind when it went into operation in Masdar City in the United Arab Emirates in November 2010.

2gethere's PRT system is of the open guideway type, with somewhat similar attributes to those of the Ultra system.

The Vectus PRT System

Vectus is a subsidiary of POSCO, one of the world's largest steel manufacturers. Despite being a British company owned and operated by Koreans, Vectus chose to establish a full-size test track, with an off-line station, in Sweden to prove operability in winter weather conditions and to meet the rigorous Swedish safety requirements. They have now accomplished both goals and moved on to implement a system in South Korea.

Figure 5. Vectus PRT Vehicles in Station

The Vectus system is of the captive-bogey type, where the undercarriage, or bogey, is not steerable, but has wheels which run along vertical side elements, thus, keeping the vehicle on the guideway. Switching is accomplished by movable wheels mounted on the vehicle. The test track vehicles were propelled (and braked) by linear induction motors mounted in the guideway. Mounting the motors in the guideway reduces the weight of the vehicles but increases the cost of the guideway. This is advantageous for high-capacity systems, but expensive for low-capacity systems. Their first application in Suncheon Bay, South Korea, uses conventional rotary motors which obtain wayside (third rail) power. Propulsion batteries are not required, allowing the vehicles to be lighter in weight.

The Vectus Vehicle is designed to carry four or six seated adults, plus their luggage. In an urban transportation mode, the vehicle can also accommodate up to six standees.

The Modutram ATN System

While not yet in public service, the Modutram system has been included here because of the extensiveness of its test track and demonstration program. A public project is understood to be imminent.

Figure 6. Modutram PRT Vehicles Leaving Station

Modutram, is being developed as a university effort with considerable funding from the Mexican government. This system is comprised of rubber-tired vehicles operating on a steel track. The vehicles have electric motors that are battery-powered.

The Modutram system has been designed specifically for the Mexican climate and is not initially intended to be capable of operating satisfactorily in snow and ice conditions. Development has progressed fairly smoothly from the initial design through a small test track to a larger test track with two stations and, more recently, a demonstration system that carries passengers in six-passenger vehicles.

Modutram appears well suited for urban operations. The system is designed for speeds up to 40 mph with minimum headways of 3 to 4 seconds. Vehicles can be physically coupled together to increase capacity.

SOLUTIONS NOT YET PROVEN IN PUBLIC SERVICE

Numerous ATN systems are in various stages of development ranging from being mere concepts to having engineering design completed and prototype systems in various stages of development. Some of the better-known names include JPods, Metrino, Futran (Milotek), PRT International, skyTran, Swift ATN and Transit X. Taxi 2000 recently closed its doors after decades of being unable to fund a full-scale test track demonstrating full functionality, the same hurdle that is holding many of the previously-mentioned systems from emerging onto the market.

Some of these emerging suppliers make aggressive claims regarding the costs and capabilities of their systems. These claims have typically not been proven in practice and have therefore been ignored in this study. Should high speeds and capacities become viable at very low costs, this will further enhance the feasibility of the solutions discussed here.

More information on ATN can be found here: www.prtconsulting.com and here: www.advancedtransit.org

CONCEPTUAL ATN LAYOUT

A conceptual layout (Figures 7 and 8) has been developed for purposes of comparison with the Scenario B rail project. Like the rail project, it extends along the Santa Cruz Branch Rail Line right-of-way from the Westside of Santa Cruz to Pajaro Station near Watsonville. Unlike the rail project, portions of the alignment (mostly those through developed areas) are one-way with return one-way guideways located in the adjacent communities, mostly along the Soquel Avenue/Drive BRT routes. These return guideways are elevated to facilitate retrofitting into existing road rights-of-way. Portions of the alignment within the rail right-of-way are also elevated to avoid at-grade crossings with other traffic (a key factor contributing to ATN safety and reliability).

Figure 7. Conceptual ATN Layout Santa Cruz to Aptos

Note that the routing and station locations shown are in no way intended to be final. The southern portion of the route could serve Freedom Blvd. (equivalent to BRT Lite in the UCS) or Highway 1. It could do so as a two-way line or it could be in the form of a one-way loop. In the latter case it would provide service/stations along two of the three routes (the rail corridor, Freedom Blvd. and Highway 1). It would also be possible to extend the system to UCSC and/or other destinations. If a goal is to improve circulation within Santa Cruz (for example), more guideway could be added, including additional north-south connectors with new stations between the loops shown.

ATN has almost infinite capability to be scaled up or down. It would be possible to start with a simple two-station demonstration shuttle system and to scale up from there in phases. As new routes and stations are added, the new stations will be accessible from the old with no transfers being necessary. The portion of the system from Santa Cruz to Aptos is likely to be very viable as a stand-alone system that could cover its own operating costs and most, if not all, of its capital costs through fare-box revenue.

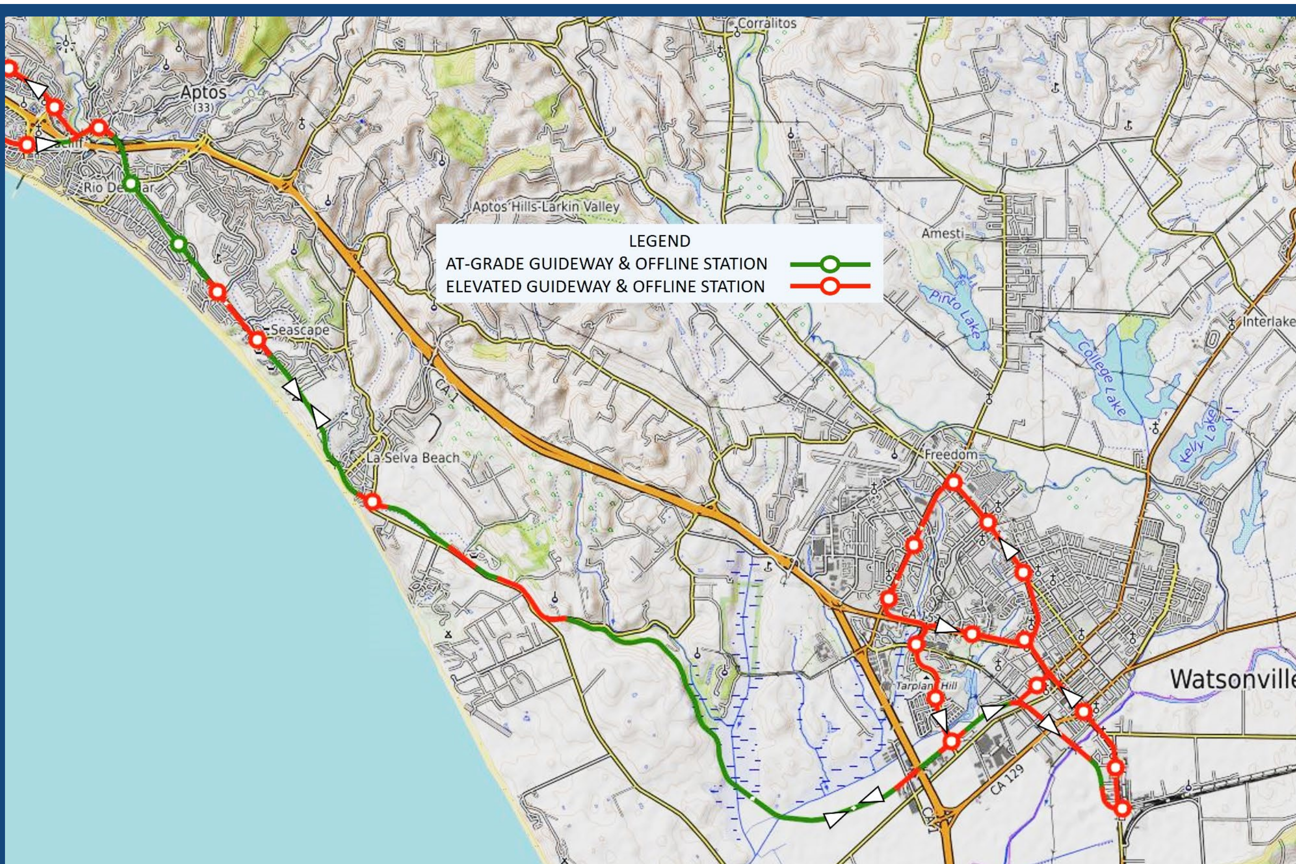

Figure 8. Conceptual ATN Layout Aptos to Watsonville

TABLE 2. CONCEPTUAL ATN LAYOUT CHARACTERISTICS

Feature	Quantity
At-Grade Track Length (miles)	20
At-Grade Stations	5
Elevated Track Length (miles)	38
Elevated Stations	52
Average Speed (mph)	39
Trip Time Santa Cruz to Watsonville (mins)	30

The ability of ATN to achieve a 39-mph average speed with a 40-mph maximum speed derives from the fact that all stations are offline, requiring no slowing of through vehicles. Note that slowing for horizontal alignment characteristics (tight curves – of which there are few) has been accounted for.

A single at-grade ATN track only requires about seven feet of right-of-way. The ATN may thus be able to co-exist with the existing rail line allowing for freight operations. However, the assumption has been made here that the rail track will be removed, and those costs have been accounted for.

CONCEPTUAL ATN ALTERNATIVE ANALYSIS – 2035 FORECASTS

This section provides a conceptual analysis of the ATN alternative with particular reference to passenger rail and bus rapid transit as envisioned for Scenario B (understood to presently be preferred by some community groups).

SAFETY

Automated guideway transit is held to a far higher standard of safety (American Society of Civil Engineers Automated People Movers Standards) than any other mode of surface transportation. ATN operates on exclusive guideways separated from pedestrians and traffic. There are no crossings, only merges and diverges. The results speak for themselves – over 200 million injury-free passenger miles. Couple this with the fact that ATN's higher level of service attracts more passengers than any other transit mode and it is clear that ATN will significantly increase safety over any other solution.

RELIABILITY AND EFFICIENCY

ATN systems for which data is publicly available (Heathrow Airport and Masdar City) are operating at availabilities more than 99.5%. This is five times more reliable than transit level of service A (97.5%).

Peak Period Mean Auto Travel Time

While an analysis of the impacts of ATN on auto travel time has not been undertaken, the significantly higher mode share with ATN (see below) will result in fewer autos on the road than with other transit modes and thus should have a greater positive impact on congestion and travel speeds.

Peak Period Mean Transit Travel Time

Referring to UCS Table 17, the ATN average travel time of 30 minutes between Downtown Watsonville and Downtown Santa Cruz is better than the average AM and PM peak period auto times of 52 and 60 minutes respectively. Referring to UCS Table 35, Scenario B, it is also better than the best bus time of 53.6 minutes and the passenger rail time of 41.0 minutes and considerably better than the worst bus time of 83.7 minutes.

Travel Time Reliability

ATN systems are designed to avoid traffic jams. Overcrowding results in people waiting a bit longer in stations which encourages ridesharing and thus boosts capacity at the time it is most needed. Trip times are always the same between any two stations with the small exception that some passengers may have a small detour or an intermediate stop or two if they have agreed to rideshare. Even these passengers will be able to count on very little daily variability in trip and waiting times.

Mode Share

The mode share for ATN has been based on the transit mode share for Scenario B adjusted to account for changes in waiting and travel times as well as revenue miles. The transit mode share for Scenario B includes 7,396 rail boardings per day (10/16/18 UCS FAQ) and an unstated number of bus boardings per day. Based on boardings reported by the Santa Cruz Metropolitan Transit District, Route 91X, the Santa Cruz/Watsonville Express has 704 daily boardings and Route 71, Santa Cruz to Watsonville has 1,920 daily boardings.

The following discussion explains how bus daily ridership and ATN daily and peak period ridership were estimated for Scenario B from this information.

The analysis was based on work done by Liu[3] and uses a Logit Model to estimate changes in mode share based on modal preferences and changes in trip times. Mode preference is the extra time a person would spend to use their preferred mode. For example, people have been shown to be willing to take a 25-minute longer trip by car rather than catch a bus. Public stated-preference surveys by PRT Consulting have shown ATN mode preference over bus to be higher than auto but, to be conservative, it has been assumed to be the average of auto (25 minutes) and rail (10 minutes). Transit wait times have been assumed to be the square root of peak headway as per UCS Table 11. Since the number of bus stops varies, the first and last mile times for all systems have both been assumed to be five minutes. The BRT times have been averaged into one time. The average fare per trip was assumed to be the same for all modes ($5.50 per trip) and was therefore not a factor.

The Logit Model can predict the increase or decrease in ridership of a given mode based on the known ridership and any changes in service level (headways, first- and last-mile times and travel times). With the addition of modal preference values, it can be used to predict the ridership if one mode is replaced with another.

First, the Logit Model was used to estimate the BRT boardings in Scenario B. To do this, the model calculated the number of BRT boardings that would result if passenger rail, which produced 7,396 boardings, was paralleled with BRT service running a mile or so away through roughly similar neighborhoods. The characteristics of the rail and BRT service used in the model are shown in Table 3. The result was 1,479 BRT trips. This seemed low relative to the existing boardings and the BRT boardings were increased by 30% to 1,920 (the same as Route 71) to be conservative.

Next, the model was run in the same manner using the factors in Table 3 to predict the number of ATN boardings that would result if the rail system was replaced by an ATN system (22,800) and, secondly, if the BRT system was replaced with an ATN system (28,100). These results total 50,900 ATN boardings.

Table 3 shows the assumptions for each mode and the resulting ATN trips.

TABLE 3. RIDERSHIP ASSUMPTIONS AND RESULTS (SCENARIO B)

Mode	Headway	Wait Time	First + Last Mile	Travel Time	Mode Preference	Boardings
Passenger Rail	30	5.5	10	41.0	10	7,396
BRT (estimated average)	15	3.9	10	70.5	0	1,920
ATN	1	1.0	10	30.0	17.5	**50,900**

[3] Liu, R et al (1997), "Assessment of Intermodal Transfer Penalties Using Stated Preference Data", Transportation Research Record 1607 pp 74-80

To test the accuracy of the Logit Model, it was used (in a previous project) to predict the bus ridership on the Red Route in Clemson, South Carolina, based on the actual automobile ridership and the differences in trip characteristics between the auto and bus trips. The model was run twice with slightly different factors each time. It predicted an average bus ridership of 3,459 which was 4% higher than the actual bus ridership of 3,239.

To compare the Logit Model to the model used in the UCS, it was used to predict the ridership on BRT in the rail corridor based on the rail ridership and the difference between the rail and BRT characteristics. The characteristics used are shown in Table 4 below. The first/last mile times used reflect the fact that the BRT has twice the number of stations as the passenger rail.

TABLE 4. RIDERSHIP ASSUMPTIONS AND RESULTS (RAIL & BRT IN RAIL CORRIDOR)

Mode	Headway	Wait Time	First + Last Mile	Travel Time	Mode Preference	Boardings
Scenario B Rail	30	5.5	15	41.0	10	7,396
Scenario C BRT	15	3.9	7.5	65.1	0	**3,698**

The 3,698 predicted BRT trips are 251 (6%) less than the 3,949 predicted by the UCS (10/16/18 FAQ).

The results in Table 3 above are consistent with those of other investigators around the world as illustrated in Figure 9, which is based on studies undertaken in the named cities using a variety of methodologies.

Part of the reason the ATN system does so well is that it covers both the rail and the Soquel BRT routes and would undoubtedly also pick up traffic from the local bus routes (a factor not accounted for above). This is largely because, unlike BRT, ATN combines high average speeds with numerous stations. Note that savings in local bus operating costs have not been accounted for here.

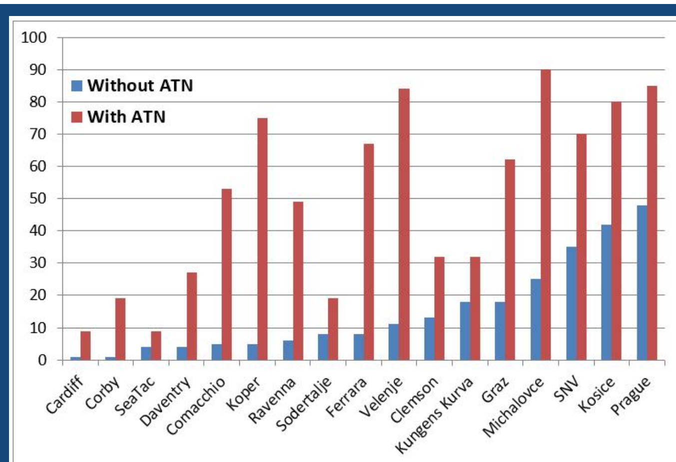

Figure 9. Transit Mode Share With and Without ATN

The 50,900 daily ATN boardings result in about 3,000 ATN pphpd in the peak hour (assuming 10% of trips are in the peak hour and a 60/40 directional split), which is less than the previously-selected maximum line capacity for this project of 5,000. The projected ATN boardings are not out of line with the 13,900 average daily boardings reported in 2010 for the Morgantown PRT system which only has five stations[4].

To estimate countywide mode share, it was anticipated that bus ridership for UCSC and Highway 17 will exceed the current level of at least 11,000 daily trips[5], for a countywide total of at least 61,900 daily

[4] PRT Facilities Master Plan, West Virginia University, by Gannett Fleming, Lea+Elliott, Olszak, June 2010
[5] Santa Cruz Metro, Comprehensive Operational Analysis, January 2016

transit trips. Therefore, assuming a total of 947,700 daily trips for all modes (10/16/18 UCS FAQ) the countywide transit mode share with ATN is likely 6.53% or better, exceeding the anticipated result for Scenario B.

Despite the comparisons and justifications, some will doubt the ability of high-quality transit with reliable express, on-demand service, numerous stations and short waiting times to attract riders. **The ATN boardings have therefore been reduced 25% in the following analyses. This results in a daily ATN ridership of 38,800.**

ECONOMIC VITALITY

Public Investment

The UCS revenue analysis appears to ignore fare-box revenues. This analysis assumes fare-box revenues at the average rate of $5.50 per boarding. In addition, to obtain a true comparison of the total cost of each system, the operating costs and fare-box revenues are estimated over a life of 30 years, assuming the 2035 ridership represents the average ridership. The daily boardings have been multiplied by 300 to determine annual boardings. The daily boardings are for weekday ridership and the 300 multiplier is used in place of 365 to account for lower ridership on weekends and holidays.

TABLE 5. TOTAL COST COMPARISON (SCENARIO B)
(All figures in thousands of year 2018 dollars, except subsidy per ride in 2018 dollars)

Mode	Capital Cost ($000)	O&M Costs Over 30 Years ($000)	Fare-Box Revenue Over 30 Years ($000)	Total Net Cost Over 30 Years ($000)	Subsidy Per Ride ($)
Soquel/Freedom BRT + bus-on-shoulder (1,920 daily boardings)	$44,863	$534,000	-$95,040	$483,823	$28.00?[6]
Rail (7,396 daily boardings)	$339,800	$420,000	-$366,100	$393,700	$5.91
Scenario B Total	**$384,663**	**$954,000**	**-$446,142**	**$877,521**	**$10.47**
ATN (38,800 daily boardings)	**$1,403,500**	**$1,158,000**	**-$1,920,600**	**$640,900**	**$1.84**

Even though table 5 shows that the ATN solution is considerably more expensive, it attracts far more passengers and thus has higher fare-box revenues. The ATN system more than covers its own operating costs through fare-box revenues (almost unheard of for US transit systems). In order to also cover the capital costs over 30 years (neglecting interest), the subsidy per ride for ATN is only $1.84. Even if the ATN ridership estimate is halved, the capital costs would be reduced (since fewer vehicles are needed). The operating cost would be approximately halved, and the required a subsidy would be $5.42 per ride,

[6] Ridership based on Table 3 assumptions. The UCS estimated BRT ridership is unknown.

about half of Santa Cruz Metro's current subsidy (for operating costs only) for intercity routes. On the other hand, as ATN ridership increases, the required subsidy decreases.

Note that it has proven impossible to ascertain the extent, if any, of BRT costs not included in the UCS Study. The study seems to imply that the costs shown are additional to existing service, which will continue, but does not provide the cost of the continuing service. Also, it is unclear whether the projected fare-box revenue has been deducted from the annual O&M costs in the study or not (Table 4 assumes not).

An analysis of the potential amount of funding from known federal, state, and local revenue sources for ATN is not included here. Even though the ATN solution has the potential to fund itself (should the contingency allowances not be required), it is eligible for FTA funding in competition with other fixed-guideway modes as evidenced by the continuing federal grants being awarded to the Morgantown PRT System.

It is likely that an ATN system can be acquired under a design/build/finance/operate/maintain/transfer procurement model requiring little to no upfront funding. The supplier team would finance the project and receive payments over time in return for ensuring the system is available for public use meeting predetermined criteria. Technical and business failure risks would be protected by performance and payment bonds ensuring all debts will be paid and the system will be removed if it fails to work.

Visitor Tax Revenues and Other Economic Impacts

While no analysis is included here, the increased transit use, shorter trip times and reduced congestion should result in increased visitor tax revenues and positive economic impacts.

Costs Associated with Collisions

Motor vehicle collisions and associated costs should reduce approximately in proportion to the increase in transit mode share.

ENVIRONMENT AND HEALTH

Automobile Vehicle Miles Traveled

If we assume the average transit trip length is 5.9 miles (UCS Page 119), we find that ATN increases the daily transit person trip miles by approximately 245,000. Assuming an average automobile occupancy of 1.29 (UCS Table16) and disregarding any induced automobile travel demand, this would reduce daily automobile vehicle miles traveled by approximately 190,000. This is about twice the anticipated VMT reduction for Scenario B.

Environmentally Sensitive Areas

While no analysis has been undertaken, ATN has a smaller footprint (seven feet wide for one-way track at grade) than any other transit mode. In addition, the lightweight vehicles produce almost no noise, vibrations, emissions or electro-magnetic interference. Accommodating a trail next to the ATN system will be relatively easy compared to train or bus, especially since the ATN guideway can be elevated the entire way or just in tight situations.

Greenhouse Gas and Criteria Pollutants

ATN vehicles themselves do not emit greenhouse gases, and in general ATN systems consume about one third of the energy per passenger mile of other transit systems. ATN guideways are well-suited to support solar panels (costs not considered here) which may be sufficient to meet the needs for motive power. Even if the system lacks solar panels, it would likely be powered with carbon-free electricity from Monterey Bay Community Power. Battery-powered vehicles could facilitate energy storage. Reduction in automobile vehicle miles traveled and congestion should have significant positive impacts on emissions.

EQUITABLE ACCESS

Transit Vehicle Miles Traveled

Unlike most other transit modes, ATN vehicles do not have to travel to the end of the line or even the end of a scheduled route before turning around. Furthermore, they do not need to move to provide availability when there is no demand. This means there is less relatively empty vehicle movement. It also makes it more complicated to determine vehicle miles traveled without a detailed station-to-station trip demand matrix. Nonetheless, the ATN vehicle miles traveled have been estimated at 43.8 million miles per year. This is 6.5 times higher than the 6.65 million shown in UCS Figure 41.

Household Transportation Cost

Since "How much a household spends on transportation depends primarily on the number of automobiles in the household" (UCS Page 130), it is clear that the increased transit mode share with ATN will do more to reduce household transportation costs than any other alternative.

The community may wish to implement a tiered fare structure to encourage ride sharing and give passengers more control over their transit spending. For example:

- Tier one passengers pay per vehicle. They get a vehicle dedicated to them and their party (one to six). They wait less than a minute and travel nonstop to their destination.
- Tier two passengers pay per ride. They must be willing to wait up to (say) five minutes for others to arrive who are on the same route and can share the ride. They may have to make an intermediate stop or two.
- Tier three passengers pay a very low fare per ride and must be willing to wait longer (up to 20 or 30 minutes) for their ride.

This fairly unique ability to match the level of service to the fare paid promotes equitable access and mobility for all. An animation of an ATN station configured to accommodate this type of operation may be viewed here: https://www.youtube.com/watch?v=dXyBJ_nyh4M&

SUMMARY AND CONCLUSIONS

ATN systems are commercially available from a number of suppliers. They have been in continuous public service since 1975 (1999 for commercially-available systems). This conceptual study has found a six-passenger ATN system to be superior to the UCS Scenario B combination of passenger rail and BRT. It is believed that consideration of a 24-passenger GRT system would probably also find superior results.

This analysis has not been undertaken to the same depth as the UCS analysis. However, the level of accuracy is adequate to demonstrate that ATN will be a far superior solution that is worthy of further consideration. The operating characteristics have been proven in public service. The costs have been derived by experienced suppliers from projects that have been implemented. Even if the ridership estimate is halved, the ATN system will still cover its operating costs with fare-box revenues and it will only require a subsidy of $5.42 per ride to also cover its capital costs. This is far lower than any other alternative.

The thirteen key criteria in the UCS study have each been addressed. ATN has been found to be superior to Scenario B for each criterion. There appears to be no credible argument to exclude ATN from consideration.

APENDIX A – PROJECT DESCRIPTION AND COST ESTIMATES

The ATN project description and cost estimates are provided below. This project has been evaluated at a conceptual level and a contingency of 50% has been used. Costs are based mostly on fixed bid prices in South Carolina in 2016 adjusted to reflect this project's size and location.

"Annual Operations and Maintenance" includes costs for new ATN service, vehicle operations and maintenance as well as facility maintenance. Maintenance costs include replacement of worn parts up to and including vehicle replacement as necessary.

Project	Table A-1: ATN System
Limits	Natural Bridges Drive in Santa Cruz to Pajaro Station near Watsonville. The route from Aptos to Cabrillo Highway near Watsonville consists of two-way track along the Santa Cruz Branch Rail Line right-of-way, mostly at-grade. The remainder of the route is mostly elevated and consists of one-way track along the Santa Cruz Branch Rail Line right-of-way forming interconnected loops with one-way track along Mission Street, Lincoln Street, Soquel Avenue/Drive, 17th Avenue, Capitola Road, Clares Street and Wharf Road in Santa Cruz and along Salinas Road, Porter Drive, Main Street, Freedom Boulevard, South Green Valley Road and Ohlone Parkway in Watsonville. See Figures 7 and 8 for maps of the layout showing proposed station locations. It should be noted that the guideway routing and station locations shown are conceptual. They are intended for use in this conceptual analysis only. Determining preferred routing and locations requires extensive public input.
Description	On-demand passenger service provided by driverless small (six-passenger) vehicles traveling along exclusive guideways and serving offline stations. Guideways and stations may be elevated or at-grade. This analysis is based on six-passenger battery-powered vehicles such as offered by Ultra or Modutram (and possibly 2getthere if they can accommodate six passengers).
Scope	Connect 57 stations with 58.3 miles of one-way track. Provide 20 hours of service 365 days a year with an average wait time less than three minutes at any station and average speeds exceeding 35 mph.

CAPITAL COSTS	
Track Removal	$5,400,000
Guideway & Control System	$609,500,000
Stations/Maintenance Facility	$114,000,000
Vehicles (480)	$50,800,000
Soft Costs (30%)	$234,000,000
Contingency (50%)	$389,800,000
Total Capital Costs	$1,403,500,000
OPERATIONS AND MAINTENANCE COSTS	
	Annual O&M Cost
ATN service 20 hours a day for 365 days a year	$25,700,000
Contingency (50%)	$12,900,000
Total Annual O&M Costs	$38,600,000