The Difficulty of Accurate Planning: A Study of Portland's Light Rail Transit System

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"Prediction is very difficult, especially if it's about the future."

– Neils Bohr

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Abstract

A successful public transit system is vital to creating the dense urban areas needed to reduce resource consumption and carbon emissions from fossil fuels. Unfortunately, planning these systems is a difficult task, and misestimating ridership or population growth could lead to an ineffective transit system. Once a certain type of transit network is built it is hard to implement newer, better modes of transportation. For these reasons, it is vital to look at the effectiveness of the public transit planning process. This paper addresses the following questions: 1) How accurate have the estimates used in the planning of the original MAX system been? 2) How have newer MAX projects been planned differently? 3) Are there understandable causes behind inaccuracies and any differences between the historic and recent planning processes? 4) How does Portland compare to other cities in the accuracy of their public transit planning? The original estimates were rather inaccurate, but this accuracy was greatly improved in the plans for later projects. This increase is accuracy is from improvements in the planning process and possibly a lack of political need. Comparisons with similar transit projects in America shows that Portland's planners are good, but not better than planners elsewhere. Although planning has become more accurate over time, it is likely that inaccuracies will always be greater for new technology. New methods, such as scenario planning which attempts to plan for multiple outcomes may be a way to avoid the pitfalls of previous planning techniques.

Public Transit: Why Do We Need It?

Public transit systems are needed to create environmentally sustainable, livable cities, but planning and implementing such a system has proven extremely difficult. Portland's MAX light rail transit system has been heralded as a success story and replicated across the nation, but its original planning process was inaccurate and its current ridership isn't spectacular;; 2,387 boardings per mile compared to Boston's 8,332. These inaccuracies were caused by a combination of two things: the technical difficulty of calculating the costs of new technology and possible political pressures to enhance the original project's viability. Planning estimates have become more accurate over time, but the estimates of Portland's planners are not more accurate than planners in other American cities. This suggests Portland's success is not entirely due to the skills of its planners. Initial inaccuracy in the planning process is problematic because implementing an alternative, more effective public transit technologies over-top an existing system is much more difficult; busses don't run on rails and vice versa. Despite these difficulties, new planning techniques and transit technologies hold promise for our urban future.

Environmentalists have long pointed to suburban growth, increased sprawl, and reliance on personal automobiles as archetypical of our modern dilemma. The American Dream has ultimately created high cost of infrastructure, excessive consumption of land, energy and other non-renewable resources, and social segregation. As more people move from rural to urban communities and their surrounding suburbs, these pressures continue to increase. In 2011, congestion from automobiles resulted in an average delay of 34 hours per commuter, costing the United States more than $100 billion dollars (Schrank and Lomax 2009). This cost is only the value of extra travel time and fuel consumed by vehicles traveling at slower speeds; if included, the negative health effects of particulate pollution and global warming caused by carbon emissions would increase costs even more.

A way to address this issue is to increase the density of urbanization, and design urban areas with transportation systems that enable car-free mobility. The past 50 years of urban development has been influenced by large subsidies for automobile travel; this does not need to be the case. The present car-oriented transit system seems as though it has existed forever, but "objects—built environment, infrastructure—are not unchanging, but the pace at which they are reworked, transformed and destroyed is relatively slow—i.e. 20 or 30 years, even several decades" (Pflieger et al. 2009, 1434). This long timeframe for infrastructure renewal complicates the planning of transit systems; they must be functional in the current, sprawling urban space while simultaneously constraining and directing future urban developments.

One of the main issues in shifting transportation away from private car use and onto public transit in urban areas is the lack of explicit costs car users face. While car users must pay for gas for their vehicle, they often receive free parking, drive for free on roadways constructed by the government, and are not charged for the social or environmental impact of their trips. These indirect subsidies have been calculated in the range of $400 billion to $900 billion per year, and one study concluded that car drivers pay only 60 percent of their total true travel costs (Vuchic 1999, 69). This impedes public transit system implementation because even a well-planned transit system will be underutilized if the costs of car use aren't explicitly paid for while the costs of using the transit system are explicitly paid.

Although many view public transit's main benefit as its ability to reduce car use and its associated ills, it also plays a vital role in ensuring social justice in urban communities. For some, the ability to live a car-free lifestyle is a luxury, but public transit and walking are the primary mode of transportation for many individuals living near poverty level. As Martin Luther King Jr. pointed out, "Urban transit systems in most American cities, for example, have become a genuine civil rights issue – and a valid one – because the layout of rapid-transit systems determines the accessibility of jobs to the black community" (Washington 1991, 57). King's observation is what economists term the "spatial mismatch hypothesis"; while poor, low skill, and low education workers live in the central city, low skilled jobs have shifted to the dispersed urban periphery. Because public transit systems are generally oriented to move workers from the suburbs into the central city, they often fail to meet the needs of those riders that rely on them the most (Sanchez 1999). Planners are incorporating public opinions and direction, but this public is white and wealthy; the issue of justice is not solved.

The creation of a successful, multi-modal public transit system is vital to livable urban areas. More than half the world's population lives in an urban area, and this number is increasing. During peak hours, a car trip requires 25 times more space than the same trip made by bus, and

60 times more space than if the same trip were taken by rail (Vuchic 1999, 55). When you have to build a place to leave your car, you end up with swaths of parking surrounding shopping malls and lots dotting downtowns; these asphalt pads decrease the density of the urban fabric. Considering that both economists and environmentalists view the high population densities of cities as efficient, there is no way current increases in urban populations can continue without a shift away from car-centric transportation systems.

Transit Planning: Issues of Implementation

In order to achieve public transit goals, a long-term vision and associated plans must be created to provide a sort of roadmap to be followed. In Portland's case, planners in 1971 created a transportation plan based on the assumption of the city in 1990, and again in in 1995 city planners worked to create a vision of the city in 2040 (Bocci 2010). While these sorts of plans are vital to maintaining a consistent urban fabric, they are based on uncertain assumptions of the future. If these assumptions, and therefore the plans more generally, are incorrect then isn't it pointless or possibly harmful to build towards these untrue futures? These inaccurate plans may lock cities into path dependent technologies, for there is some sort of continuity in technological change and. This path dependency may lock-in old technology, an inferior mode of development resulting in a loss of competitiveness and decreased economic growth (Scheinstock, 2007).

While one may assume that the people writing these plans are experts, and their opinions therefore trustworthy, this is not necessarily the case. A study of demand forecasts in transportation projects found that 72% of rail and 25% of road project forecasts had inaccuracies larger than ±40%, 9 out of 10 rail passenger forecasts were overestimated by 100%, and the accuracy of these forecasts had not improved over the last 30 years (Flyvbjerg 2005). Efficient transit systems, roadways and railways alike, must be built to accommodate a specific number of passengers; misjudging future users by 40% results in overspending and underutilization or underbuilding and congestion, both of which are undesirable. Psychologists describe this flawed decision-making process "planning fallacy", in which people "make decisions based on delusional optimism rather than on a rational weighting of gains, losses, and probabilities" (Lovallo and Kahneman 2003, 58). While phrases such as "most likely scenario" imply a certain level of security in their planning, this "most likely scenario" occurs much less commonly than one would hope.

Beyond the issue of planning fallacy in creating a public transit system are the actual politics of implementation, consisting of a set of actors each attempting to achieve their own vision of what the city's public transit system should be. Broadly speaking, there are three main actors in planning and building a transit system: the state and city government which plans, the private sector which constructs, and public interest groups which regulate public transit systems through litigation. The government wants to achieve a mandated goal of reduced vehicle miles driven, the private sector wants to maintain profitability, and public interest groups want to protect state policy and counter private sector demands. These groups "work together in an informal network, drawing on and contributing their respective resources to the achievement of a common goal", but each group has a slightly different vision of what that goal should be (Bianco and Adler 2001, 7).

Considering these apparent failings and conflicts of interest in the planning process, one must wonder how accurate the plans and forecasts have been and what political interests dominated in their creation? This question is too large to answer fully, but some insight may be gained by focusing on one aspect: the use of Cost-Benefit Analysis (CBA). In its ideal form, CBA is a method of rationally weighing the benefits and costs of a project of policy, as measured in monetary terms, in order to fairly decide what the best choice is (Pearce 1998). The reality, however, is more complex; how you assign proper monetary values to the benefit from non-tradable goods is unclear. In the case of carbon emissions, for example, the social cost has been valued from less than $1 to more than $1,500 per ton emitted (Intergovernmental Panel on Climate Change. Working Group II. 2008). This uncertainty turns a seemingly unbiased, rational economic tool into a fulcrum that can be leveraged to achieve specific goals. By examining the accuracy of costs estimates assigned it may be possible to extrapolate unspoken political goals and pressures.

Cost Benefit Analysis: A Short Summary

Cost-Benefit Analysis has a long history; in 1808 Secretary of State Albert Gallatin stated the need to compare costs and benefits in water related projects, but it was not until Flood Control Act of 1936 that were legally instructed to build water projects "if the benefits to whosoever they accrue are in excess of the estimated costs" (Pearce 1998, 85). CBA continued to be applied primarily to public water resources such as dams, but its use spread until all government agencies were required to "set regulatory priorities with the aim of maximizing the aggregate net benefits to society, taking into account the condition of particular industries affected by regulations, the condition of the national economy, and other regulatory actions contemplated for the future" (3 CFR 1981, 127). This proclamation made CBA a cornerstone of public works planning.

In general, any CBA consists of multiple stages; although there is no official body governing the process, they are broadly: "defining the project, identifying impacts which are economically relevant, physically quantifying impacts, calculating a monetary valuation, discounting, weighting, and sensitivity analysis" (Hanley and Spash 1993, 8). The specific nature of each of these steps is not vital to our understanding, but the choices made by practitioners in each step are vital to the final outcome of the analysis. One of the more contentious steps is a process called discounting. In effect, a sum of money is worth more if you receive it now than in the future years, and conversely a cost is discounted if it is incurred in the future rather than the present. While there are certainly ethical issues in claiming future generations are worth less than current generations, there are practical issues in discounting too. If a project generates $100 in benefits over 50 years, a discount rate of 1 percent leads to a current value of $61, while a discount rate of 4 percent suggests a current value of $14; there is no standard discount rate used, so the decision is in many ways arbitrary and open to manipulation (Morrison 1998).

In public transit planning, CBA is used as a means of deciding the best option for a transit system. It costs much less to build a carpool lane than a separate rail system, but a rail system may provide benefits which carpool lane does not. Accurate pricing of construction and operating costs, as well as benefits such as reduced air pollution, increased safety, and increased property values are vital to a fair and rational policy decision. While CBA is only a part of the planning process, its opaqueness allows it to be easily manipulated. Furthermore, even if the costs are measured fairly, pricing new technology is inherently difficult. As the technology is adopted, its costs tend to rapidly fall, but it is impossibly to know by how much or even if such adoption will occur.

A History of Portland's Public Transit

Portland, like many growing western cities, has evolved through a variety of transit modes over the last century. The original horse drawn trolleys carrying passengers installed in 1872 gave way to electric trolleys less than two decades later. In the deregulated and highly competitive business environment of the time, multiple trolley lines owned by different people were established. City boosters, financiers, and real-estate developers created many of these lines as a means of promoting new subdivisions, speculating on increases in homebuyers they would provide. As evidence, the founders of Portland's Transcontinental Street Railway Company, including prominent Portlander and future mayor William S. Ladd, almost all had ties to banking or real estate (Bianco 1999).

In this way, Portland's original public transit system was created without a master plan, instead directed by the economic forces of supply and demand and the bourgeois class's desire to increase returns on investment. Because most people did not have horses to travel long distances on, the trolley line was the only way of getting around; if there was no trolley service, you couldn't go there. Because the transit system was vital to the city's daily functioning, bureaucrats wanted to ensure it would operate smoothly, and politicians endorsed improving and expanding trolley lines while maintaining a low, five cent fare (Bianco 1999). These two constituent groups are only a small sample of the actors that shaped Portland's public transit system at the turn of the 1900s.

It is important to note that no individual force shaped the transit system in a meaningful way; a combination of laws, economic interests, ridership preferences, transit employees, and available technologies were all interacting in their attempts to shape the transit system in their own interests. The rapid changes between these actor relations are exemplified by the rise of jitney use in Portland around 1914. Jitneys are privately operated multi-passenger vehicles, basically small busses operated on predetermined routes. Rising unemployment created a huge workforce to operate this new transit mode, and although transit company officials protested their profit losses, Portlander's city council and citizens in general were unwilling to massively restrict Jitney's as had been done in other cities; their use declined not due to government regulation but from rising levels of employment after World War One (Bianco 1999).

Although it did not result in lasting changes to the city's transit regime, the jitney disruption illuminates the distant forces that can directly influence local action. New technologies in vehicle manufacturing, nationwide economic depression created workforce, and Portlander's historic distrust of business all functioned together to create a climate in which the jitney could prosper. As theorist Bruno Latour says, "although every state of affairs deploys associations of *mediators*, everything is supposed to happen as if only chains of purely passive *intermediaries* were to unfold" (Latour 2010, 482). In Portland's case, passive intermediaries would be the intersection of humans and new transit technology, where improvements in mobility are passed along as new modes are created; we simply pick the best mode in the moment. This view is flawed; it was the associations active mediators: state economies influenced by capitalist business cycles, enterprising individuals influenced by this downturned business cycle, city officials influenced by a history of libertarianism, all dynamically turning and tumbling together to create a seemingly singular state of affairs in any one moment.

We may try to examine individual processes, momentary events, anything in isolation, but to do so is to ignore our reality. Any planning is relies on assumptions for the future, based on knowledge of the past. However, if any situation is the result of numerous forces and actors, the past may not provide a useful bearing on the future. The more limited a planner's methodology is in the actors it accounts for, the more likely the planner's forecast will be wrong.

After World War One, streetcar lines began shutting down as automobiles became more affordable and commonplace. Funding which had been use to expand streetcar service and maintain the trolleys was used to convert equipment for automobile operation instead (Bocci 2010). This conversion toward trackless transit was logical, considering that transit firms had to pay for their own rail maintenance, yet Federal and State governments were expanding roadways. The Oregon State Highway Commission at the time reported "Federal aid for highways in now a well-established governmental policy…the entire system covered by the present state highway map…will be open to travel" (Oregon State Highway Commission 1922, 22) **[ZOTERO]**. This shift towards auto over rail travel resulted from a combination of subsidies in road improvement, lower replacement as compared to maintenance costs, and increased population growth on Portland's Eastside in places where streetcar lines didn't exist.

Portland's transit system remained successful at serving the its growing population, even when its streetcars had been replaced by trolleybus, and a multitude of private owners had been bought out by PGE. At its peak in 1944, transit ridership in the region was 160 million people, mostly as a result to constrained car usage during World War II. However, as wartime restrictions on automobiles ceased, suburban expansion increased beyond the old transit networks; ridership plummeted to 28 million by 1958 (Bocci 2010). As ridership continued to fall, Rose City Transit, the area's main transit provider, stated that it must either initiate a massive fair hike or discontinue all service. In response, Portland City Council passed a resolution creating the Tri-County Metropolitan Transportation District of Oregon (TriMet) to take over operations. In this act, the Portland metropolitan area gained a new type of transit company, responsible to tax-payers, integrated with city planners, and focused on the long-term future of public transit in Portland.

TriMet and the Portland MAX

Shortly after TriMet was created, a study of the Portland-Vancouver Metropolitan area concluded that 54 new highway projects would need to be created by 1990 to keep pace with the region' growing automobile use. These improvements had an expected price of $2 billion (in 1969 dollars), and would focus almost entirely on infrastructure for private automobiles. One of these proposed improvements slated for construction at the time was the Mt. Hood Freeway. This freeway was planned to run from Johns Landing out to Gresham, generally following the route of Powell Road. In order to be built, over 900 homes, apartments, and businesses were slated for demolition (Portland Planning Comission 1965, 41). Although a coalition of concerned neighborhood activists attempted to halt construction, they made little progress until then City Councilmember and soon to be Mayor Neil Goldschmidt stepped in.

Goldschmidt and the Oregon Transportation Commission petitioned the Federal Government to allow a shift of funds from the Highway Trust Fund to be used for public transit instead. Until that point, the construction of highways were massively subsidized by the Federal-aid Highway Program, which was funded by a tax on gasoline; the money could not be used elsewhere. The Federal Aid Highway Act of 1973 allowed for a State to not build an unpopular urban interstate, and receive the equivalent amount of funding for other transportation projects (Pub.L. 93-87, 1973). In the summer of 1974, Portland's city council voted to kill the freeway; Commissioner Connie McCready explained, "This freeway will hurt the people inside the city to the benefit of those outside" (highway to hell). The money gained in the transfer was used to fund the construction of MAX light rail and other improvements along Banfield Corridor, as well as other transportation projects in the area (Thompson 2006). The Federal funds transferred from the Mount Hood Freeway accounted for 83 percent of the total project costs (TriMet 2004).

Once one unpopular freeway had been deleted from the region's future and replaced by light rail, the expansion of the light rail system over new freeways became the norm. The original Eastside MAX was completed in 1986, followed by a Westside extension to Hillsborough in 1994, a line to Portland International Airport in 2001, and a line to North Portland in 2004. Along with the new MAX system, TriMet expanded their bus network; as a result of these improvements, total transit ridership in the Portland area increased from 35 to 105 million people between 1978 and 2010 (Bocci 2010).

With its past successes, Portland Metro and TriMet are continuing their light rail expansion. A line from connecting Portland to Milwaukie is slated for completion by 2015, and a new highway bridge over the Columbia River is planned to continue the line into Vancouver. All of this is a part of Metro's 2040 regional plan, which guides planning and investment for all sorts of transit infrastructure, from sidewalks to carpool lanes (Metro, 2012). While the city has such plans, are they being executed in the most fair, cost effective way possible, with alternative possibilities being examined?

Research Questions

The primary question I am attempting to answer in my research is: How accurate have the estimates used in the planning of the original MAX system been? Secondary questions that arise from this inquiry are: Given past inaccuracies, how have newer MAX projects been planned differently? If these planning differences exist, are there understandable causes behind them? Lastly, how does Portland compare to other cities in the accuracy of their public transit planning?

Methodology

While there are a variety of ways to examine the planning process, this research focuses around the estimations that TriMet planners made in 1980 before building the Banfield Project MAX line. These estimations exist in two broad categories, the first is "population characteristics", and the second is "pricing characteristics". Population characteristics include: projected population changes, vehicle miles traveled, and the number of passengers. Pricing characteristics include: construction costs, annual operating costs, and cost per passenger. In 1980, these metrics were estimated for 1990; comparing the estimates with reality will provide a sense of how accurate the planning process is and which aspects of the planning process are prone to inaccuracy.

Because the Portland MAX system continues to be expanded, there are similar versions of the 1980 planning documents, updated for 2010 with estimates about Portland in 2040. I will compare the 1980 and 2010 documents to see if and how the planning process has evolved over the last 30 years. If the original estimates were inaccurate, how has the planning process been updated to reflect this? If the original estimates were accurate, then has the planning process been changed in ways that may hamper its future effectiveness?

Once an understanding of accuracy in Portland's planning process has been reached, the geographic scope will be expanded to other U.S. cities with similar transit systems. By comparing Portland to other cities, some perspective can be gained on the hype surrounding Portland's transit system; it is ranked highly by major news sources, but is this due to the skills of the city's planners or publicists?

Data Collection: 1980-1990

The data for the 1990 estimates was found in the *Banfield Transitway Project Final Environmental Impact Statement*. The National Environmental Policy Act of 1969 requires these statements for actions "significantly affecting the quality of the human environment" (Congress 1969). In the case of the Banfield project, the Oregon State Highway Division and Tri-County Transportation District produced the statement for the U.S. Department of Transportation. The 489-page document details five solutions to Portland's increased travel demand. These consisted of: building nothing, creating express bus lanes and other traffic improvements on city arterials, building two high occupancy vehicle lanes on the freeway, building a separating busway along the freeway, or building a light rail line along the freeway (TriMet 1980). The light rail was chosen as the best option, this research therefore focuses around its related estimates.

This document contains a figure listing estimated project construction costs, 1980 operating costs, cost per passenger, and vehicle miles traveled (TriMet 1980, fig. 2–1). Elsewhere in the document were estimations of daily passenger use, and population growth for the area. The estimations have been recreated in the table below.

Table 1 – 1980 Estimates

CONSTRUCTION COST (millions)	ANNUAL OPERATING COST (millions)	TOTAL ANNUAL TRANSIT COST PER PASSENGER	VEHICLE MILES TRAVELED (millions)	AVERAGE WEEKDAY RIDERS	POPULATION GROWTH BY 1990
$108.5	$25.8	$0.48	971	45,500	47% increase

In order to gather 1990 data for each metric, a variety of sources were used. Construction costs, operating costs, cost per passenger, and weekday riders were collected from various TriMet publications. All monetary amounts were adjusted for inflation to 1978 values, as used in the 1980 report. Population data was collected from the US Census Bureau, and data for vehicle miles traveled was provided by the Oregon Department of Transportation. Some of the original definitions in the report, especially for vehicle miles traveled and population increase are vague but that issue will be addressed in the analysis. The 1990 data has been recreated in the table on the following page:

Table 1 Sources: Data from TriMet 1980

Table 2 – 1990 Values

CONSTRUCTION COST (millions)	ANNUAL OPERATING COST (millions)	TOTAL ANNUAL TRANSIT COST PER PASSENGER	VEHICLE MILES TRAVELED (millions)	AVERAGE WEEKDAY RIDERS	POPULATION GROWTH BY 1990
$127.04	$34.6	$0.67	2,709	22,000	9% increase

Data Analysis: 1980-1990

In order to gage the accuracy of each metric, the percent error between the 1980 estimate and the 1990 value was calculated. This is calculated by taking the difference between the measured and estimated value, dividing this difference by the measured value. This resulted in a percentage of relative error, which can then be compared across metrics. A positive percent error indicates that the estimate was larger than the measured value, and a negative percent error indicates that the estimate was smaller than the measured value. The percent error is presented in Chart 1 below:

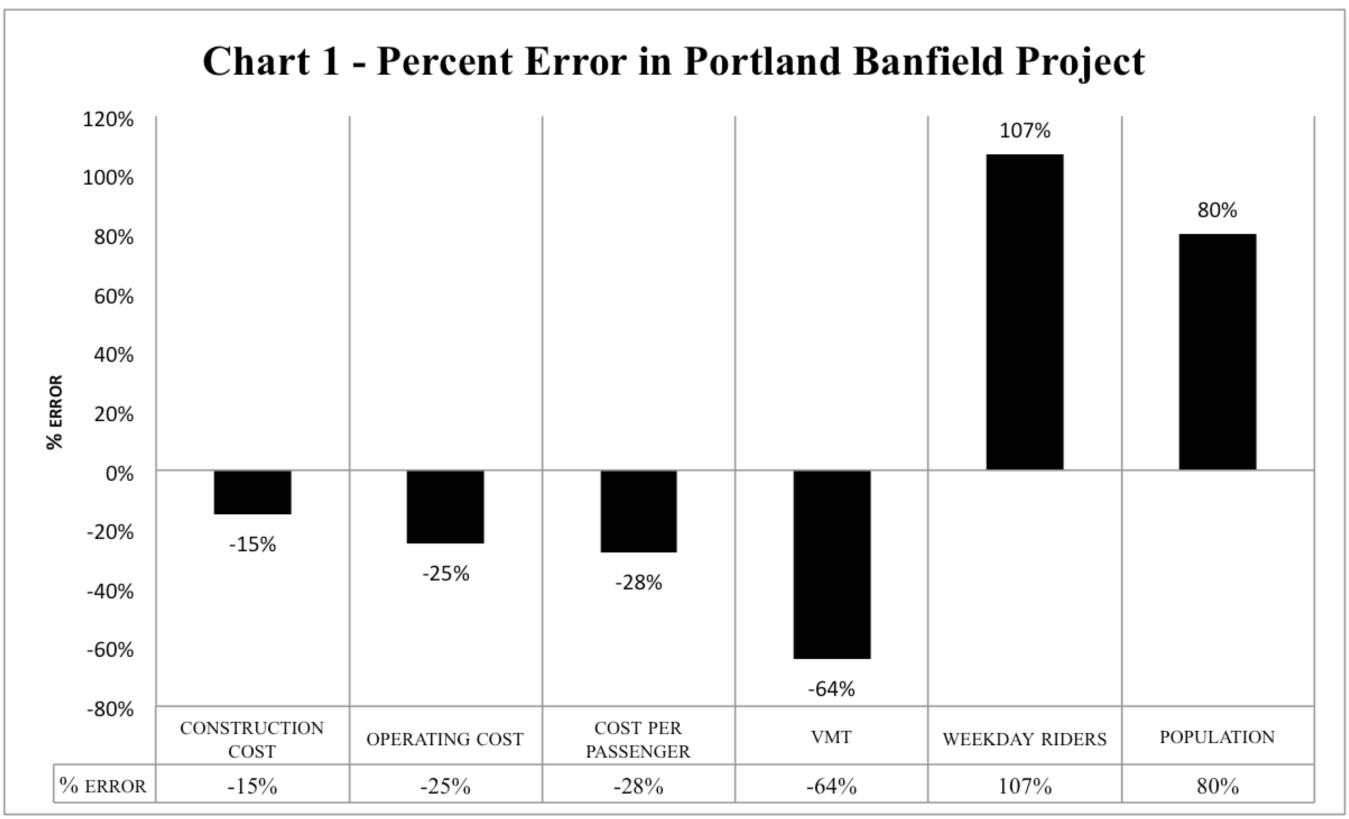


Table 2 Sources: U.S. Census of Population and Housing 1991, TriMet 2002, TriMet 2009

On average, the absolute measured value in 1990 differed from the 1980 estimation by 53.3% Breaking these results down into population characteristics and pricing characteristics shows that on average pricing estimates were 22% inaccurate, while population estimates were 83% inaccurate.

The project's construction costs exceeded estimates by 15%. In the realm of large public works projects, especially transportation, this is a surprisingly small amount. Studies show that on average, rail construction projects exceed costs by 44.7% (Flyvbjerg and Holm 2002). In this regard, Portland's planning process is more accurate than most, but an interesting disparity appears when reading TriMet's official literature. On their website, TriMet states that "All five MAX projects (Eastside, Westside, Airport, Interstate and the Green Line) have been completed on or ahead of schedule, and on or under budget" (TriMet 2012). The logical explanation of this discrepancy is that TriMet is basing this statement off of a later estimate. Construction didn't begin until 1982, two years after the environmental impact statement was published. As planning proceeded and more detailed plans made, a more accurate cost estimation should have emerged. This statement by TriMet is not therefore true, but it could be seen as sort of manipulation by the agency to increase the attractiveness of light rail and justify further expansion of the system.

The annual operating cost in 1990 was 25% higher than the 1980 estimate. In an earlier report studying European light rail systems, the Tri-Met planning and development department stated that "…an initial impression is that the Banfield LRT operating costs are understated by roughly 25% to 35…" (Jermain 1978, 32). It seems that planners were correct in their estimation that costs were understated. This leaves the question, if planners knew that costs could be understated, why didn't they inflate their estimations as appropriate? This may indicate some purposeful manipulation on the part of planners to make light rail operations appear cheaper than other transit options.

The net operating cost per passenger was 28% higher than estimated. This is in line with the higher than projected operating costs, as they are directly related. One of light rail's advantages is its high capacity, which decreases costs per passenger. However, this benefit is only actualized if the line is able to achieve high levels of ridership. In the case of the Banfield line, to system did not achieve its expected ridership by 1990, increasing costs per passengers beyond the 1980 estimate.

The vehicle miles traveled were estimated to be 64% lower than they were in 1990. The environmental impact statement states that the use of Light Rail was chosen because it "would provide the best overall levels of traffic and transit service" (TriMet 1980, sec. 2–52)**.** Research of transit systems conducted when the statement was written had shown that individual people tended to view transit as an inferior good. That is to say, as a user's income rose, they chose to use personal automobiles rather than public transit. Studies of impacts from higher gasoline prices, increased parking chargers, and increased bridge tolls showed that these factors had little impact on the movement of people from autos to transit (Lave 1978, 298–299). Although it was cleaner and safer than busses, light rail still faced the issue of shifting drivers out of an urban geography which had co-evolved to support automobiles. The smaller than expected reduction in vehicle miles suggests that planners were optimistic in their expectations of this new transit mode. Since its construction was justified by the positive environmental impact of less vehicle miles, it is important to see how the current MAX projects are being justified.

The average weekday ridership was estimated to be 107% higher in 1990 than it actually was. This number is in line with other rail project forecasts, which overestimate passenger ridership by an average of 105.6% (Flyvbjerg 2005, 133). Fares cover around half of light rail's operating cost, so low ridership numbers means that it takes longer for construction costs to be paid off due to reduced passenger revenue. A survey of researchers and project managers found that over 50% of inaccuracy was caused by "uncertainty about trip distribution" and "deliberately slanted forecasts" (Flyvbjerg 2005, 139). While it is impossible to know if Portland's planners increased their estimates deliberately, the 107% overestimation the largest of all the studied metrics.

The estimated population growth was 80% higher than actual growth by 1990. The environmental impact statement discussed an expected growth of 47% in the East Multnomah County area, but did not define this area. To get 1990 population data, the percentage growth of Portland City and Multnomah County was averaged. Maps of population densities in 1980 and 1990 show no particular growth in the east side of Portland, so while the 80% error may not be truly accurate; the general trend of overestimating population growth is still valid (PBS, 2012). One possible explanation for this overestimation is the implementation of an urban growth boundary in the Portland area in 1980. This boundary controls urban expansion onto farm, forest, and resource lands by limiting where new construction can take place. While the effectiveness on this boundary has been debated, in 1990 40% of new housing was constructed outside the urban growth boundary, and 26% of the new housing was constructed in Washington State (Jun 2004, 1343). The light rail line was constructed completely within the boundary; the planners overestimated the impact of the urban growth boundary in directing development & misunderstood the area's future growth patterns in their estimates.

In general, the estimations made in 1980 were far from accurate when compared to their actual values in 1990. Estimates about prices tended to be lower than actual values, while estimates about populations tended to be higher than actual values. Considering the inaccuracy of these metrics, it is now necessary to examine current planning documents to see if similar metrics are being used, and how inaccuracies are being accounted for.

Data Collection: Current

Since the 1986 Banfield Transitway Project, the MAX system has been expanded to 4 lines with 52 track miles and 85 stations. The system runs East/West from Hillsborough to Gresham, and North/South from Clackamas to Portland International Airport, as well as from the

North from the Rose Garden to the Expo Center. The most recently planned expansion is along the South Corridor, which runs from Milwaukie to Downtown Portland, crossing the river close to OMSI. This route was chosen for study because it is the most recent line that is currently under construction, so planning documentation is finalized and readily available. The primary document used was the *Portland-Milwaukie Light Rail Project: Final Environmental Impact Statement* from 2010. Since it is impossible to compare the estimates made in this document to their real costs, the analysis of this is inherently more qualitative than quantitative. However, quantitative comparisons have been used wherever possible.

Data Analysis: Current

Construction costs for the project are estimated to be $1.15 billion in 2010 dollars. While the 1980 statement provided little explanation for how that number was reached, the 2010 document details costs into 10 categories. This suggests that planners are constructing these estimates with more care than 30 years ago. The Banfield MAX line cost roughly $8.5 million dollars per mile, where the South Corridor line is projected to cost $47.6 million per mile in 1978 dollars. While this 5x increase in cost may seem large, the project includes a bridge over the Willamette River, 11 elevated track structures over roadways, and the creation of 1,400 new parking spaces for park-and-ride structures (TriMet 2010, S-14). Considering that the Banfield line followed an existing freeway for most of its route, these increased per mile construction costs on the South Corridor line appear appropriate.

Operating costs for the South Corridor project are estimated to be $37.61 million in 2010 dollars (TriMet 2010, 2-42). For comparison, in 1990 the Banfield project cost $56.9 million dollars when adjusted to 2010 inflation rates. The lines are fundamentally different; the Banfield line is almost twice as long, and has 6 more light rail trains running on it than the South Corridor line. While this difference may explain the significantly lower operating cost, there are still some interesting comparisons; increasing the 2010 estimate by 25%, the same amount that the 1980 estimate was off by, results in an operating cost of $47 million. This seems more appropriate given the Banfield line’s operating costs. The majority of the operating cost consists of equipment maintenance and vehicle operation, even with six fewer vehicles the South Corridor will face similar costs to the other light rail lines. Although there is no way of knowing, the estimated operating costs seem low when historical operating costs are taken into account.

No explicit operating cost per passenger is given in the planning document. This suggests that the metric is no longer useful in the planning process. Because it requires estimation of both operating cost and ridership, estimates of operating cost per passenger have two factors that contribute to inaccuracy. However, the Environmental Impact Statement states that, “operation and maintenance costs for the Portland-Milwaukie Light Rail Project are based on ridership forecasts for 2030 and on the resulting transit operating plan that would accommodate that ridership demand” (TriMet 2010, 5-28). So, although the metric is not explicitly used as a justification of costs, operating costs are still calculated on passenger estimates; this still leaves the possibility of inaccuracy in both the cost and ridership calculations.

The project is estimated to decrease vehicle miles traveled by 66,100 miles in the year 2030. As in 1980, the reduction of vehicle miles is a top priority for the project because congestion is expected to grow by more than 70% in South Portland and more than double in Milwaukie by 2030. The projected changes are segmented into nine areas, indicating a more careful examination of the projected increases. Interestingly, most of the projected increase in vehicle miles traveled occurs in areas beyond the Southern end of the line. While users in these areas will be able to drive their cars to Park-and-Ride lots, this does not reduce the vehicle miles traveled in those areas the line doesn't reach.

An estimated 25,570 daily trips on the South Corridor's light rail are expected to take place by 2030. An interesting development in the ridership estimation process is the incorporation of socioeconomic characteristics from census data of the area. Recognizing that low-income and minority populations often rely on public transit, planners calculated percentages of minority and sub-poverty riders within a quarter mile of stations. Furthermore, estimations of station usage (ons and offs) by mode of access are provided for each station along the corridor. Estimating population 20 years from now seems difficult, considering how closely population movements tie to national economic trends. To account for this, the planners also estimated an average weekday ridership of 19,500 in 2016, when the line is slated to open. Although more estimations does not necessarily result in greater accuracy, the increased level of detail suggests that the planners are attempting to construct more accurate estimates.

The South Corridor transit system is being built not only to provide a car-free transit option, but also "to accommodate 720,000 additional residents…while limiting the expansion of the urban growth boundary" (TriMet 2010, 1-6). Household growth in the corridor is expected to increase by 59% by 2030, which is higher than expected regional averages; employment in the corridor is expected to be lower than the region-wide average. Like the daily trip estimations, these population and employment estimates are done for specific districts within the corridor. This suggests that these estimations may end up being more accurate than their 1980 counterparts, assuming they aren't being inflated for political reasons.

In general, there appear to be efforts made to increase the accuracy of estimates for both economic and population factors in the 2010 planning documents, but these are not consistent for each metric. There is no explicit mention of the inaccuracies of the 1980 environmental impact statement, but there is evidence that more care is being taken in the 2010 estimates. Most of this is seen in the increased number of estimates for population characteristics, specifically ridership by stop and population growth by sub-area. The significantly higher estimate of per mile construction costs and the disuse of cost per passenger are also examples of positive efforts in increasing the accuracy of estimates. The estimation process for future vehicle miles traveled is more detailed than the 1980 estimate, but the use of these estimates in the impact statement seems misguided; if most increases are expected to occur outside of the corridor, the total reduction in vehicle miles traveled may be limited. The estimate for operating costs appear low when compared to the Banfield Corridor's operating cost; even though the South Corridor is only slight smaller in the number of cars on the line, it has significantly lower operating costs. These sorts of disparities suggest that there is still some political maneuvering in the creation of estimates, even if the general trend is towards increased accuracy.

Discussion

Using a broader perspective of the economic and political climate at the time, some interesting observations can be made about the 1980 and 2010 planning processes. In 1980, the main goal was to develop a planning system that could be accepted and implemented in a short time frame, because otherwise the diverted freeway funds could not be used. Mayor Goldschmidt did not consider light rail to be the best way of achieving this, and the entire light rail option was actually defined in a footnote to the Governor's Task Force on Transportation (Thompson 2006, 10). In some ways, this was a battle between TriMet and the Oregon Department of Transportation (ODOT); if busways were built than ODOT would have managed the project, but TriMet was able to lay claims to running the light rail system because it was clearly outside of ODOT's management expertise. Despite its disfavored beginnings, the light rail system was implemented with a goal of stemming automobile use and revitalizing downtown. One of the main assumptions about the light rail system was that it would integrate with a system of feeder busses. Feeder busses are busses running on routes to the rail line where people then transfer from bus to rail, avoiding car use entirely. In a crafty bit of calculus, these feeder bus lines are counted not towards the rail line they support, but towards bus system costs. This made light rail more appealing than bus expansion, even if it costs more to build. The overstated ridership levels and understated reduction in vehicle miles traveled are logical considering the project's goal of revitalizing downtown and reducing automobile use. If the estimates weren't convincing, the project may have never gotten off the ground.

In 2010, with the MAX system securely entrenched within the fabric of the city, planners' goals shifted more towards directing development and providing transit to specific places. Developers of waterfront property to the South of Downtown as well as OHSU, one of Portland's largest employers view the new MAX line as a means of generating profitability; reductions in parking expenses and easy access to the Eastside are concrete reasons for these powerful entities to promote transit stops at their front door. Instead of relying on feeder busses, the South corridor project is using a much larger system of Park-and-Ride lots. These are lots where people can park their car along the rail line and finish their commute by taking the train into the city. One possible problem with this system, as seen with San Francisco's BART, is that the parking lots may reach capacity before the transit system does. This leads to possible transit users still using their cars, because the inconvenience of finding a parking space by the rail line is larger than the cost of parking at their downtown destination (Ceder 2006). This is an increased accommodation of car users who may be new to transit, reflecting the continued rise and dominance of the automobile as a transportation mode despite the current light rail system.

One of the major successes of the Banfield corridor trying to be recreated with the South corridor is the promotion of development near the MAX line. Nearly 5 billion dollars in development occurred within walking distance of stations the Banfield line (TriMet 2009) . The South Corridor line passes through a few town centers and is generally close to highly populated areas, so expecting a lot of new development as a result makes sense. This may have made it possible to raise construction cost estimates, with the knowledge that taxes revenues from increasing property values would pay off those costs in a reasonable time frame.

Although the planning process has evolved, it does not seem to have fundamentally changed over the last 30 years. The major documents and their requirements are very similar in 2010 as they were in 1980. While the modeling techniques and computing power used to solve them were certainly worked and increased, there is little evidence to show these technological advanced have led to more accurate estimations. One of the more important developments has been the adoption of a regional framework plan, which places transportation in a regional context united with all of the land use policies and requirements: the urban growth boundary, urban design, parks, housing density, and more. There are 10 goals for transportation, and while some of them are standard transit goals: expand transportation choices, promote environmental stewardship; there are others which show a more cohesive worldview on the role transportation: fostering vibrant communities, sustaining economic prosperity, ensuring equity. These latter goals are certainly valuable, but too much focus on these larger social goals may hinder the transit system's primary goal; getting people where they need to go. Even though the MAX system still feeds from the suburbs into downtown, half of Portland's jobs are located outside of the downtown area (O'Sullivan 2009). And while there is an increased focus on social equity, many jobs downtown are managerial and corporate. There seems to be a gap in the transit system planners want to build, and the one currently being built. The planning process is still based on future projections of what Portland will look like in 30 years, or perhaps what planners hope Portland will look like. Unfortunately, this is a fundamental flaw that may be impossible to avoid; there must be a future to plan for, even if that same future is bound to change in unpredictable ways. While the regional framework plan does not promote light rail transit as the only form of transportation, it does not explicitly promote brand new modes of transportation.

The city of Portland and TriMet are no better at planning or estimating future costs and ridership than any other planners. TriMet currently has a $18 million budget shortfall, which is being addressed by increasing ticket prices, ending the fareless square downtown, and huge cuts in the administrative budget. Many transit companies are facing similar budget issues, highlighting a false assumption underlying their visions of the future: steady economic growth. This issue is perhaps not an issue of planning for the individual MAX lines themselves, but speaks to the overly optimistic frameworks planners and humans in general use when thinking of the future. Part of light rail's appeal in the 1980s was in its insulation from rising gas prices.

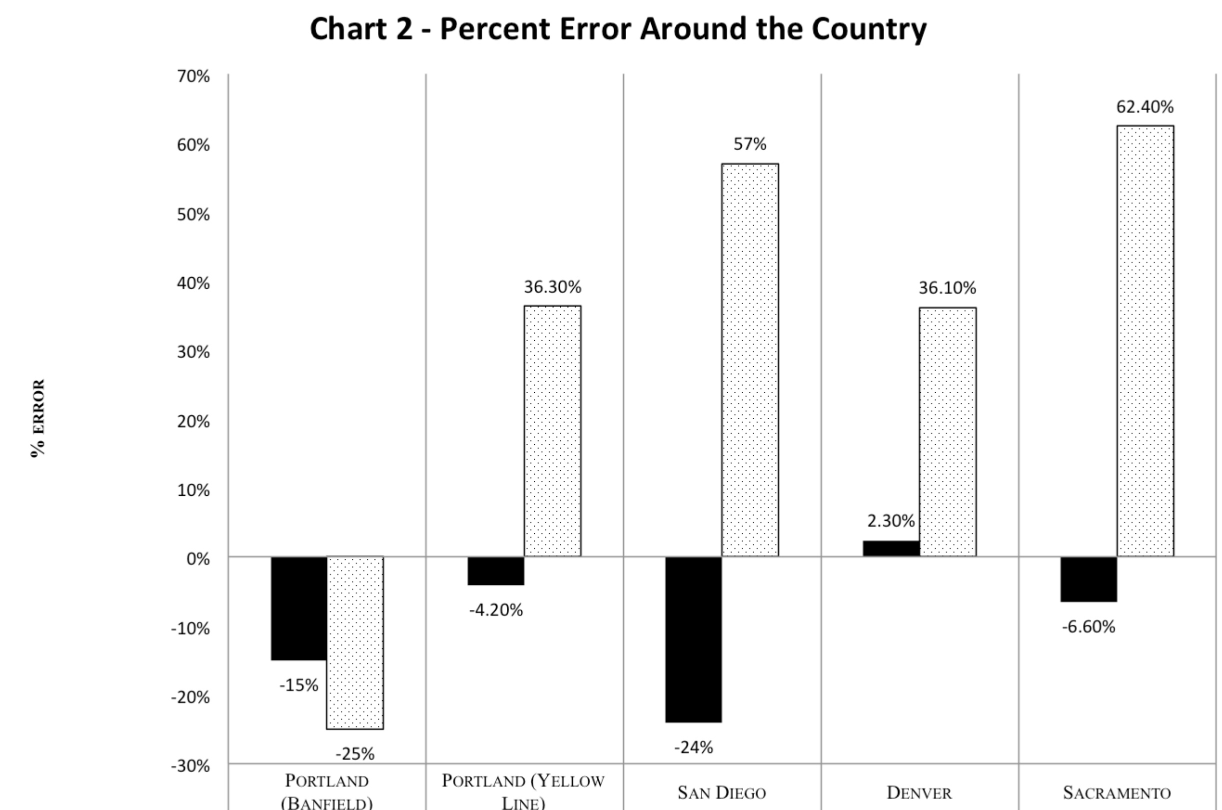
With the recent rise in the price of gas, the electrically powered MAX should become gain some cost effectiveness for drivers, but so far this has yet to dramatically increase ridership (TriMet 2012). Considering TriMet's large operating deficit and MAX's high construction costs, one must wonder about other options. Preliminary planning documents for the South Corridor mentioned the feasibility of bus rapid transit, which involves giving larger busses their own separated right of way. Such systems are operated successfully in Brisbaine, Australia and Bogota, Columbia, and are generally cheaper to construct than light rail by $21 million per mile (General Accounting Office 2001). Perhaps Portland is facing constraints from path dependency; the longer a certain technology or practice has been adopted, the more difficult it becomes to move away from it. The light rail is a symbol of the city's political progressiveness, environmental consciousness, and willingness to move beyond the status quo. To move away form light rail could then be seen as a defeat, as an expression of planning failure and wrong sightedness in the Portland ethos more broadly.

Despite, or perhaps due to the accuracy issues in the 1986 Planning process, Portland and other city planners around the country have the accuracy of their estimates. The original Portland MAX project was one of the first modern light rail systems in the country, preceded only by projects on San Diego and Buffalo. Since MAX's construction, light rails have grown in popularity; 24 light rail projects have been built around the country since 1988. An examination of some of these other light rail projects shows that cost and ridership estimations have become more accurate over time, and that Portland's planners aren't more accurate in their estimations than other planners.

In a 1990 study of ten major capital transit projects, the Federal Transit Administration found that none had ridership greater than 72 percent of their forecasts, and nine out of the ten projects had achieved less than 50 percent of their forecasted ridership. Capital cost estimates were also inaccurate, with costs exceeding estimates by 50 percent (NSPA 2007, 2). A study of 21 major capital transit projects completed between 2003 and 2007 found that both capital cost and ridership estimates were much closer to actual costs and ridership than previous transit projects. On average, actual construction costs exceeded estimates by 11.8 percent. Furthermore, the projects are expected to carry 74.5 percent of their estimated ridership levels.

This increase in accuracy contradicts research on transit projects globally, which had found that newer projects were no more accurate than estimates made 30 years earlier. The FTA study only observed new-start projects, a specific funding program for supporting locally planned, implemented, and operated transit systems which run on a fixed guide way. This suggests that the new-start program is promoting better planning than the average transportation initiative. A unique aspect of this program is that 80% of the capital costs of these state run projects are covered by Federal funds. Perhaps this joint funding leads to greater accuracy on the State's part to ensure funding for future projects.

A sample of four light rail projects completed between 2003 and 2007 provides a more nuanced view of percent error for capital cost, operating cost, and ridership. A positive percent error indicates that the estimate was larger than the measured value, and a negative percent error indicated that the estimate was smaller than the measured value. They are presented in chart 2 below:



	Portland (Banfield)	Portland (Yellow Line)	San Diego	Denver	Sacramento
■ Construction cost	-15%	-4.20%	-24%	2.30%	-6.60%
□ Operating cost	-25%	36.30%	57%	36.10%	62.40%

The construction cost of Portland's 1986 Banfield project was 15% higher than expected, while the 2004 Yellow line project's operating costs were 4% higher than expected. This is a concrete example of increased accuracy in the estimation process. The Yellow line was the third line the city constructed, and it seems that by this time they had a much better understanding of the costs. The operating cost of the Banfield project was 25% higher than expected, while the Yellow line's operating costs were 36% lower than expected. Although the Yellow line's estimations were more inaccurate in absolute terms, the overestimation of costs is preferable to the underestimation and tends to be in line with estimations in other cities.

When compared to other cities, Portland's planers provide accurate, but not the most accurate estimates of costs compared to other cities. Denver's actual capital cost was 2.3% below their estimate, while Portland's was 4.2% higher. Not only was Denver's project cheaper than expected, its actual cost was closer to the estimate than Portland's. This level of accuracy is even more impressive considering the different scale of the two projects. A larger project means that any errors in estimations on a per unit basis are multiplied during construction, increasing the difference between estimated and actual costs once the project is complete. Denver's 19 mile project cost $850.8 million compared to Portland's $310.6 million, 6 mile project.

Both Portland and Denver's operating costs were 36% lower than estimated. San Diego and Sacramento's operating costs, on the other hand, were 57% and 64.4% lower than estimated. While it may seem better to be in the California city's position of having much lower operating costs than expected, accuracy is still an issue. If operating costs must be set aside, over-estimating them may lead to unwarranted underfunding of other needs in the city.

The accuracy of the ridership estimate for all four projects is impressive. Each project is estimated to be within 20% of its estimated ridership number at whatever future date the estimate is made for. Portland's ridership is noted in the study as being able to "easily achieve" this goal, a distinction which is not made for the other projects. This exemplary ridership is the result of Portland's longer-standing commitment to promoting urban infill as opposed to suburban development. This is a huge improvement over Portland's original ridership estimates, which were over 100% higher than the actual ridership numbers.

Out of the 21 projects reviewed in the study, 12 were light rail, 4 were commuter rail, 4 were heavy rail, and 1 project was bus rapid transit (BRT). This dominance of rail in the new starts program is surprising. A study conducted by the US Government Accountability Office found that BRT systems were more effective than light rail: BRT systems had significantly lower capital costs per mile, operating costs per vehicle mile, and higher average speeds (GAO 2001). Although some transit planners debate these claims, if BRT is more effective than why isn't it being built? The most obvious answer is that our fixed guide public transit system is constricted by path dependencies supporting rail infrastructure.

Path dependence is simply the idea that history matters, basically that the choices made in the past affect the possibilities of the future. In the case of transit, railroads and trolley lines had been built earlier in the century. Even as the popularity of the railway diminished, the tracks and right-of-ways persisted; this allowed for newer rail systems to be superimposed over old routes, sometimes even making use of existing track. Once a rail system starts to be redeveloped, building non-rail fixed transit systems such as BRT becomes less likely. The interconnecting of transit lines is vital to the effectiveness of the system as a whole, and building connections between different modes is more complex and expensive than expanding the network using a single mode. Although BRT may be a better transit mode, it is unlikely to gain traction in cities that have already chosen to build out their rail networks. This is simply an unfortunate reality of the current situation.

This path dependency is an issue if the initial planning process does not take the inevitability of inaccuracies into account. Poor estimates don't affect just one project, but every project that follows it. This increases the impact of initial accuracies by a huge amount; even if estimations are more accurate, the cost of being stuck in a single paradigm is massive. Planning which acknowledges unknown future developments is difficult to execute, and has yet to be adopted by Portland's planners.

Closing Thoughts

It is possible that public transit may be one of those issues that work itself out through time. Urban living presents the current standard of life, but with increasing urbanism and prosperity comes a desire and ability to move back out to the countryside (Jørgensen 2012). Alternative energy sources may decrease some of the negative environmental impacts of automobiles; in particular the reduction in particulate pollution and carbon emissions by adopting fuel cells or electric vehicles (Van Mierlo and Maggetto 2007). Research and development in self-driving automobiles are being made by Google, which could lead to the end of stop and go traffic and long waits at red lights (Henn). The acceptance of smaller vehicles, such as SmartCars and more progressive parking fees, such as charging different amounts on each block depending on demand could reduce the amount of land required for parking in cities (Gordon).

These predictions are of an unlikely future, but even if there is no need for public transit systems in the future large public works of other sorts are still going to be planned and constructed for other reasons. The conclusions reached above suggest that, although cost-benefit analysis and cost comparisons more broadly have been used in the past for a large variety of projects, they may not be useful in certain situations. It is certainly successful in projects involving shifting natural resources controlling, such as building levies and dikes, as that is what the methodology was developed for. However, when the projects involve some sort of human interaction, the inaccuracies of cost prediction increase so much as to make the entire system of analysis invalid. This is not to say that the methodology is a bad one, only that its wide application across so many issues may not be appropriate.

It has been shown that by looking back to similar projects instead of thinking about their own, planners can greatly increase the accuracy of their estimates (Lovallo and Kahneman 2003). This reference-class forecasting is a step in the right direction, but it still has the downside of assuming the future will look similar to the past. A possible solution to this exists in the concept of scenario planning. Scenario Planning requires planners to consider multiple realistic versions of the future, and attempt to develop a plan that will remain successful no matter which scenario plays out (Schwartz). In the case of public transit, this could mean developing transit systems with can be more easily updated with new, different transportation technologies. There are downsides of course; this sort of planning required more work and resources, and there is still no way to account for every possible scenario. However, it seems to be a plausible framework to increase the functionality, if not accuracy, of the planning process.

For the field of environmental studies, and environmental policy and planning more broadly, this insight into the failures of planning pose an important question. If there will always be a level of uncertainty surrounding any particular future, and if seemingly straightforward estimates are wrong, what levels of uncertainty of wrongness are acceptable? As a field, environmental studies is well equipped to figure out a baseline of acceptability based on a study of planning inaccuracies and their associated environmental impacts. There have been studies around transit economics of specific projects, the planning accuracy of transit projects in general, and about the political factions and historic events surrounding specific projects, but few studies attempting to link the two together. The interdisciplinary nature of environmental studies is useful in connecting the research of disparate fields of history, economics, urban studies, and more under the broad theme of the environment.

Although this research has been illuminating unto itself, some further investigations of other MAX lines would be useful. A study of the Westside Extension, built 10 years after the Banfield Corridor, would provide another case at an intermediate time between the two studied projects. Also, a study of the Red Line to the airport, which was uniquely constructed with private funds would provide yet another case from which to see if the planning process differs as a result of who's paying for the project. Further research could involve cross-city comparisons, constructing a database of accuracy for each metric by planning district; this aggregation could lead to new understandings of how to increase the accuracy of estimates on a per metric scale. Increased knowledge of the political forces and historic climate surrounding each project would also be useful in understanding the limits and distortions placed on the planning process.

As much as any researcher hopes that their results are clear and the ramifications obvious, such has not been the case in this instance. There are trends suggesting increased accuracy on the part of Portland's planners, but before the system was built up these estimates were rather poor. This suggests that the costs of new transit technology are difficult to accurately estimate, and therefore difficult to properly implement.

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