



The Connected Bus

Estimating the Economic and Environmental Impacts of The Connected Bus in San Francisco

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1 INTRODUCTION

The cities of Amsterdam, San Francisco, and Seoul and Cisco Systems (Cisco) have made a commitment to the Clinton Global Initiative (CGI) to work together on the Connected Urban Development (CUD) program. The CUD program will develop ways to use information and communication technology to reduce carbon emissions and improve environmental sustainability while fostering economic growth of cities. As part of this program, the City and County of San Francisco has selected the Connected Bus Pilot Project (Connected Bus) as one of the 2007/2008 CUD activities. The Massachusetts Institute of Technology (MIT) has been selected as the urban research, design and development partner for the CUD pilot projects.

A demonstration project of a connected bus was delivered for the CUD conference in February, 2008. This demonstration project showcased the look and feel of the connected bus and provided some initial information on the economic and environmental costs and benefits of the technology.

This work estimates the value of a connected bus both in terms of both economics and greenhouse gas emissions. The working hypothesis of the study is that investments in improving the effectiveness of the bus service is a positive Net Present Value Proposition (NPV) that can lead to a net reduction in emissions. The NPV is established by comparing a business as usual calculation against a technologically enhanced approach.

While there is a broad consensus that human activity is increasing the temperature of the planet (anthropogenic warming), there is a range of views of the impact of this warming, ranging from indistinguishable from natural variance to rendering the planet uninhabitable. This work undertakes no primary analysis on these issues and rather, draws on conclusions provided by the Intergovernmental Panel on Climate Change (IPCC) and the assessment of the distribution of economic benefits indicated by the Stern report¹

The remainder of this document shows the method to estimate the economics of bus travel and the net environmental impact and an assessment of the range of possible reductions using a Monte Carlo method. Finally, in keeping with the literature, metric units are used in the analysis and imperial units are provided in brackets where appropriate.

¹ Stern Review on the Economics of Climate Change, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

2 A TYPICAL BUS

A range of data are required to undertake the economic and environmental analysis. These data provide the baseline against which incremental changes can be assessed. A typical MUNI bus has the following characteristics:

The bus:

- is in service 330 days per year
- receives a weighted average fare of \$0.69 per passenger²
- takes the average passenger 7.0 kilometers (4.4 miles)
- takes 300 passengers on board each day
- is on the road 15.00 hours per day
- passengers have an average hourly wage of \$12.00
- provides \$2000 per year in advertising revenue
- has 45% of passengers on a transfer from another MUNI bus
- replaces a car trip for 5% of passengers
- is taken off the road 10.00 day per year for unscheduled maintenance
- picks up passengers who on average have waited 10.00 minutes
- passenger is on board for 45 minutes on average

This suggests an annual passenger load per bus of 99,000 passengers, providing 693,000 passenger km (433,125 passenger miles).

² Service standards report, page 2.

3 FUNCTIONALITY AND COSTS

This section details the functionality and the economic and environmental costs of the technology.

3.1 FUNCTIONALITY

The technology platform will provide the following functionality:

- Wireless internet access through some Mobile Access Router (MAR). Assumed to cost \$10,000
- Passenger count information
- Handicapped access and bicycle rack use information
- Operational status download
- IP platform available for vendor use
- Stored video information

3.2 ECONOMIC COSTS

To deliver this functionality, hardware costs are assumed to be \$20,000 per bus, with an annual maintenance charge of 33% which includes internet traffic. A technical refresh cycle of 3 years is assumed. In addition, real hardware costs are assumed to decrease by 10% each year. This provides the cost profile as indicated in Figure 1 which has a present value of \$67.73 thousand and a cumulative cost of \$ 144.9 thousand over the ten year period.

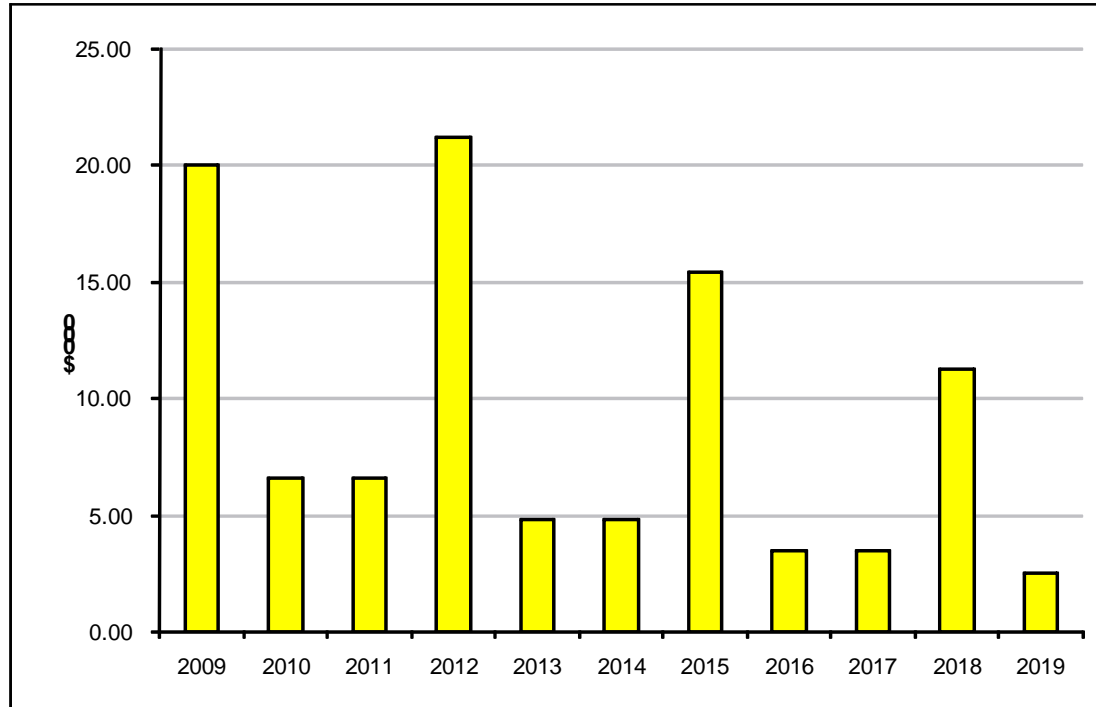


Figure 1: Hardware and operational costs

A simple calculation of dividing the passenger load over 10 years (990,000) by the 10 year present cost yields a cost of 6.841 cents per passenger. This compares with the \$2.38³ operating cost per passenger.

³ Page 2, ibid

3.3 ENVIRONMENTAL COSTS

The construction and disposal footprint counts the CO₂ and other environmental costs associated with making and delivering hardware to a user's premises. Estimating this number is not straightforward and an initial estimate for carbon dioxide is provided below based on the following assessments:

1. In 2005, the USA produced some 7,260.4 Teragrams of CO₂⁴ and had a Gross Domestic Produce (GDP) of \$US 12.5 trillion⁵. This indicates that $(12,500,000,000,000)/(7,260,400,000) = \$US 1721$ of GDP produces a tonne of CO₂
2. Disposal requires little marketing and less transport and are assumed to produce 50% as much CO₂.

Undertaking this calculation shows a cumulative 10 year emission, per bus, of 87.39 tonnes based on hardware and operational expenditures.

⁴ <http://epa.gov/climatechange/emissions/downloads06/07ES.pdf> , page ES-4. 1 teragram = 1,000,000,000 kilograms = 1,000,000 tonnes

⁵ [http://en.wikipedia.org/wiki/List_of_countries_by_GDP_\(nominal\)](http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal))

4 ECONOMIC BENEFITS

Introducing a new technology platform has a range of benefits with different levels of certainty. The following classification is proposed.

Type of benefit	Example	Comment
Certain	<ul style="list-style-type: none"> a) Improved reliability based on reduced unscheduled maintenance. This leads to increased ridership or better asset utilisation and lower bus inventories b) Improved passenger information leading to increased ridership and increased productivity 	Short term results within 2 years, supported by empirical data
Likely	<ul style="list-style-type: none"> c) Reduced vendor costs d) Decreased bus transit times (through traffic signal integration) e) Productivity improvements as passengers work on the bus 	Medium term results (2-5 years)
Speculative or not quantified	<ul style="list-style-type: none"> f) Additional services g) Provide real time bus transport information to web sites for third party use including traffic operations h) Better asset utilisation. For example, bus size better suited to route demand i) Matching federal funds j) Decreased congestion k) Fit with wider political objectives l) Reduced parking space demand m) Flexibility with IP platform to introduce new unspecified functionality.. (for example, radiological detection) n) Consolidate “Central Control” information to improve preventative maintenance 	Long term results (> 5 years), qualitative argument, possibly low materiality or not practical to quantify

Type of benefit	Example	Comment
	<ul style="list-style-type: none"> <li data-bbox="512 289 1482 354">o) Better asset utilization leading to reduced maintenance yard real estate requirements <li data-bbox="512 370 1507 435">p) Increased value of real estate in the vicinity of bus stops as knowledge of bus arriving can stimulate retail sales <li data-bbox="512 451 1146 492">q) Improved public safety through video capture 	

Figure 2: Benefit classification

The certain and likely benefits are discussed in detail below. The speculative and qualitative benefits form part of the broader narrative of the connected bus and may provide material, though uncertain benefits.

4.1 RELIABILITY

The model assumes that the bus is currently out for unscheduled maintenance 10.00⁶ days per year and that the connected bus technology can lead to a 20% decrease in this figure. In addition the bus is assumed to be on the road 15.00 hours per day, 330 days per year and that the average wait time for a bus is 10.00 minutes.

Using these figures, the model shows that the bus is available for an additional 30 hours per year. With an average ride time of 45 minutes this is 40.00 additional trips per bus per year. Assuming this supply is met with demand, this is an increase in ridership of 3000 passengers and an increase in revenue of \$2,070 per year.

An alternate calculation would involve retiring the equivalent assets and realising their value. The work focuses more on meeting demand than improving supply through cost reduction.

4.2 PASSENGER INFORMATION

Additional passenger information focuses on transfer information. The principal benefit of this information is that it reduces the perceived time for a transfer⁷.

⁶ This may be too conservative. Mean Distance Between Failure is around 3,000 miles (Service Standards Report, Q2 FY08, Page 25), though the bus may not be out of service for the full day.

The model assumes a transfer wait time of 10.00 minutes and the perceived reduction in time is a modest 25%, equivalent to 2.5 minutes for transfer passengers. With an average bus trip length for transfer passengers of 60 minutes, this is a 1.88% reduction in their trip time. Assuming that 50.00%⁸ of this reduction passes onto increased ridership, the model indicates the equivalent of an additional 61.875 bus trips a year, an annual revenue of \$ 3,202.

4.3 VENDOR INTEGRATION

An IP platform would allow equipment vendors to swap and transmit information using IP standards rather than propriety standards. This would allow tighter and more effective integration of vendor services, likely leading to lower costs in the long term. The model assumes that there are 10 systems on a bus, and the cost to MUNI would decrease by 500 as vendors used the new standards. Over the 10 year life of the bus this is equivalent to \$500 a year.

4.4 TRAFFIC LIGHT INTEGRATION

The connected bus allows information to be passed to local traffic lights, either holding the green light for an extended time or shortening the red cycle. The model assumes that the average wait at a red light is 90 seconds and that on a typical route, the bus experiences 25 sets of traffic lights. To keep the results conservative, the model assumes that only 7.5% of the requests are effective, given road congestion and other factors that reduce the impact of traffic light integration.

This provides a 3.13% decrease in the usual bus route trip time of 90 minutes, applying the scaling factor of 50.00% suggests a 1.56% improvement in ridership, some 7,734 additional riders each year and revenue of 5,337.

The public benefits for this are material based on labor rates and salary multipliers, though are not calculated at this stage.

4.5 OTHER REVENUES

Other revenues included internet access and additional advertising that is enabled through digital signage. At this stage MUNI is not expected to charge for internet access, though a place holder has been provided in the model with a \$0 tariff.

⁷ The information does not affect actual transfer wait times, but the availability of the information improves the management and perception of the wait time.

⁸ This scaling factor maps decreases in transit time to increases in ridership. There is a complex relationship between these two parameters and the estimate should be seen as indicative.

Digital advertising is assumed to provide an incremental \$500 per bus per year.

4.6 PRODUCTIVITY IMPROVEMENTS

This occurs as people use internet access on the connected bus to access emails and other information. The value of this is difficult to estimate, though a range of proxy prices exist in the market. In any case, the benefits accrue to passengers and rather than MUNI and have not been estimated at this stage.

5 ENVIRONMENTAL BENEFITS

The environmental benefits are calculated in a simple manner that avoids some of the complexity of a detailed environmental impact analysis. The aggregate increased ridership per year is estimated to be 15,375. Assuming that 5% of these trips replaced a car trip then some 769 additional car trips were avoided. With an average car trip of 6.3 miles (10 kilometres) this provides a reduction of 1,538 tonnes.

Subtracting the 87 tonnes construction footprint, yields a net environmental benefit of 1,450 tonnes over the ten years.

6 RESULTS

This provides a net present value of \$ 19.9 thousand at a discount rate of 12% per bus. The work has a ten year cumulative revenue of \$144.9 thousand and a ten year cumulative cost of \$100.3 thousand. The proportional revenue contributions are shown below in Figure 3:

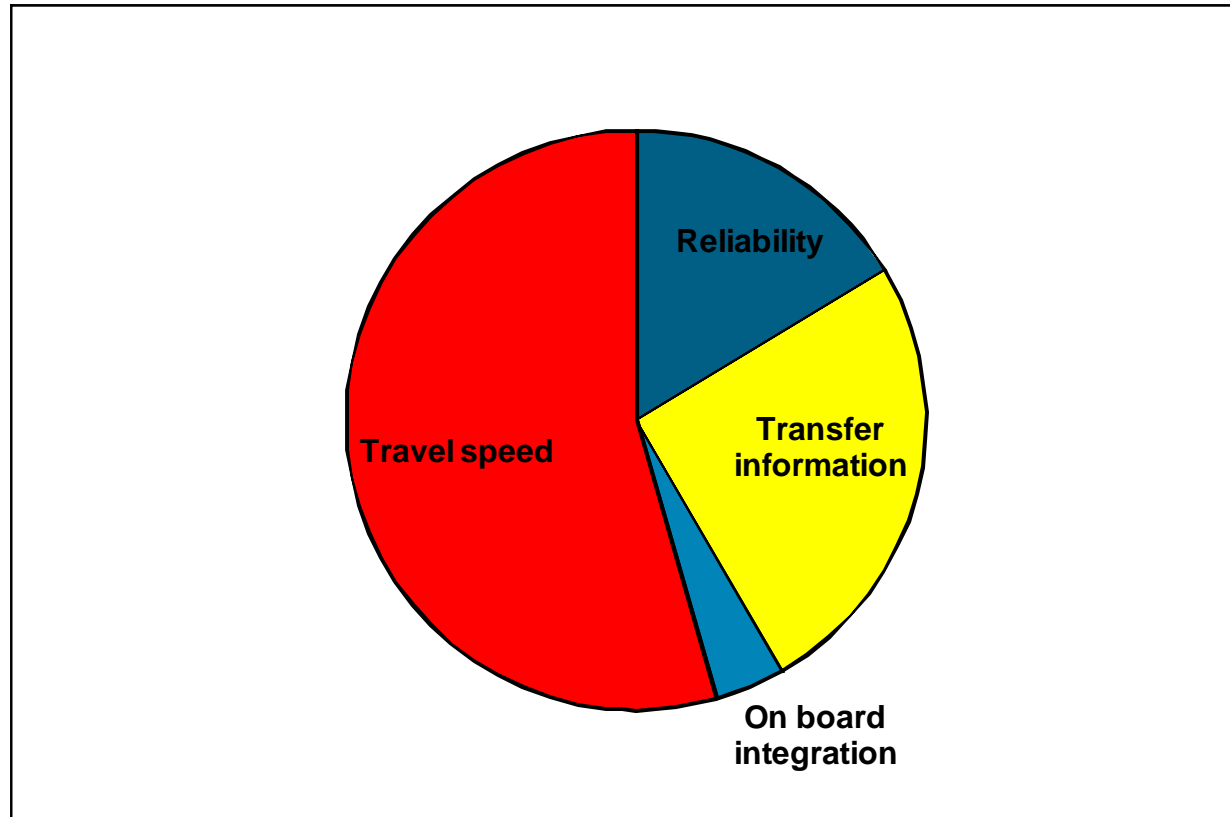


Figure 3: Revenue contributions