WHITE PAPER 2011-02

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Organization before Electronics before Concrete
and Supporting "Networked Transit" Principles

1. Overview

Ever since the U.S. first landed on the Moon in 1969, a popular parlor game has been: "We put a man on the moon, so why can't we easily solve _____?" Fill in the blank.

The "moonshot analogy" is faulty because "down to earth" problems are very complex and intractable compared to moon travel. Cultural and social problems present rapidly growing, idiosyncratic complexities as more humans become involved. But with Apollo, brute force (e.g., $98 billion in 2008 dollars and 100,000+ scientists) was easy, and the technical performance needed was simple to predict.[1]

Figure 1. This is Easy Compared to Public Transit

The moonshot analogy also leads to the belief that simply applying new, allegedly "revolutionary" technology to difficult transportation problems necessarily leads to easy solutions. This sort of thinking is exemplified by "personal rapid transit" (PRT)[2] enthusiasts, whose efforts so far–*over 50+ years*–has produced only *three* significant PRT systems that have achieved revenue service open to the public: a costly PRT network in Morgantown, West Virginia, a 1.2 mile, $47 million low capacity parking lot shuttle at Heathrow International Airport Terminal 5 that replaced a $500,000/2-vehicle shuttle bus route, and a short PRT parking lot shuttle in Masdar City, Abu Dhabi.[3]

Many tech boosters believe that smart phones, with built-in mapping and other apps, lead inexorably to "revolutionary transit." In most versions, this is enhanced taxi-sharing automatically dispatched by smartphone software.[4] But fixed routes running on "clock-face"

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1. For an insightful comparison of the Apollo Program with the Manhattan Project and U.S energy research and development, see www.fas.org/sgp/crs/misc/RL34645.pdf.

2. See http://en.wikipedia.org/wiki/Personal_rapid_transit

3. See http://en.wikipedia.org/wiki/Morgantown_Personal_Rapid_Transit, http://en.wikipedia.org/wiki/ULTra_%28rapid_transit%29#Heathrow_Terminal_5, and www.youtube.com/watch?v=PB_5TBZQNRY.

4. This video, http://vimeo.com/25688970 pontificates about converting fixed routes to taxi-sharing, which actually would be more applicable to better service for seniors and persons with disabilities while lowering paratransit costs.

headways at the same times past the hour are simple and easy to remember compared to digging through a complex smartphone app *every time* one checks to see when a bus or train will arrive, or ordering up a taxi.[5]

The dynamics of bureaucracy, the natural political affinity for "pork-barreling," and desires of consultants and contractors for maximum billings too often leads to astronomically expensive mega-projects that actually do little to solve transportation problems. Amtrak has proposed a 25-30 year project to upgrade the Washington, D.C.-New York City-Boston Northeast Corridor to 220 mph high speed rail (HSR), with a goal of 3-hour travel times between Washington, D.C. and Boston. The scope of this project is similar to Apollo at $117 billion. This HSR proposal includes a 10-mile, $10 billion tunnel segment through Central Philadelphia connecting to a new underground station complex directly adjacent to the Southeast Pennsylvania Transportation Authority's (SEPTA) Market East underground 4-track station, which is currently at about 25% of its capacity.[6]

However, at least two well-informed if outspoken transportation bloggers have argued[7] for cooperation between Amtrak and the Southeast Pennsylvania Transportation Authority (SEPTA) so Amtrak intercity trains could use the *existing* SEPTA regional rail station at Market East–or upgrades to the existing Amtrak route through central Philadelphia–would be far more cost-effective and efficient than Amtrak's current $10 billion tunnel proposal.

Relations between Amtrak and SEPTA aren't exactly cozy, and the SEPTA bureaucracy is rather insular, highly entrenched and set in its ways, generally unable and unwilling to implement new ideas or improve relations with other transportation providers, such as Amtrak. Even "bribing" bureaucracies such as SEPTA with new revenues in exchange for cooperation would be more efficient than the $10 billion tunnel. One blog commenter also points out:

> *Good philosophy, but really, do *not* underestimate the difficulty of changing institutional culture. A lot of techies underestimate it by many, many orders of magnitude.*
>
> *It often requires shutting an organization down completely.[8]*

But it is also certain that U.S. taxpayers no longer can afford "solutions" that are not cost-effectively designed and optimized to meet real transportation needs, versus meeting the cultural and ego-driven "needs" of archaically organized bureaucracies, or costly, ineffective monuments to outsized political egos, or projects meant to maximize billings for consultants and contractors. In contrast with too typical U.S. practice, Germany's national railway, Deutsch Bahn (DB), and the most efficient and effective German operators (and virtually *every* Swiss network), follow a simple, vital principle:

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5. See http://pedestrianobservations.wordpress.com/2011/08/17/why-smartphones-effect-on-transit-is-overrated/ and http://www.humantransit.org/2011/07/los-angeles-gensler-architects-attack-citys-transit-future.html.

6. Summary at http://www.amtrak.com/servlet/ContentServer/Page/1248542787937/1237405732517

7. See http://pedestrianobservations.wordpress.com/2011/05/20/philadelphia-link-or-organization-before-concrete/ and http://philadelphia2050.blogspot.com/2011/05/what-should-high-speed-rail-look-like.html.

8. From reader comment No. 3, http://pedestrianobservations.wordpress.com/2011/05/20/philadelphia-link-or-organization-before-concrete/,.

Organisation vor Elektronik vor Beton[9]

That is:

Organization before Electronics before Concrete

Current U.S. politics makes it immensely difficult for transit managers and decision-makers to successfully implement this key Teutonic principle. However, Publictransit.us believes that such efforts are well worth it however frustrating the process may be. This appears to be the only way to successful efficient and effective U.S. transit. Taxpayers also deserve and increasingly demand it.

2. Supporting Principles: "Networked Transit"

A key aspect of proper organization is implementing a practical, successful transit network design philosophy. As with *Organization before Electronics before Concrete,* German, Swiss and a few other international examples provide practical examples and philosophy for the U.S., which Publictransit.us calls "Networked Transit." We have distilled from several academic papers and other sources the fundamental premises of Networked Transit. These are:

  a. Transit networks must be as simple, consistent and understandable as possible, and

  b. Accepting and understanding that coordinated connections are essential due to widely dispersed home, work and other travel patterns, with the realization that 'one seat rides' are feasible only for the largest destinations such as downtowns, universities, large medical centers, et al.

  c. In many cases, many if not most passengers must transfer. Therefore transfer points must be well-designed with very short distances between modes, convenient, comfortable and safe.

  d. Well-designed networks with coordinated timetables lead to a number of key transit planning practices[10] supporting Networked Transit. These are:

  1. Design the network to be simple and direct

  2. Implement a hierarchy of lines/services within the total network

  3. Provide consistent, fast and reliable service

  4. Maximize coordinated, convenient connections and inter-operator coordination

  5. Provide clear, consistent and complete information and marketing

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9. http://www.zukunft-suedostbayern.info/2010/02/bahnknoten-munchen-organisation-vor-elektronik-vor-beton/

10, Adapted from *The Principles of Public Transport Network Planning: A review of the emerging literature with select examples.* March 2011. Dodson, Jago; Mees, Paul; Stone, John; Burke, Matthew. Urban Research Program, Issue Paper 15. Griffith University (Brisbane region, Australia). Available at http://www.griffith.edu.au/environment-planning-architecture/urban-research-program/publications Though written in dense and wordy Australian academic-speak, this paper is the best, most concise summary of "Networked Transit" we have found in the English language.

e. Within transit systems, every network link regardless of type of mode, must smoothly connect in terms of both transfers and fare policies. In regions with multiple transit operators, schedules and fares must be coordinated and well-integrated. Transferring should not be penalized.

f. Transit managers and decision-makers for every transit system need to clearly understand local social and political values. In practice this means making tradeoffs between "general purpose" transit designed to meet patronage and productivity" goals, and "lifeline" services designed to meet the specific needs of those who cannot drive–usually the frail elderly and persons with disabilities. Asking community members to specifically indicate their preference for "productivity vs. lifeline" service–stated as a percentage of the operating budget dedicated for each type of service–is very effective and helpful to transit managers and decision-makers.[11]

The above listed "Best Practices" for implementing Networked Transit are discussed in Appendix A. Appendix B discusses how different transit modes relate to transit goals and their suitability relative to urban and rural area size. Appendix C discusses the relationship between transit patronage and level of service, and as a tool for transit network planning.

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11. For a detailed explanation of this tradeoff process, see *Purpose Driven Public Transport:creating a clear conversation about public transport goals*. Jarrett Walker. 2008. www.thredbo-conference-series.org/.../thredbo10-themeA-Walker.pdf

Appendix A. Networked Transit "Best Practices"[12]

1. Design the network to be simple and direct

It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience. -Albert Einstein

e.g.,: *Keep it simple, st------, but not simpler than required. (*The Amended KISS Principle)

Generally, transit networks should be designed on the "one segment, one line" principle, e.g. with duplication only where absolutely needed. Transit lines should follow paths that are simple, direct and easily remembered by patrons. Direct routes are also faster and shorter than "coverage" lines that wander all over a community. Such "coverage" routes are not precluded in a transit network, particularly to meet specific needs of seniors, persons with disabilities and others who need door-to-door services. But such routes will generally have low patronage and productivity.

Deviations on most fixed lines should be limited to the largest destinations, since fast and direct routes will attract more riders since, for a given amount of subsidies available, more frequent service can be provided and service is faster. For major trunklines, reduced coverage should be mitigated by separate feeder lines or services. In low demand areas, some feeder services may be "2nd tier" as explained in the next section, e.g., indirect "community" fixed routes designed to maximize coverage, flex routes and demand-responsive services.

2. Implement a hierarchy of lines/services within the total network

Generally, the less frequent a transit line or service, the harder it is to plan and integrate connections with the rest of the transit network. With many high frequency services, one can "forget" the timetable and relatively little coordination is required. Frequent services such as rail transit and higher level bus rapid transit (BRT) do require operational planning to ensure reliability and speed, but these are generally engineering issues. In general, the highest

Figure A-1. Simple Connections & Minimal Duplication

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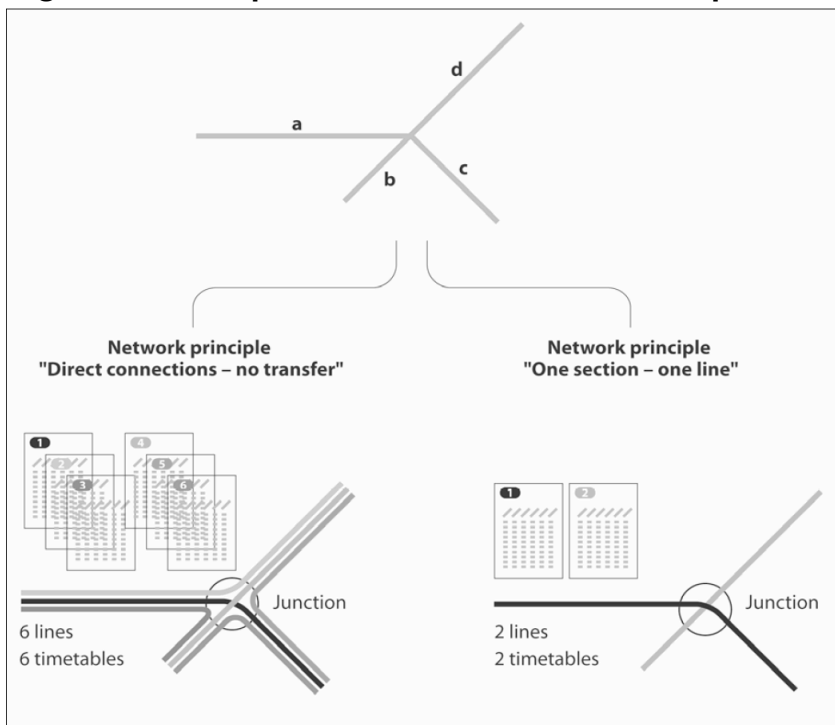
12. Adapted from *The Principles of Public Transport Network Planning: A review of the emerging literature with select examples.* See Footnote 1.

patronage lines, and most important regional services, top the "transit hierarchy."

Fast regional services often on their own rights-of-way are at the top of the transit network hierarchy. San Francisco Bay Area examples include BART, Caltrain, S.F. Muni Metro lines, the Vallejo Baylink ferries, future SMART trains in Marin/ Sonoma, and various regional express buses such as Golden Gate Transit's Route 80 along Highway 101, Vallejo Transit Routes 78 and 80 to BART in Contra Costa County, FAST Route 90 from Fairfield/ Suisun to BART, and the

Figure A-2. Timed Connections *and* Clocks

A key item often missing at U.S. transit centers, particularly for buses

embryonic VINE Route 10 regional route through the Napa Valley. Other North Bay *proto-trunk* lines include a number of Sonoma County Transit intercity routes such as Santa Rosa-Sonoma, Santa Rosa-Petaluma, Santa Rosa-Russian River, and Santa Rosa-Cloverdale.

The next tier in the transit line hierarchy are frequent service, local trunk lines such as several dozen operated by S.F. Muni and AC Transit, and to a lesser extent by Samtrans and VTA.

Most local, general purpose fixed route lines mostly in Bay Area suburbs are in the next level of the hierarchy, generally operating every 30 minutes, or in many cases, every 60 minutes. As a rule, most local lines and services operating at low frequencies, such as every 30 or 60 minutes, or even longer in rural areas, require coordinated timed connections. With low service levels, consistency, reliability and easy connectivity ensures maximum patronage.

As previously mentioned, fixed routes designed to maximize coverage, along with flex routes and demand responsive services are "2nd tier" services at the "base" of the transit patronage-based hierarchy. This doesn't mean such services aren't important, particularly for providing "lifeline" mobility, but just have the lowest patronage and overall productivity.

3. Provide consistent, fast and reliable service

In most areas, Networked Transit should ideally aim to provide travel times competitive or better than driving. In larger areas and along high demand corridors, this means right of ways insulated from auto traffic and delays at road intersections. This is typically some form of rail transit where demand is high, and often grade-separated or segregated busways. For lower volume Bus Rapid Transit (BRT) lines that cannot justify off-street busways, bus traffic priorities, well-located super-stops and other infrastructure measures are needed to maximize reliability and minimize delays.

Lines should operate <u>consistent clock headways</u> and consistently make stops with minimal deviations from the timetable. Clock headways are easy to remember compared to inconsistent times that change each hour requiring patrons to always consult timetables.

4. Maximize coordinated, convenient connections and inter-operator coordination.

Since many people need to make connections ("transfers"), this must be easy, convenient and quick. In larger areas, a significant portion of transit service will be on the "frequent service" network, generally operating every 10 minutes all day or more frequently. While planning coordination between frequent services is less complex than less frequent lines, close attention is needed for well-designed, weather protected stops at key transfer points, including adequate information. Stop design is important when waiting times are long, but less crucial with high frequencies. Good stop design helps ensure passenger safety, particularly at night and in some neighborhoods.

In most U.S. regions, relatively few lines will have frequencies of more than 15 minutes, and even those frequencies will be restricted to trunk lines. Most routes will operate on 30 and 60 minute headways. Therefore timed connections at well-designed transit centers are essential. Ideally, transit centers will be designed to minimize walking distances between various routes and services.

Pedestrian access is central to designing transit centers. Easy to understand, direct and clear pedestrian access is essential. In general, bus stops should be located as close to activity centers as possible. Simple vehicle circulation is a must, as are comfortable waiting areas with proper amenities.

Coordinated, integrated fares are essential. No one should be penalized for transferring between routes or between operators. More and more people must transfer because 21st Century travel is widely decentralized and it is economically impossible to provide direct, "one seat rides" at acceptable frequencies between the vast majority of destinations. Within transit systems, all services and all modes must be integrated in terms of both connections and fare structure.

In regions with multiple transit operators, schedules, connections and fares must be coordinated and well-integrated. Transferring should not be penalized. Increasingly, riders and the general taxpaying public–the majority who are generally *not* transit users–will tolerate nothing less.

5. Provide clear, consistent and complete information and marketing

Clear, consistent, readily available information about transit services including frequencies, fares and zone information (if any) should be provided at each bus stop. At transit centers, clear information about where each line stops is needed, as well as detailed information about the network as a whole. Major locations should provide ticket sales, from either a human or automated ticket machine. *At major facilities in the U.S., a simple but effective passenger information tool is often missing: e.g, a large, visible, easy to understand and use everyday device: a clock!*

Appendix B. The Transit Mode Spectrum

As a general rule, as the potential for transit patronage increases, increased capital investment in vehicles and fixed facilities are justified. Similarly, as a transit service area increases in population, more capital investment is generally justified, again by higher demand. Based on these principles, a matrix summarizing how and where different transit technologies and modes are justified has been prepared. A number of suitability factors are also discussed briefly in this Appendix, which are summarized in Figure B-1.

Suitability for Larger Regions. In general, the larger the region the more transit investment can be justified due to larger populations and potential ridership. As regions get larger, there are more potential travel markets where more frequent service and capital-intensive modes such as bus rapid transit and various forms of rail make sense. On the other hand, most large urban regions can support the entire spectrum of transit modes. Various forms of rail transit can effectively serve the busiest and densest travel corridors. Paratransit modes such as vans or "parataxis" meet the needs of mobility-limited persons area-wide, whether in the lowest density suburbs or densest portion of the core cities.
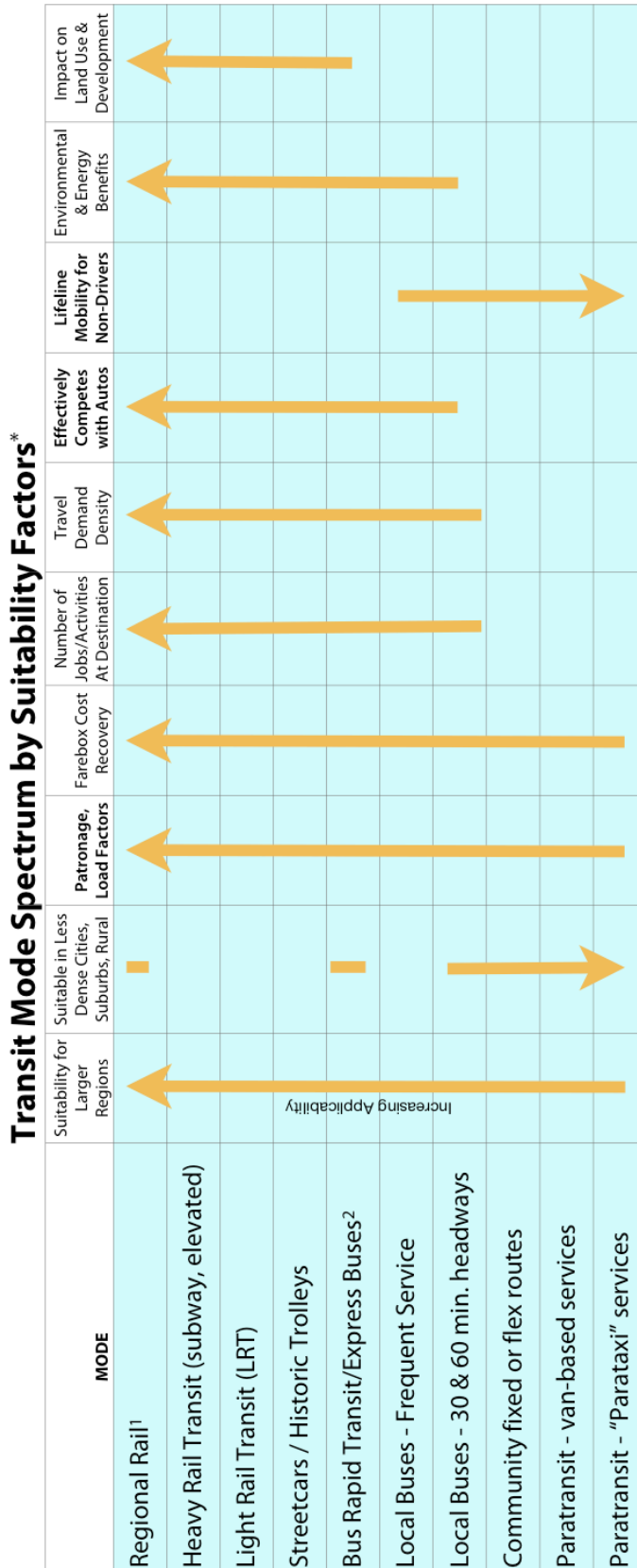
Suitability in Less Dense Cities, Suburbs and Rural Areas. In general, the most suitable modes for these areas range from local buses operating on 30-60 minute headways down to van and parataxi services. Regional rail and bus rapid transit can work in some circumstances, usually with rather large travel destinations such as a university or major employment and other activity centers in a nearby, larger urbanized area.

Patronage & Load Factors. In general, patronage and average load factor (e.g., on average, the number of people riding at any given time a vehicle is in service). For parataxis and vans, 1-2 people "on board" would be a typical load factor. Community fixed or flex-routes may carry 3-5 persons on average, local buses 4-10, frequent local service, bus rapid transit, and historic trolleys/streetcars from 8-20 depending on the local market, LRT and heavy rail from 15-30 per car and 50-300 per train, with regional rail serving anywhere from 25-50 per car, and 200-500 per train. More capital intensive modes require higher average loads to justify their cost, reduce dependence on driving, maximize energy savings, travel cost savings and other benefits.

Farebox Cost Recovery. In general, more heavily used transit modes achieve higher farebox recovery, though not always based on local fare policies. While some services may not always achieve the highest farebox cost recovery ratios, many have very heavy patronage and thus provide significant net benefits to both individuals and society as a whole.

Number of Jobs/Activities at Destination, Travel Demand Density. Higher patronage requires a higher number of jobs and activities within easy access of transit stops. This proxy for density is probably the most important factor attracting patronage. Higher residential densities also favor high transit patronage whether bus or rail. In dense, walkable urban neighborhoods, most transit access is by walking. In lower density cities and suburbs, trunkline transit requires a variety of feeder modes, including walking, bicycling, feeder vans or buses, as well as automobile park & ride and dropoff in many cases. "Travel Demand Density" means the magnitude of trips made in a particular travel corridor. In general, travel demand density increases directly with the size of the job/activity destinations served.

Transit Mode Spectrum by Suitability Factors

Figure B-1. Transit Mode Spectrum by Suitability Factors*

Increasing Applicability

MODE	Suitability for Larger Regions	Suitable in Less Dense Cities, Suburbs, Rural	Patronage, Load Factors	Farebox Cost Recovery	Number of Jobs/Activities At Destination	Travel Demand Density	Effectively Competes with Autos	Lifeline Mobility for Non-Drivers	Environmental & Energy Benefits	Impact on Land Use & Development
Regional Rail[1]										
Heavy Rail Transit (subway, elevated)										
Light Rail Transit (LRT)										
Streetcars / Historic Trolleys										
Bus Rapid Transit/Express Buses[2]										
Local Buses - Frequent Service										
Local Buses - 30 & 60 min. headways										
Community fixed or flex routes										
Paratransit - van-based services										
Paratransit - "Parataxi" services										

* Arrow direction indicates increasingly effective and efficient applications of each mode relative to each factor.

[1] Including "commuter rail." Regional rail often carries lower ridership than local transit services, but has higher load factors and longer trip lengths. Regional rail can also efficiently serve low density suburbs and rural areas, given large job/activity concentrations in adjacent larger urban areas or special destinations such as very large universities.

[2] Rural intercity and inter-community buses with limited stops included in this category.

Effectively Compete With Autos. The ability of a given transit service to effectively compete with driving increases along with patronage potential, and particularly when transit travel speeds can match or exceed autos through strategies such as express service or separated transit rights of way for rail and BRT. In general, reasonably high frequencies– usually at least every 15 minutes over short to medium distances and longer headways over longer distances. Local buses on 30-minute headways can be competitive with driving under some circumstances, but 60-minute headways, community and flex routes, vans and parataxis are rarely if ever competitive. Frequent "jitneys" can be very competitive with driving in some circumstances, but require high density of demand to turn a business profit.

Lifeline Mobility for Non-Drivers. More personalized services such as community fixed or flex routes, paratransit vans and parataxis are best suited to meeting the lifeline mobility needs of non-drivers, mainly because of near to door-to-door or door-to-door services. Where frequent transit services–every 15 minutes or more frequent–are provided, average wait times for paratransit modes typically exceed access and wait times for regular transit. On the other hand, taxis and hired car/limousine services are often preferred by affluent persons but are very expensive per ride unless shared.

Environmental & Energy Benefits, Impact on Land Use & Development. High ridership is necessary to obtain the many benefits possible from transit. Determining what these benefits are and their magnitude is a site-specific exercise beyond the scope of this white paper.

However, as a general rule, the higher the average occupancy of a transit vehicle, the higher the potential benefits. Low occupancy modes such as parataxis, vans or community flex routes usually have no environmental benefits, but are justified by the basic mobility they provide to the frail elderly, persons with disabilities and other vulnerable persons. Such services also benefit family members and care providers who otherwise would have to meet their mobility needs or pay for very expensive alternative transportation.

For typical fixed route services based on current (2011) motor vehicle usage rates of 20-21 mpg (combined auto/SUV/light truck) and average urban occupancies of 1.5, buses getting 4-5 mpg require a minimum of 4-5 persons "onboard to "break even" with driving. As a general rule, each passenger mile traveled on a local bus substitutes for 2 miles driven in a motor vehicle, and for 3 passenger miles by automobile (1.5 average occupancy).[13] This is explained by transit users generally owning fewer automobiles compared to non-users, more efficient shorter trips, and a larger proportion of all trips by both transit and walking.

Good transit service is a catalyst for maintaining or improving the "walkability" of many neighborhoods and business districts. Transit makes possible much denser concentrations of employment and other activities than possible with motor vehicles, partly through dramatically reducing or eliminating "needed" parking, as well as allowing dramatic downsizing of motor vehicle infrastructure such as streets, offramps, wide arterials and grade-separated expressways.

[13] See http://www.apta.com/resources/reportsandpublications/Documents/land_use.pdf

Appendix C. Ridership vs. Level of Service Provided

The figure below[14] shows the relationship between patronage and level of service. This relationship is very strong, with an $R^2=0.8908$.[15] We highlight current data for selected small operators in the San Francisco region's North Bay area (e.g., Sonoma, Napa and Solano Counties.) In general, larger transit operators also provide a higher level of service (generally greater than 1.0 annual revenue vehicle hours (RVH) per capita; San Francisco Muni's figure is more than 4.0 RVH/Capita) than the smaller systems, with resulting higher and increasingly productive ridership rates.

One important thing to note is that at any given level of service–e.g., "RVH/Capita"–the number of "Annual Revenue Riders Per Capita" (Rc/Capita) can vary by up to 4 to 1. For example, for the 0.8 annual RVH/Capita level of service for Fairfield & Suisun Transit, Rc/Capita can range from 7 up to around 26-28 Rc/Capita, for different systems as the range of blue data dots show.

In general, systems that operate indirect service, large one-way loops, infrequent service, etc. are on the lower part of the "curve" compared to those built around "Networked Transit" planning principles.

Figure C-1. Transit Ridership vs. Transit Supply
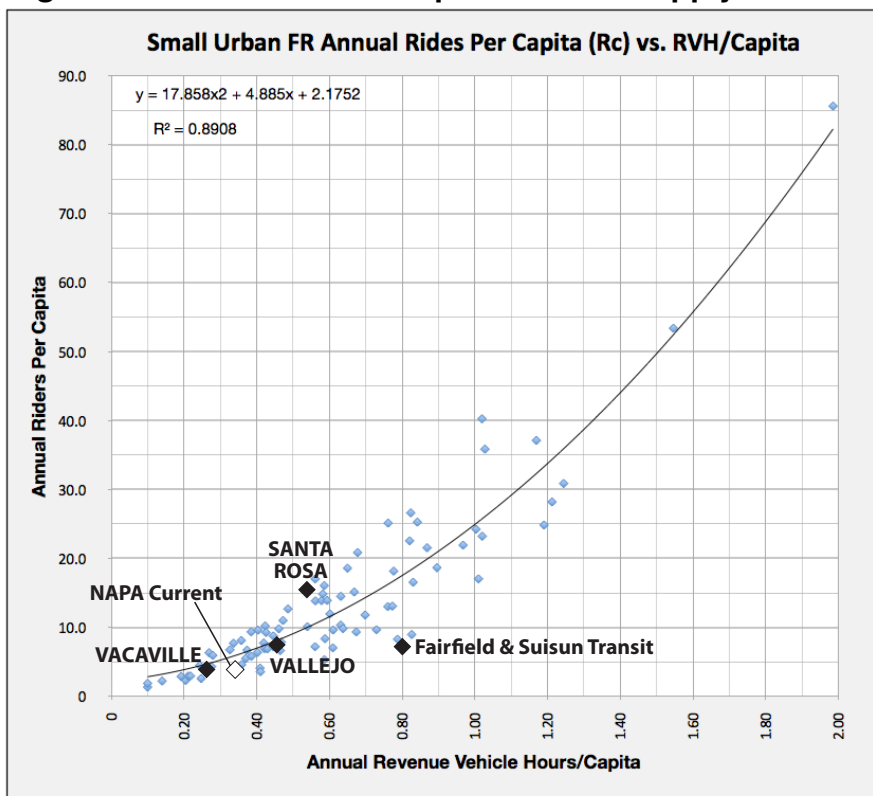
14. Base Data: *National Transit Database FY 2008*. http://www.ntdprogram.gov/ntdprogram/

15. R^2 refers to the strength of a correlation between two variables. An $R^2=1.0$ means "perfect" correlation, though not necessarily that the first variable "causes" the outcome of the second variable. In Figure 2, the blue dots represent data points for a number of transit systems showing the relationship between Annual Riders Per Capita compared to transit service levels, e.g., Annual Revenue Vehicle Hours per Capita.

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