

Alternative Transit Systems For the Albuquerque Metro Region

*A companion volume to "A Democratic
Approach To Land Use and Transportation
Planning for the Albuquerque Metro Region"*

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Contents

Summary.....	2
The Modes.....	2
Evaluation Process.....	8
Baseline.....	9
Plan A.....	10
Loop-Radial.....	12
Just PRT.....	15
Ridership & Total Profit.....	17
Goal Evaluations.....	21
Final Comments.....	25

Summary

This report is a collection of three possible transit systems designed for the Albuquerque metropolitan region, a study of their cost, and the measurements of the extent to which each system meets public goals. The systems are primarily about transit links but also include land use assumptions that support those links. The goals are taken from the companion report "A Democratic Approach To Land Use and Transportation Planning for the Albuquerque Metro Region". The other volume outlines the approach; this volume is the evaluation part of the planning process.

This is a draft, based on some estimated or incomplete information. We expect to solicit more ideas for transit systems, correct errors, improve numbers, and publish updated drafts.

The systems presented are not the only options, but they show how different design concepts can produce very different results.

You can participate if you are technically minded, by downloading the cost spreadsheet from www.abqtransp.org. In the spreadsheet, you can change assumptions, and see the results instantly. You can also download the ridership model and change the assumptions; however this requires some programming experience. It is a democratic process.

The Modes

List of modes studied

Before the full systems were developed and analyzed, a study was done of the modes in isolation. These modes are as follows. Each one has a consistent code that includes its average speed in miles/hr, so BUS12 refers to buses that go 12 miles/hr.

- **BUS12** = Standard city bus, with room for 60 in a pinch, with service that stops as often as every quarter mile.
- **BRT20** = A premium bus service, like Rapid Ride, which goes significantly faster than a standard bus route. BRT stands for Bus Rapid Transit, which can mean a lot of different things. In this case, it refers to large articulated buses holding up to 110 passengers, with service that stops every 1 mile.
- **BRT25** = A true Bus Rapid Transit service, using the same type of vehicle as BRT20, but with its own lane. This type of service still has to negotiate cross-streets, but is a little faster because it does not have to contend with traffic between signals.
- **LRT25** = Light Rail Transit, holding 150 passengers per train, and with the same speed and operating characteristics as BRT25.
- **GRT40** = Group Rapid Transit, a small vehicle elevated concept that offers elevator-type service. A GRT service is operating in West Virginia, and there are more advanced systems in development. The vehicles would have a capacity of 12 people for the purposes of this study, although different sizes have been

proposed. It can go much faster than buses and LRT because it is elevated, and because it only stops at stations where needed, not at every station.

- **PRT50** = Personal Rapid Transit, a service that most resembles a taxi. Like GRT, it operates on an elevated guideway. It is even faster because it makes no intermediate stops. Some vendors have developed guideway that can be used for both GRT and PRT service. The vehicles, regardless of their size, are assumed to carry an average load of 1.2 for this study.

Most people are not familiar with the PRT and GRT service concept. Some good web information is:

- ◇ en.wikipedia.org/wiki/Personal_Rapid_Transit - A collaboration between pro and con points of view.
- ◇ faculty.washington.edu/jbs/itrans - Large library of resources on emerging transit technology
- ◇ www.advancedtransit.org - Professional and advocacy organization for advanced transit.

This list of modes is by no means complete. One could deploy a BRT-like bus service using small buses, for example.

We did not include heavy monorail trains or any other heavy elevated structure, such as elevated busways or elevated rail. This is because of the much higher capital cost and the visual obstruction that large elevated structures make. It is important to consider an elevated system, because the speed advantages are so great, that it could produce very high ridership. However, the construction should be visually attractive. The installation should include tree plantings, walkways, lighting, and removal of existing utility poles, to make the overall package something that makes the area more attractive.

We did not list "maglev" as one of the modes because it is not a mode; it is a component. GRT or PRT could use maglev without changing the operational characteristics. The cost assumptions for GRT and PRT are based on wheels for this study, however.

Finally, we did not include any intercity modes because this particular study deals with urban transit only.

The spreadsheet assumptions

The costing spreadsheet is available for anyone to download and manipulate. If you want to do a parallel analysis for a different mode or variant of one of these, you can download the cost spreadsheet and add in your numbers. Or, if you think some of our assumptions are inaccurate, you can make the correction and see how the results work out.

The assumptions in the spreadsheet are listed here. If you want to jump ahead to the results, you might want to skip this section.

- *Depreciation* - A straight-line no-interest depreciation is used, with no provision for present-value calculations. The depreciation period is 15 years. That means that 1/15th of the capital cost is included in the annualized cost. (the results show low sensitivity to this variable within the range 10-25) [An economist should comment on this choice.]
- *Labor* - Assumed to be \$20/hr. (medium sensitivity)
- *Private cost of driving* - Using government estimate of 0.36 \$/mile.
- *Savings percent of not driving* - You don't save the full cost of driving by not driving because you still have to pay part of the cost of the car in the driveway. Also, transit miles may be more circuitous while car miles are often closer to a straight line. Therefore only 75% of the cost of driving is assumed to be saved by each avoided car mile.
- *Vehicles needed* - The number of vehicles needed to serve a route is based on speed, capacity, and the estimated ratio of empty vehicles. The worksheet calculates the loading of the minimum number of vehicles required to meet the headway policy, then calculates how many additional vehicles are needed to service the remaining boardings. Extra vehicles are added in beyond the number that exactly matches the ridership, since the ridership is not even throughout the day. Fixed service modes have a 30% penalty added, which translates

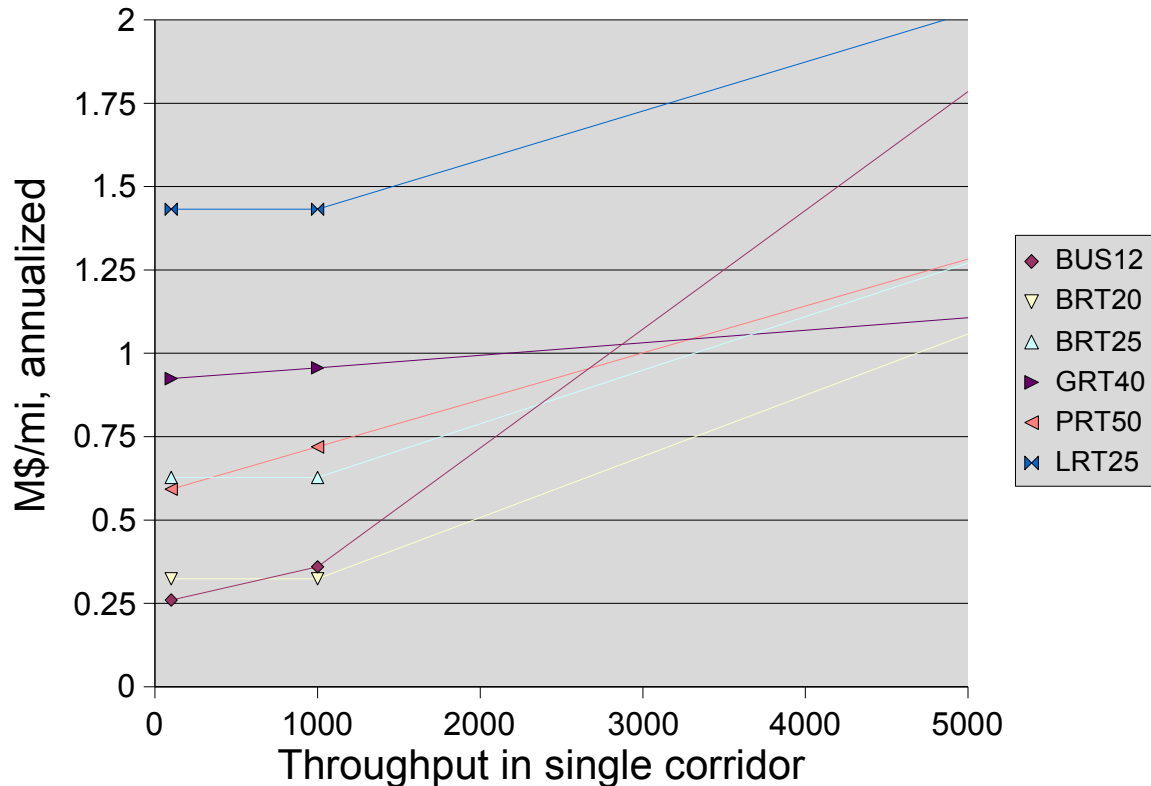
to <100% load factor. All modes have a penalty for deadheading or empty vehicles. PRT has the highest penalty since it circulates empty vehicles in anticipation of demand. The worksheet is also coded into a Basic function.

- *Speed* assumptions are based on average speed of the vehicle (not including transfers or walking). The speed should take into account a penalty for stops.
 - ◇ bus - 12 mph (based on national estimates)
 - ◇ BRT w/o lane - 20 mph, based on an estimate of speed in mixed traffic with stops every mile
 - ◇ BRT with lane - 25, based on an estimate of speeds up to 50 mph between stops, with stops every mile and intersections with cross-streets
 - ◇ LRT - 25 - same as BRT w/lane
 - ◇ GRT - 40 mph, based on top speed of 55+ and infrequent, short stops
 - ◇ PRT - 50 mph, based on nonstop travel with a top speed of 55+ mph
- *Energy cost /mile* (high sensitivity)
 - ◇ Notes: (1) Energy is different per speed, so in this model it is only estimated for the design speed. (2) Stop penalties should be included in the estimate. Systems with nonstop service or smaller vehicles are credited with less stop penalty. (3) All data in Btu's is from Transportation Energy Data Book 2004, produced by Oak Ridge National Laboratory, at cta.ornl.gov. (4) Assuming diesel fuel has 125,000 btu/gallon, which depends on the actual fuel grade.
 - ◇ See worksheet for calculation of energy use by mode.
 - ◇ BRT is assumed to use 1.4 times the energy that a city bus uses, because national data is less available. Actual energy use depends heavily on the specific bus model and route characteristics.
 - ◇ PRT energy cost has to be calculated somewhat differently than for other modes, because the way the service is dispatched is different. This information is adapted from an energy study done by Cities21, at http://www.cities21.org/PRT_NRG.htm.
 - Power is 11 kW per accelerating veh - Assumes 15 hp vehicle @ 0.746E3 Watts/hp
 - Coasting takes 40% or 4.4 kW
 - 75% coasting and 25% accelerating, so average power is 6 kW
 - At 50 mph, it takes .02 hrs to go 1 mile
 - At 0.12 \$/kW-hr, it costs (6 kW * 0.12 \$/kW/hr * 0.02 mi/hr) = 0.0144 \$/mile
 - ◇ GRT energy cost is assumed to be double that of PRT. Note that 12-passenger vehicles are not the size used at the one US installation in West Virginia, so data from the WV site was not used.
- *Capital cost* for a **one-way** guideway with stations and all other fixed infrastructure
 - ◇ BRT costs actually could range from almost zero to 20 M\$/mile or so, depending on what specific changes are made to the roadway. On the low end, if only signal priority and bus stops are included, the cost could be under 1 M\$/mile, while building new lanes could be 6 M\$/mile. Roughly 1 M\$/mile is assumed for BRT20, and 6 M\$/mile for BRT25
 - ◇ LRT costs vary considerably, but average 17 M\$/mile (one way) (GAO, 2001, summarized at ite.org/meetcon/2005AM/Evans_Tues.pdf).
 - ◇ PRT costs are estimated at advancedtransit.org/doc.asp?id=1015 at 5 M\$/mile (one way) based on the average of a number of costing studies. Most emerging technology has been estimated too low, but most projects of any kind are also estimated low. The certainty of those studies can be debated, but a possibly more commonsense estimate is that the low-load guideway would use only one quarter as much materials as a heavy LRT track. Some designs use much less material than that. For now, we will

estimate the cost at half of LRT (8.5 M\$/mi), which is an extreme high estimate for a market price, but possibly realistic as an early deployment.

- ◇ GRT costs were not estimated as rigorously, but assumed to be about 60% higher than PRT, due to the higher guideway loading.
- *Capital, vehicle, each*
 - ◇ bus - 300 k\$, from APTA, summarized by Evans (see LRT capital)
 - ◇ BRT - 940 k\$ (Evans)
 - ◇ LRT - 2.5 M\$ (Evans)
 - ◇ PRT - See ATRA (link above), showing an actual prototype vehicle at 50 k\$, and three costing studies supporting a cost of 26 k\$ (in 2002). We use 30 k\$
 - ◇ GRT - As we are assuming 12-passenger cars, we arrive at the cost by tripling the PRT cost, or 90 k\$
- *Vehicle lifetime, years*
 - ◇ Notes: The spreadsheet depreciates vehicles based on their lifetime, not based on the 15-year depreciation assumption.
 - ◇ bus - 15 (estimated by Evans)
 - ◇ BRT - 15
 - ◇ GRT - 20 (smaller lower cost vehicles produced in larger numbers may have a shorter lifespan than LRT)
 - ◇ PRT - 20
 - ◇ LRT - 30
- *Maintenance cost* - estimated (low sensitivity)
- *Boardings* - The number of boardings is set as an *assumption* of the model, not calculated by the model. The system boardings (linked trips) are input, as well as the component boardings (unlinked trips), which normally add up to more than the total. For example, if 10 people ride a bus and 3 of them transfer to rail, and 4 other people just rode the rail, the component boardings would be 10 and 7, and the total (linked trips) would be 14.

Idealized Cost By Mode



Cost results by mode

Based on the above assumptions, the costs are calculated for three different ridership levels: 100, 1,000, and 10,000 passengers per hour per direction. Note that in Albuquerque, we have ridership measured in the tens or hundreds per hour, not thousands. We should be looking at the left side of the graph for any realistic application.

The costs for each mode at each ridership level are shown in the graph here (up to 5,000 pas/hr). The costs are idealized, meaning they represent the cost of a steady stream of passengers over a 1 mile route, a situation that can't exist in reality. The costs are annualized, meaning part of the capital is included each year with all of the maintenance and operations.

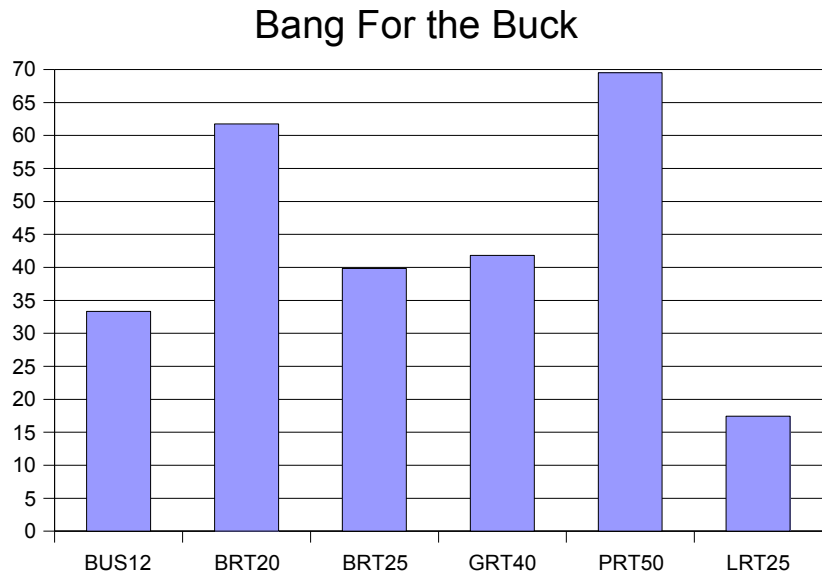
What is interesting about these results?

- First of all, LRT is much higher than all the other modes at the kind of ridership levels we might expect. To understand the high cost, consider that it is heavy (despite the name "light") and it requires a lot of materials to support it (steel and concrete in the track), it requires a completely new infrastructure (unlike buses), it requires drivers, and the energy cost is high because of the weight.
- GRT is the flattest line, meaning it doesn't cost much to operate it. That makes sense, because it is a light vehicle with no driver, so the labor and energy costs are very low.
- PRT is a steeper line that starts under the GRT line. The steep line represents the higher energy and capital cost inherent in moving people each in their own vehicle. However, PRT could attract the highest ridership due to its highest average speed, so the cost of an area-wide system could still be justified, given the cost assumptions.
- BUS is the lowest cost and the lowest speed at low ridership; no surprise there. However, it goes up steeply because it has the highest driver cost. BRT20 starts out close to the same cost, and the cost goes up less steeply with ridership, and compared to BUS12, it is a big jump in speed. There are a variety of viable

concepts in between BUS12 and BRT20, such as intermediate sized vehicles and intermediate speed; these would fall somewhere in between BUS12 and BRT20 on the graph.

What is the best value? To answer that, we calculated the ratio of the speed to the cost for each mode. That gives a "bang for the buck" statistic, shown here. The costs are based on the 1000 pas/hr ridership level.

These bars should be taken lightly. It simply shows that PRT and BRT20, for the cost, gives the passenger a lot of value. LRT, because it is so expensive, has a low value. The other modes are in between.



Evaluation Process

Which systems are compared?

We attempt to be neutral regarding which ideas can be included for analysis in this report. The basic conditions that a system should meet to be included and compared are:

1. It has to be a *public* system not requiring privately owned vehicles. (That is just a limitation of the scope of the study; public transit is not necessarily the best way or the only way to meet transportation related goals.)
2. It has to be usable by the young, elderly, blind, disabled, etc. It must not require driving.
3. It has to be mapped out with specific fixed infrastructure (e.g. tracks), a specific number of vehicles, and all the other components needed to be able to calculate the capital cost. Just saying it is "expandable" or "demand driven" is not enough; you have to assume a specific level of demand and calculate the details. (In this study, each concept is costed out at two demand levels: 100,000 and 1 million boardings per day.)
4. It has to have specific service parameters, such as a schedule. In the case of complex or demand-responsive routing, it has to be backed by a simulation model showing that the system works.

These alternative systems are evaluated. In the next draft of this report, we can include more alternatives, if more are submitted.

- "Baseline" is the situation as of 2005. All other plans are evaluated based on COGs 2030 population projections.
- "Plan A" is what is being offered by governments today. This includes a network of light rail lines developed by the "Middle Rio Grande Connections" study and the "Rapid Transit Project" study (www.abqrtp.com), as well as the local bus system proposed by ABQRide's Short Range Transit Plan. The new development patterns are assumed to be mainly large low-density auto-oriented housing tracts.
- "Loop-Radial" is a plan that features a high speed loop connecting the major employment centers in Albuquerque, as far north as Cottonwood Mall. It also has radial BRT routes expanding from the loop. In this and the other alternatives, the land use is as explained in the companion volume, with much more of the new growth occurring as transit oriented redevelopment, and less on the edge of the metro area.
- "Just PRT" is a plan that blankets the region with a network of PRT lines.

Ridership, costs, and goal evaluations

The alternative plans (except the baseline) each have a low and high ridership level, of 100,000 and 1 million boardings per day. Each plan is evaluated twice, one for each ridership level. Only after that is the actual ridership predicted. Once there is a ridership prediction, then a synthesis of the low-ridership and high-ridership versions can be built by using the weighted midpoints of each of the cost numbers and other statistics.

The synthesis plans are then evaluated against each of the goal kings (see the companion report). Finally, the study concludes by showing each alternative, with its cost, and the extent to which it achieves the goals. This is the key summary of the information that decision makers should use.

Baseline

Components

The baseline (2005) transit system consists of about 12 miles of BRT20 (Rapid Ride), and about 180 miles of BUS12 road coverage, of which a large majority is two-way coverage. The routes can be measured different ways, since some roadways are covered by more than one route. Each route has its own schedule. All route information is available at www.cabq.gov/transit.

Component	One-way route (mi)	Bidirectional route (mi)	Total route (mi)	Frequency (min)
BUS12	~50	~130	310	40
BRT20	0	12	24	10

Reasoning

The bus routes are mainly geared towards providing mobility for those who don't drive. However, the Rapid Ride service is also aimed to draw some drivers, particularly in the UNM and downtown areas where parking is scarce. Historically the main factors driving decisions about transit have probably been (1) low acquisition cost, (2) widespread coverage, (3) low to zero impact of the transit system on driving. The transit department has done what it can for a given budget, but transit has not been an integrated part of urban planning.

Performance

Much of the transit coverage is sporadic. It can take up to two hours to go six miles as the crow flies if you have to transfer between two of these sporadically served routes, for example between Coors & Bridge and Carlisle & Kathryn. That is an average speed of three miles per hour, which is no better than walking. However, certain routes are much faster than this; it depends a lot on where you are and where you are going.

Cost

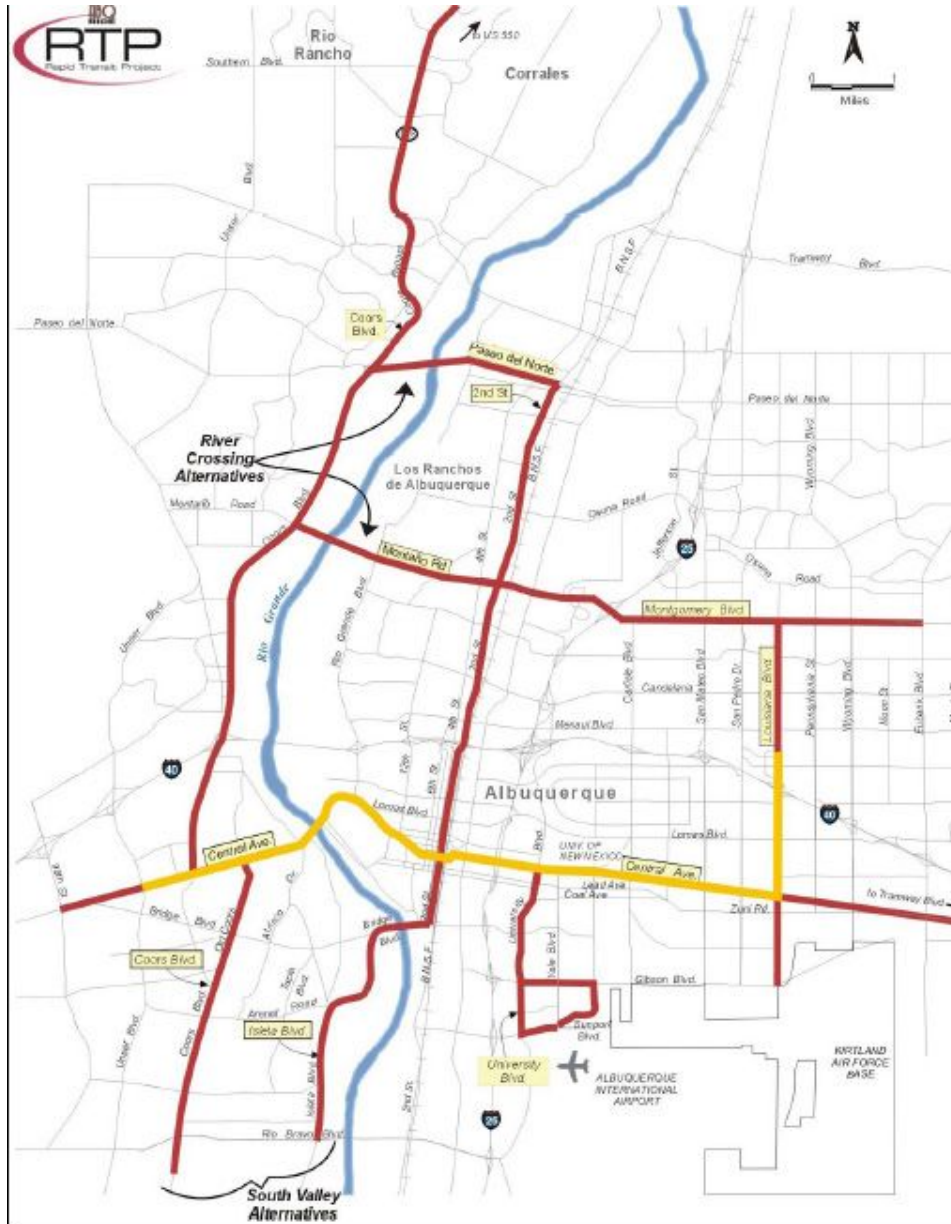
Some cost spreadsheet assumptions are:

- Boardings: Based on the National Transit Database, weekday boardings are about 27,000. The allocation between modes is estimated.

The cost model predicts that the system costs around 14 M\$/year. Remember, this cost figure includes capital depreciation, even though transit agencies usually leave that out.

According to the national Transit Database, the actual expenditures of ABQRide in 2003 were 24 M\$ in operating expenses, and 10 M\$ in capital. The spreadsheet predicts only 14 M\$ total, which means that some of the assumptions are not correct. These should be corrected in the next study revision; however it is unclear at this point which assumptions are off. The correction will affect all the alternative systems in similar ways, so it will not change the results very much.

Plan A



Components

Plan A includes a network of light rail lines developed by the "Middle Rio Grande Connections" study and the "Rapid Transit Project" study (www.abqrrtp.com), as well as the local bus system proposed by ABQRide's Short Range Transit Plan. One has to read between the lines since Plan A isn't an actual published plan. It is the combined musings of consultants and elected officials. The RTP study shows about 55 miles of LRT route, bidirectional. We are assuming an increase in the bus route. As with the baseline, each route is different, so the results of this study will be round numbers, and not as accurate as if the routes were modeled in detail with a simulation model.

The new development patterns are assumed to be mainly large low-density auto-oriented housing tracts, because that is what is in the pipeline today and that is what is legal and what is being proposed by developers

Component	One-way route (mi)	Bidirectional route (mi)	Total route (mi)	Frequency (min)
LRT25	0	55	110	10
BUS12	?	?	400	30

In January 2006, it was learned that ABQRide will be changing the technology and route of the first link of "Plan A", in order to avoid having to go through the federal environmental assessment process. The new idea is to use steeptcars, which are smaller than LRT, and run them in lanes shared with auto traffic. If this technology is assumed for the whole Rapid Transit Project map, the cost would be less, but the speed and ridership would also be less.

Reasoning

The idea behind Plan A appears to be centered on the image of light rail has as an attractive form of transit, whose presence will elevate the image of Albuquerque as a whole. Because of the draw of the system, real estate investments will follow, and the economic consequences will be beneficial. There is a widespread belief that light rail is more efficient or cost effective or perhaps less polluting than other forms of transit. So, Plan A is mainly about having a certain mode of transit, not the routes or transit's ability to meet other goals.

Performance

The performance of Plan A is slightly better than the baseline, with a higher portion of the population closer to a higher speed service.

Loop-Radial

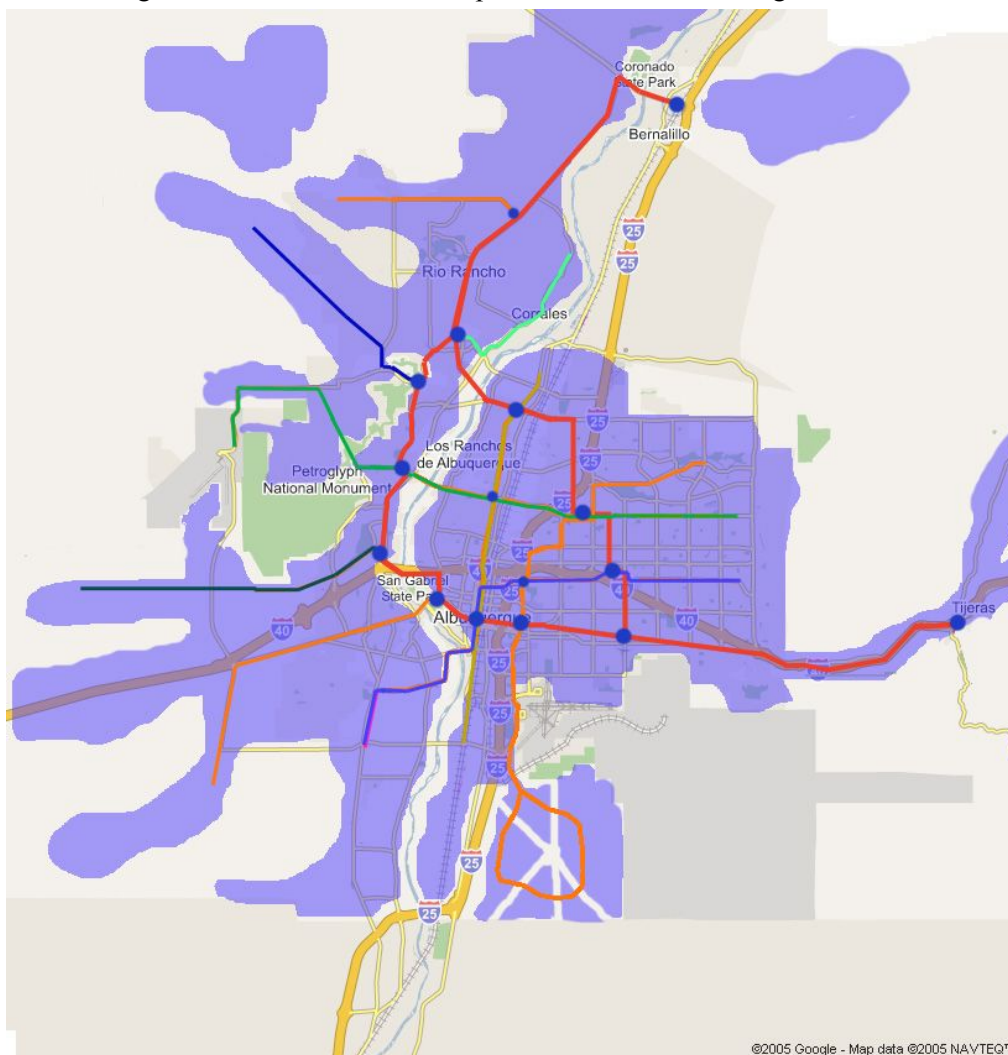
Components

In this plan, there is a high speed loop connecting the major employment centers in Albuquerque, as far north as Cottonwood Mall. This is shown in red on the map. The red lines are the level-B transit service, which means they offer high speeds and limited access to connect all parts of the metro region.

The loop part of the red lines is proposed as elevated GRT service. The North extension to Bernalillo is proposed as lane-separated BRT25, and the East extension to Tijeras is proposed as BRT type buses on the existing highway. Both the extensions are omitted from the cost/benefit analysis in this draft.

It also has radial BRT routes expanding from the loop, which go on arterial streets in mixed traffic. However, high priority signals are proposed to nearly eliminate jams that affect the buses.

In this and the other alternatives, the land use is as explained in the companion report, with much more of the new growth occurring as transit oriented redevelopment, and less on the edge of the metro area.



Component	One-way route (mi)	Bidirectional route (mi)	Total route (mi)	Frequency (min)
GRT40	0	30	60	3
BRT20	0	80	160	5
BUS12	?	?	400	30

It is assumed that half of the trips will use GRT only; one quarter use bus only; and one quarter use both. The existing bus system is included as a feeder, although it is assumed that much of the new ridership would bypass the service because it is so infrequent. For estimation purposes, it is assumed that half the number of people who use GRT will use the local buses.

A few special flyover lanes are proposed to make connections that otherwise would slow the system down considerably. These are:

- From 2nd street near Lomas to Broadway & Odelia. (blue route)
- From Indian School & San Pedro (south of the highway) to a parking lot on Indian School (north of the highway) (blue route)

The guideway capital cost was assumed to be 2 M\$/mile per direction to account for the cost of these flyovers.

Reasoning

The combination of a loop and radial lines is a pattern that collects traffic into hubs, but does not route everything to one super-hub. It is a compromise between a single-hub pattern and a totally dispersed pattern. The pattern could be installed with existing hardware (buses), and then upgraded. For example, the loop route could be a regular bus route, then upgraded to BRT, then upgraded again to GRT.

The technology proposed for the loop is GRT because the lightweight elevated system can span the river with minimal environmental impact, it will not take away any auto travel lanes, and it will be faster than driving near the major employment centers. The loop hits Old Town, downtown, UNM, uptown, Jefferson/I-25, Cottonwood mall, and Coors/I-40.

The GRT loop will operate with on demand vehicles which only stop when needed, so there will be very little wait time and fast travel time. The BRT radials will operate at 5-minute spacing. Therefore the whole system can be navigated without a schedule. Typical trips would use one of the radials, part of the loop, and possibly another radial.

The BRT20 option is proposed instead of the BRT25 option. This means that only signal priority is proposed to obtain the 20 mi/hr speeds, but no dedicated bus lanes are proposed for the majority of the system. The signals should track approaching buses up to two cycles in advance, and shorten the cycles as needed to make sure that the bus arrives at the optimal point in the cycle.

Smart signals cannot work well when routes cross. However, in this plan, the BRT routes cross very rarely, so that makes the smart signals very workable, and very inexpensive.

Under the Loop-Radial plan, the "last mile problem" is handled partly by existing scheduled local bus service. However, wheeled access is encouraged by low boardings, ramps, or level boardings on all vehicles, and a large area of open space in every vehicle to fit bicycles, electric scooters, and wheelchairs. So it is expected that many people won't bother to wait for the local bus, but will use other means to get to the nearest BRT stop.

Performance

Because of the high frequency of service, the speed, the accommodation of wheeled personal devices, and the easy way to navigate the system, we anticipate that the catchment area will be somewhat wider than is typically experienced in US cities.

The loop-radial network topology has a concentrating effect on travel, not as pronounced as a pure hub system (like Boston or Philadelphia), but much more pronounced than a grid system. This means more frequent GRT vehicles will need to be dispatched, which in turn helps with ridership.

Just PRT

Components

In this plan, 200 miles of PRT50 (Personal Rapid Transit) is proposed in a system that follows the main arterials. No specific network map has been designed. It would most likely follow a grid in the middle of the city and a more radial design on the edges. It doesn't matter how complex the routing is for PRT, since the routing is automated, and the user only has to know his or her destination. The large extent of the guideway ensures that a stop is within a half mile of almost anywhere, and a quarter mile of nearly all jobs.

[It is noted that many readers will not be able to envision a network without seeing a map. There are many unanswered questions. For the next draft, we should include a map, or a detail of part of the city to illustrate how this might work.]

Note that PRT networks are predominantly one-way because for the same cost, you can achieve the almost double the coverage using one way links. The topology is therefore one-way loops that connect at merge and diverge points. The links cannot intersect.

Component	One-way route (mi)	Bidirectional route (mi)	Total route (mi)	Frequency (min)
PRT50	200	0	200	N/A

Reasoning

The reasons for modeling a system composed only of PRT stem from the fact that the ratio of benefits to currently estimated costs is higher than for any other mode. PRT vendors have claimed that in some circumstances, PRT networks could pay for their own capital and operating costs just from fare revenues.

Most people are not familiar with the PRT and GRT service concept. Two good places to learn more are www.advancedtransit.org, and faculty.washington.edu/jbs/itrans

PRT is a paradigm-shifting technology, so it takes some patience and study to understand how it works. There is often a tendency to dismiss it as unworkable, even among professionals, even though it has been demonstrated in actual operation and more extensively in simulation modeling.

You might consider 200 miles of PRT to be so futuristic that it is not feasible, or you might see several downsides to this concept. It is included to show what the results *would* be *if* such a system could be procured and the assumed costs and performance characteristics turned out to be correct. Including this system does not constitute a judgment that it is equally feasible as the other concepts.

Like the GRT loop, PRT would be able to make several river crossings in an environmentally acceptable way, because the light weight guideway can span long distances.

There are several known risks. There is the risk that costs will not be as low as estimated. Also, it is not practical or advisable to place a single order for a system of this size, when it has not been built before. It would be more reasonable to work with a private operator on a smaller scale, then based on the results of that operation, redo the projections from this study with more accuracy.

Performance

PRT networks are more complicated to model than fixed route service. A simulation model from skywebexpress.com shows that many departures require no wait time at all, because a vehicle is already waiting at the station, and that a wait time of up to three minutes is a reasonable estimate.

Ridership & Total Profit

The relationship of profit and ridership

The profit or loss of a transit system can be seen from two points of view: the operator or the user. Since the operator is usually the public, and so is the user, the distinction is really between our *collective* profit as a commonwealth and our *individual* profits. The collective profit is defined as the revenue (fares) minus the capital and operating costs. The private profit is defined as the avoided driving expenses minus the transit costs (fares). If you look at the combined profit of the commonwealth and individual wealth, the fares simply move money from one account to another. So, they cancel out if you add the two profits together. The spreadsheet column "total profit" does just this.

The total profits of the different concepts range from tens of millions per year of loss, all the way up to hundreds of millions in profit. The main component of the total profit is avoided driving. This is because driving is less efficient than *any* transit system when transit demand is high enough. Driving is an unnecessary drain on the economy. Higher transit ridership is better for the economy, even if the transit system itself is not particularly efficient to operate or cheap to build.

Because of this fact - that profit is mainly due to ridership and not the cost of the transit system - we should be looking at what system produces the most ridership, even if it is more expensive than other systems.

Description of the ridership model

Transit ridership is based on personal choices that we all make. A ridership model must take into account the reasons why people make travel choices. The model used in this study uses a small set of numerical inputs that describe these reasons. The model is available for download from www.abqtransp.org; it requires some programming experience to manipulate.

The model is based on the theory that a person will choose the "least cost" travel option, where "cost" includes money, time, discomfort, and inconvenience. Since people are different, they will value their time, discomfort, and inconvenience at different monetary rates. For example, one person may value their travel time at 5 \$/hr, and another one at 10 \$/hr. This could be due to income differences, and also partly due to personality differences. People also have different commute distances, and they live and work at different distances from transit stops. All these differences are the basis of the model.

The model segments the population into several thousand groups based on all possible combinations of each individual difference.

Limitations of the model include:

- All the model does is calculate how many trips would use transit versus driving.
- It is not a data-centric model. It does not take into account land use or spatial data of any kind.
- It is not sensitive to local network conditions like the river crossing bottleneck.
- It is not a simulation model.
- The results are significant only when comparing with other results produced by the same model. The model cannot actually predict the future. So, if the model predicts 10% transit share in one scenario, and 4% transit share in a second scenario, this only means that the first scenario is a lot better for transit; it is not a tool that can predict that ridership will actually be 10%.

The main advantages of the model are:

- It works off a small number of inputs and formulas, which can be understood without training.
- Each input number is a reasoned estimate that does not require extensive research to derive.
- The model takes into account the fact that people are different, and those differences cause them to choose different travel options. Some other models base behavioral choices on averages that do not take personal differences into account.
- It runs almost instantly, and in a few seconds, one can make changes in inputs and see the results.

Because the mode is based on segmenting the population into groups based on differences, many of the inputs are lists of values. The lists give different values to segments of the population. For example, the input for commute distance is {1, 2, 3, 4, 5, 7, 10, 15}. This indicates that there are eight segments of the population, and one-eighth has a one-mile commute; one-eighth has a two-mile commute, etc. up to 15 miles.

The list given above has not been checked for accuracy, and it turns out that this is not very important. It is important that the inputs pass a reasonableness test, but doing the research to determine precise commute distances would not be of much help. The results are going to be quite general indicators of ridership in any case.

In the model, all forms of "disutility" are converted to money. The total cost of driving includes the actual monetary cost and the cost of time. The total cost of transit includes the fare cost and the cost of time, as well as additional costs for walking, waiting and discomfort.

The model is roughly calibrated so that it predicts today's actual transit share of about 1%.

Detailed ridership model inputs

The model inputs are as follows:

Personality and socioeconomic inputs

- *Valuation of travel time* - This input primarily reflects income. The US DOT suggests using an average of \$11 per hour. We expand that to a range around 11, and adjusted it downward for two reasons: (1) Albuquerque wages are lower than national averages; and (2) it calibrates the model to show existing conditions. Studies on this topic have not been consistent, and there is a fair amount of guesswork in them. (Source: "The Value of Saving Travel Time: Departmental Guidance for Conducting Economic Evaluations" at <http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf>. An update of the data tables is available at http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf.)
- *Valuation of waiting and transfer time* - Waiting time is more onerous than travel time, as evidenced by the fact that many people will choose a longer trip if it avoids transfers. Therefore these numbers are higher than travel time valuation. The DOT study referenced above suggested not to do this, however.
- *Transit aversion* - Some people dislike transit more than others for a variety of reasons such as personal safety and the loss of a sense of freedom. Segmentation by transit aversion allows the model to account for this fact.
- *Walk aversion* - Some people like walking more than others, and some people can't walk very far. The model accounts for differences in walk aversion through a "dollars-per-mile" input.

Situational inputs

- *Commute distance*

Transit system inputs

- *Wait time* - This measures the average wait+transfer time per trip. Since there is a huge variety, it is hard to estimate. It should not be assumed that the wait time is half the service frequency, since people would time their arrival to bus stops according to the bus schedule. But still, this is the input that is used to penalize systems with infrequent service, since the model does not take into account anywhere else the difference between infrequent and frequent (or demand-responsive) service.

- *Walk distance* - There are two inputs - origin walk distance and destination walk distance. For this study, the model assumes the morning commute to work; therefore the origin walk is likely to be longer than the destination walk.
- *Transit speed* - Average speed of trips on the system.

Background regional inputs

- *Fare* - Fare for one one-way trip. Since the fare policy is basically unrelated to the cost or characteristics of the transit system, it should be set the same for all systems being compared.
- *Parking costs* - The model allows a low parking cost, which is always zero for Albuquerque, a high cost, and a walk-distance threshold. As an example, if the threshold is 0.125 miles, then any commute whose destination walk from transit is under 0.125 miles has the high parking cost.
- *Driving cost per mile* - Assumed to be the same as in the cost spreadsheet, which is 75% of the government estimate of 0.36 \$/mile. The 75% multiplier is used because the marginal cost of driving is always less than the full cost of driving, and it makes sense to choose the mode based on marginal costs.
- *Driving speed* - Average driving speed for the full commute distance.

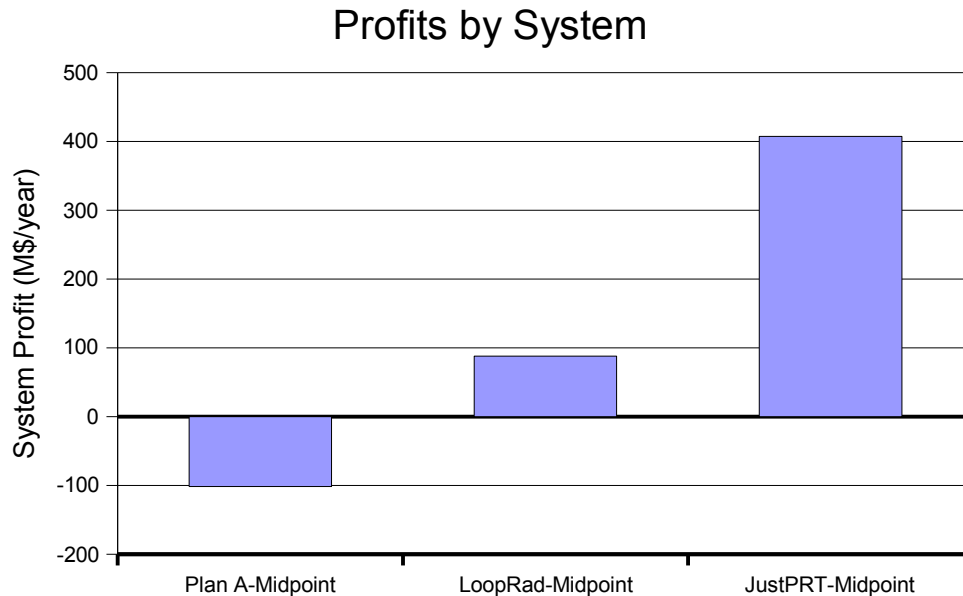
Ridership model inputs and results

Input	Values for all alternatives			
Valuation of travel time (\$/hr)	{4, 7, 10, 13}			
Valuation of waiting time (\$/hr)	{6, 10, 15, 21}			
Transit aversion factor (multiplier)	{0, 0.33, 0.66}			
Walk aversion factor (\$/mile)	{0, 0.3, 0.5, 1.0, 2.0}			
Commute (mi)	{1, 2, 3, 4, 5, 7, 10, 15}			
Parking cost	low = 0; high = 3 \$; threshold = 0.125 miles			
Driving cost (\$/mi)	0.27			
Driving speed (mi/hr)	20			
Transit fare	1			
Input	Baseline	Plan A	Loop-Radial	Just PRT
Wait time (min)	{5, 10, 15, 30}	{5, 10, 15}	{3, 4, 5, 15}	{1, 2, 3}
Origin walk (mi)	{0.125, 0.25, 0.5, 1.0}	{0.125, 0.25, 0.5, 1.0}	{0.125, 0.25, 0.5, 1.0}	{0.125, 0.25, 0.5}
Destination walk (mi)	{0.125, 0.25, 0.5}	{0.125, 0.25, 0.5}	{0.125, 0.25, 0.5}	{0.125, 0.25, 0.5}
Transit speed	12	15	25	50
Transit mode share	<1%	3%	15%	39%

Profits based on ridership

The ridership model predicts transit share as a percent of all trips. To turn this into real numbers, we must assume a total number of trips. Multiplying a number with a wide margin of error by another uncertain one gives a number with little predictive value, BUT it still does have value in distinguishing the differences in the transit systems that are being compared.

We use 2.5 million trips per day as the multiplier. Using the "synthesis" page of the spreadsheet, this results in the final bottom line profits as follows:



The numbers in this graph are the combinations of individual profit and operator profit, which boils down to the savings of avoided driving minus the cost of building and operating the transit system.

The "breakeven fare" is the fare that would have to be charged to pay for the system with no subsidy. For Plan A, this is over \$4. For Loop-Radial, a fare of \$2.50 would break even, while for Just PRT, a fare of just 55 cents would break even. Since a private operator could fairly charge more than 55 cents per trip, providing transit could actually be a profitable venture. They would make money, AND customers would be saving hundreds of millions of dollars per year in transportation costs. The win-win situation is possible because of the inherent efficiency of transit.

So, it matters quite a bit *which* transit system you build. All transit is not equal. Building the wrong system could lead to an endless political battle over who covers the losses and a continued public feeling that transit is a lost cause. Building the right system could lead to a robust market economy that competes to offer the best service to customers.

And that is just the financial side. The next chapter deals with all the other goals.

Goal Evaluations

This section is about scoring the transit alternatives against public goals. The goals are suggested by the author, and explained in the companion volume "A Democratic Approach To Land Use and Transportation Planning for the Albuquerque Metro Region."

It is a fundamental point of this approach, that decisions *should* be made based on how well an action addresses public goals. In order to determine that, the goals have to be of a quality that can be numerically evaluated, and the resources have to be put towards doing the evaluation properly.

Because this report is a volunteer effort, many of the evaluations can't be done. Those are left out. Some of the goals are not greatly impacted by transit, and those are left out too.

Following is a list of the goals that were used in scoring the alternatives, and the results.

1. Safe roads

MEASUREMENT: Transportation fatalities on regional scale facilities, per year, per 1,000 people.

EVALUATION METHOD: Federal data on fatalities by mode is available. The change in mode share is used as the basis for projecting fatalities by mode. The "goal worksheets" page of the spreadsheet has the full calculations.

LIMITATIONS: The data on transportation accidents involves gray areas; for example when a car and a streetcar touch, you might say it is usually the car driver's fault, yet it is still a danger to the transit riders. The federal government data does not come with much explanation of this sort. Local data may be different than national averages, and the difference will be greater for cars than for transit; if driving is less safe here than for national averages, this this method will slightly underrepresent the safety benefits of all transit.

SOURCES:

- www.bts.gov, Publications, National Transportation Statistics, 2005, Table 2-17, year 2003 shows rate of crashes at 220 per 100-million **vehicle**-miles (1.5 fatalities, 100 injuries)
 - ◇ At 0.015 fatalities per million vehicle miles, divide by 1.2 (load factor) to get 0.013 fatalities per million passenger miles.
- transit-safety.volpe.dot.gov, 2003 contains safety statistics, per **passenger-mile**
 - ◇ Automated guideway - miles=8.4M, incidents=33, incidents/Mmiles=3.9, fatalities=0, fatalities/Mmi=0
 - ◇ LRT - miles=1462M, incidents=983, incidents/Mmiles=0.67, fatalities=17, fatalities/Mmi=0.012
 - ◇ bus - miles=17241M, incidents=11053, incidents/Mmiles=0.64, fatalities=87, fatalities/Mmi=0.005
 - ◇ heavy rail miles=13606, incidents=5554, incidents/Mmiles=0.41, fatalities=49, fatalities/Mmi=0.004

RESULTS: By mode, autos have the worst safety record, with LRT almost as bad. (Autos are getting safer every year, however.) Bus has under half the fatality rate of LRT, and heavy rail has even less. Automated guideways have had no fatalities. To understand the high rate of LRT accidents, consider that they often share the road with cars, but cannot turn to avoid an impact. Buses are more agile in that respect. Heavy rail and other modes that are totally separated from cars have better safety because they are segregated.

The baseline alternative projects 82 fatalities; Plan A projects 81; Loop-Radial projects 74, and JustPRT projects 55. These are total regional fatalities including autos in each case.

2. Safe walks

MEASUREMENT: Incidence of crimes against persons committed on public land, per 1,000 people

HYPOTHESIS: The way that the use of transit and walking could make people safer from crime is by having more people out and about, so it becomes less likely to be alone and in danger of being a target of crime.

RESULTS: The web site www.fbi.gov, 2004 crime data, and a brief web search of correlations between crime and public transit use reveals that there is probably no link, either positive or negative, between crime and public transit. Therefore this goal was dropped from this analysis.

8. Sharper image

MEASUREMENT: Regional transportation facilities, as judged by survey on a scale of attractiveness of 1-10 (where the scores are normalized for a set of control images)

EVALUATION METHOD: This could be evaluated with a carefully designed survey. However this is beyond the capability of this volunteer effort, so this evaluation was not done.

9. Safety net

MEASUREMENT: Number of people stranded from employment or education due to transportation cost or availability, by survey, per 1,000 people

EVALUATION METHOD: The way a transit system would help meet this goal is by having late night or 24 hour service, and extend to all parts of the city. The modeling done did not take into account service hours. However, it is a safe assumption that any additional money spent on the existing local bus system would be spent partly to extend service hours. Therefore all alternatives that have extended local buses would see a reduction in stranded persons. We assume a 50% reduction for this effect. Since the GRT and PRT modes are driverless, there is very little cost in providing 24 hour service, so we assume those modes will operate 24 hours every day. Therefore the Loop-Rad system will result in slightly less stranded persons, and the PRT mode will result in almost no stranded persons.

Because the results are estimates, and we don't know the rate of being stranded per 1000 people, we have stated the results as percent-of-baseline.

RESULTS: Baseline=100; Plan A=50; Loop-Radial=40; JustPRT=5

11. Efficient transport

MEASUREMENT: Average personal income in the region going to transportation

EVALUATION METHOD: To evaluate the total cost of transportation, we will use the combined public and private costs, which are borne by individuals either directly or through taxes. The current cost of transportation in the region is estimated at 1.6 B\$/year. For each transit alternative, we reduce that cost by predicted driving reduction, then add back in the total cost of the transit system. The "goal worksheets" page of the spreadsheet has the full calculations.

RESULTS: (Note the results are only meaningful comparisons with each other, because the scaling factor was estimated. All dollar figures represent transportation costs per person per year.) Baseline=\$2133; Plan A=\$2269; Loop-Rad=\$2016; JustPRT=\$1691

INTERPRETATION: It may be surprising that Plan A actually results in more expense than the baseline. This is because the savings from avoided driving are less than the cost of the transit system. The low savings is due to a low level of service, which doesn't attract ridership.

12. Clean air

MEASUREMENT: Sale of fossil fuel in the region (gallons)

EVALUATION METHOD: Air quality is influenced by, but not directly proportional to energy use. Even without any reduction in energy use, changing to renewable sources of energy would clean the air. An additional gray area is the fact that some energy sources pollute locally and others pollute elsewhere. In particular, electricity use in Albuquerque results in coal pollution in the four-corners area. It is not ethical to claim that we can meet our air quality goals by shifting more pollution to that heavily polluted area. Therefore, as a rough approximation, we will use the cost of energy as the predictor of air quality. This analysis is similar to the "efficient transport" goals, except that it measures only energy cost of the alternatives instead of the total cost. The "goal worksheets" page of the spreadsheet has the full calculations.

RESULTS: (In M\$/year) Baseline=\$616; Plan A=\$609; Loop-Rad=\$548; JustPRT=\$409

INTERPRETATION: There are several assumptions and intermediate calculations, which may not be well calibrated with reality, so the baseline result may not be correct. However, it is important to use all numbers from the model, not some from the model and some from other sources. This ensures that the calculations are meaningful when compared to each other.

14. Short commute

MEASUREMENT: Average commute time, by survey, in minutes

EVALUATION METHOD: The average commute time for each transit alternative is proportional to the average speed. This is calculated as the weighted average of the driving speed and the transit speed, where the weighting factor is the transit share. The speeds used here are the same values that were used in the ridership model. While this is not a survey, as originally intended, the evaluation can be done with available projections. The "goal worksheets" page of the spreadsheet has the full calculations.

RESULTS: Baseline and Plan A both come out to 19.9 mph; Loop-Rad shows a slight improvement at 20.8; and JustPRT shows a dramatic improvement at 31.7 mph. (The percent improvement depends on the arbitrary target number used; in the spreadsheet, 40 mph is used as the target.)

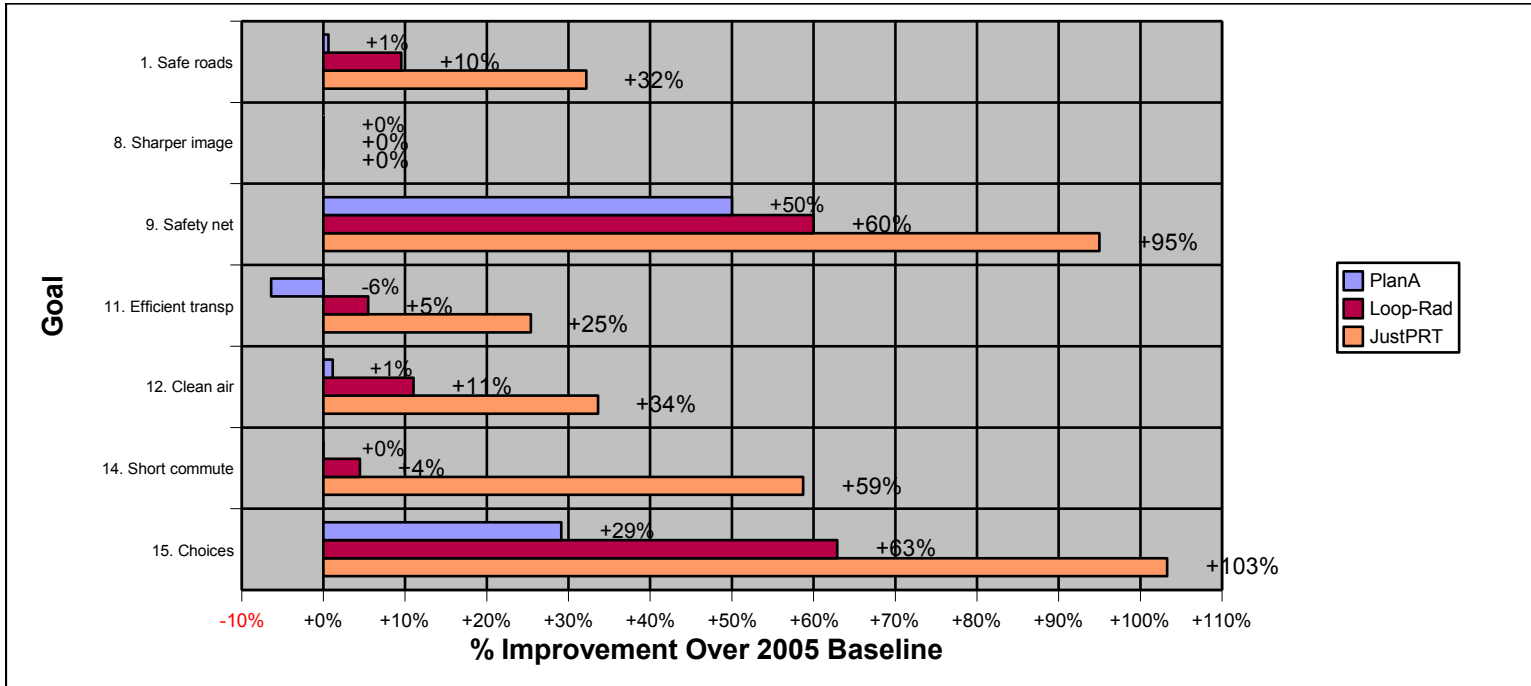
15. Choices for everyone

MEASUREMENT: The end-to-end travel time (including walking) it takes to use the fastest available *non*-driving mode, averaged for selected trips, expressed as a percent of the time it takes to drive (lower is better). As an example, if transit takes 125% of drive time (25% longer), then that is pretty good; but if transit takes 280% of drive time (2.8 times drive time), that could be considered an injustice to people who can't drive.

EVALUATION METHOD: The ridership model inputs are sufficient to calculate this goal. The walking speed is assumed to be 2 mph. The ridership model sums walking time, transit time, and wait time; and separately sums driving time, and compares the two.

RESULTS: The baseline measure is 338% (meaning transit takes over three times the time of driving on average). Plan A reduces this to 276%; Loop-Rad reduces this to 204%; JustPRT reduces this to 118%.

Summary of goal evaluations



Of the three systems studied, Plan A costs the most, has the lowest ridership, and has the least impact towards the goals that were selected for study. The other two alternatives cost roughly the same, but since JustPRT is projected to have much higher ridership, its overall effect on the economy and the other goals is much more beneficial.

JustPRT outperforms the other alternatives in every area except "Sharper image", which was not evaluated. With some funding, this study could be extended to evaluate the attractiveness of the alternatives.

Final Comments

Why are the results of the alternatives so different?

Many readers will be surprised to see that the plan favored by government is the one that has the least benefits. We would like to trust our leaders to do the best thing for us, but often they don't or can't. This report shows that a well reasoned democratic process, with the aim of serving common goals, can achieve those goals. The way government is structured today does not often promote a well reasoned democratic process, so it should be no surprise that it fails to meet common goals.

Let's look at the roots of the three alternatives to see how they are fundamentally different. Plan A was what came out of the *political* process. Millions were spent on Parsons-Brinkerhoff. (According to the Charlotte, NC newspaper *Creative Loafing* (1/29/03), this company has "a notorious history of scandal, massive cost overruns, engineering snafus and deceiving the public." The full article is on www.abqtransp.com.) Who knows what went on in back rooms while creating that proposal.

The "Loop-Rad" plan was designed by the author to use mostly simple low-cost technology to get maximum regional ridership. The fundamental motivation is different. The "JustPRT" plan is based on a technology that was designed in the 60's from the ground up, specifically to address common public goals that exist in every city, like safety, environmental impact, and transportation equity.

Sensitivity analysis

A sensitivity analysis shows how important a particular variable is. For example, would changing the price of parking affect transit ridership? The ridership model can project this. Changing the average "high" parking costs from \$3 to \$6 would change the Loop-Rad ridership from 15% to 22%. This suggests that parking cost is an important variable, and public policy could be coordinated so that parking costs help a transit system achieve its maximum benefits.

What about fares? Eliminating the \$1 fare would increase the Loop-Rad ridership from 15% to 26%, but would eliminate the operator's revenue. Is it worth it? Fortunately the calculation of "total profit" (public + private) is easy to make in the spreadsheet. This reveals that with the \$1 fare, the Loop-Rad system makes a total profit of 88 M\$/year, and with the fare eliminated and ridership increased, it makes a total profit of 241 M\$/year. Based on that measure, it would definitely be a good idea to eliminate the fare.

There are many other such sensitivity analyses that could be performed, with the aim of optimizing the solution.

Immediate steps in transit service

Besides the recommendations given about the *process* for choosing a good long term strategy, there are various short term steps that can be taken to improve transit service that are supported (loosely) by the findings in this study.

1. Since the main regional bottleneck is the river crossings, dedicated transit lanes could be used on Central, I-40, and Montano. The remaining capacity after transit vehicles are served could be used by high occupancy vehicles, and/or sold using tolls to any driver, using "congestion pricing."
2. A limited scale PRT or GRT system could be installed along part of the proposed loop. This could be, for example, from uptown through the Jefferson/I-25 corridor.

3. Several routes that have been identified either in the Comprehensive Plan or in this study as main routes could be upgraded from infrequent buses to frequent RapidRide-type service.
4. New developments like Volcano Heights could be required to be massively transit oriented, and new RapidRide-type routes should run to those developments.
5. Parking policies should be written to increase transit use, instead of to ensure ample parking availability. Parking and fares should also be coordinated. For example, a business could provide transit passes in lieu of building the required number of parking spaces.

Conclusions

The most important conclusion of this study is that different transit systems perform very differently. All transit is not equal. The push for "more transit" could be counterproductive if we are not careful; we should be asking for government actions that achieve well-stated goals, not just "any transit at all."

This report does not conclude with any recommendation on a specific transit system. Before decisions are made, the following procedural recommendations are offered:

- Goals should be set by a public process
- More systems concepts should be solicited
- The evaluations should be done by a public agency based on this framework.

A longer list of recommendations is given in the companion report.

Areas of improvement for this study include:

- Perform review of the cost models by a qualified economist. For example, with the proper use of net present value (NPV) calculations, the fraction of cost represented by capital cost could be different than what was assumed here.
- Perform review of the ridership models by a second qualified engineer
- Perform more extensive calibration of the ridership model, based on data from behavioral analysis.
- Perform a visual acceptance survey of the alternatives.
- Include the cost of roads and examine the Metropolitan Transportation Plan 25-year budget, to see if focusing money on transit can save money on roads. This study did not take road spending into account.