Assessing the health impacts of road pricing in San Francisco: *a case study of land use and transportation planning decisions*

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San Francisco Department of Public Health

Presentation Walking Trail

- Policy Background
- Screening
- Scoping
- Assessment – Preliminary Results and Methods
- Summary and Next Steps

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What is road pricing?

US Department of Transportation – Federal Highway Administration

- **Pricing:** fees or tolls on a vehicle's use of the road that vary with demand based on ***time of day, location, type of vehicle, number of occupants, or other factors***
  - also referred to as congestion pricing, value pricing, variable pricing, peak-period pricing, or market-based pricing
  - used to account for and manage demand:
    - generating revenue
    - while achieving other goals, such as reduced congestion, environmental impacts, or other external costs occasioned by road users.

- *As opposed to* **Tolling:** per-use (typically flat) fee on motorists for a given highway facility to generate revenue; may vary by number of axles, distance driven, but not by time of day.

- *Revenue* reinvested in transportation system - capacity expansion, operations and maintenance, repayment for long-term debt (toll roads), etc.

Road Pricing Defined at: www.fhwa.dot.gov/ipd/revenue/road_pricing/defined/index.htm

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Notably, road pricing includes both the pricing of roads *and* the re-investment of that revenue back into the transportation system in a number of ways including those listed on the slide as well as other potential improvements.

Congestion pricing is being studied in San Francisco, California

- Feasibility study approved by the San Francisco County Transportation Authority (SFCTA) Board: December 2010

The Northeast Cordon (AM/PM) was the best performing among dozens of scenarios:

- 12% fewer peak period auto trips
- 21% reduction in VHD
- 16% reduction in Northeast Cordon GHGs (5% citywide)
- $60-80M annual net revenue for transportation services and amenities
- 20-25% transit speed improvement

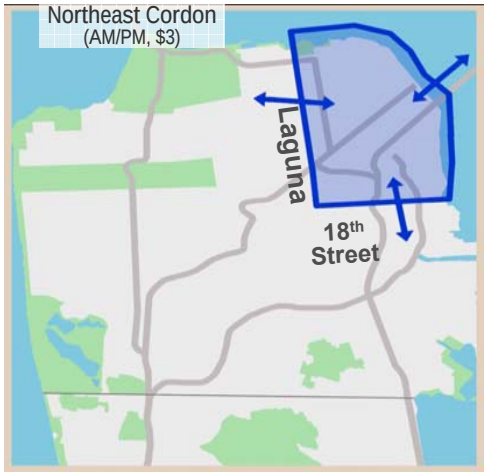
- Next steps: further study/analysis, including environmental review
- Implementation decision: likely 2-3 years, following environmental review

SFDPH noted SFCTA study assessing:

- **Transportation System Performance**
- **"3 Es": Environment; Economy; Equity**

www.sfcta.org/sfmobility | twitter.com/SanFranciscoTA | www.facebook.com/sfmobility

Health Impacts? The SFDPH-led HIA is examining the Northeast Cordon scenario that charges motorists $3 during AM/PM rush hours to travel into or out of the northeast quadrant of San Francisco (*see map*, below).



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NE Cordon scenario determined by: density of congestion today (average speeds on over half of streets in downtown areas operate below 10mph for motor vehicles and 8mph for transit vehicles); areas where planned growth likely to exacerbate existing congestion, or create new availability of transit; flexibility/feasibility to improve transit services and other modes of travel to/from/within the area; availability of net revenues generated to produce sufficient funding to cover cost of improved services.

Program details included in the scenario, to be analyzed further in next phase: variety of discounts for key groups including disabled persons, low-income travelers, residents & immediate abutters of zone; exemptions for transit vehicles, taxis, emergency vehicles but not government; maximum daily cap of $6 to help mitigate impacts on delivery-oriented businesses, families w/school-age children, etc (which would be further mitigated by programmatic enhancements to be outlined further in next phase of evaluation); impacts do not include mitigations that would be programmatic in nature, such as streetscape & landscape improvements, school ridesharing, etc that may further help to enhance travel options or mitigate/minimize traffic and potential environmental impacts (also to be outlined further in next phase of evaluation).

Revenues re-invested in transportation improvements: including transit services, signal timing, bicycle access, streetscape enhancements, etc.
Additional information regarding the SFCTA Feasibility Study can be accessed at the link at the bottom of this slide.

Healthy Transportation Networks = Healthy People

Able to walk, bike, take transit, play, access basic needs – safely:

traffic injury, physical activity, obesity, depression, cancer, heart disease, diabetes, social cohesion

Able to sleep well, concentrate, communicate:

traffic-related noise levels associated with stress, hypertension, blood pressure, heart disease, learning delays, sleep disturbances, hearing impairment, community annoyance

Able to breathe clean air:

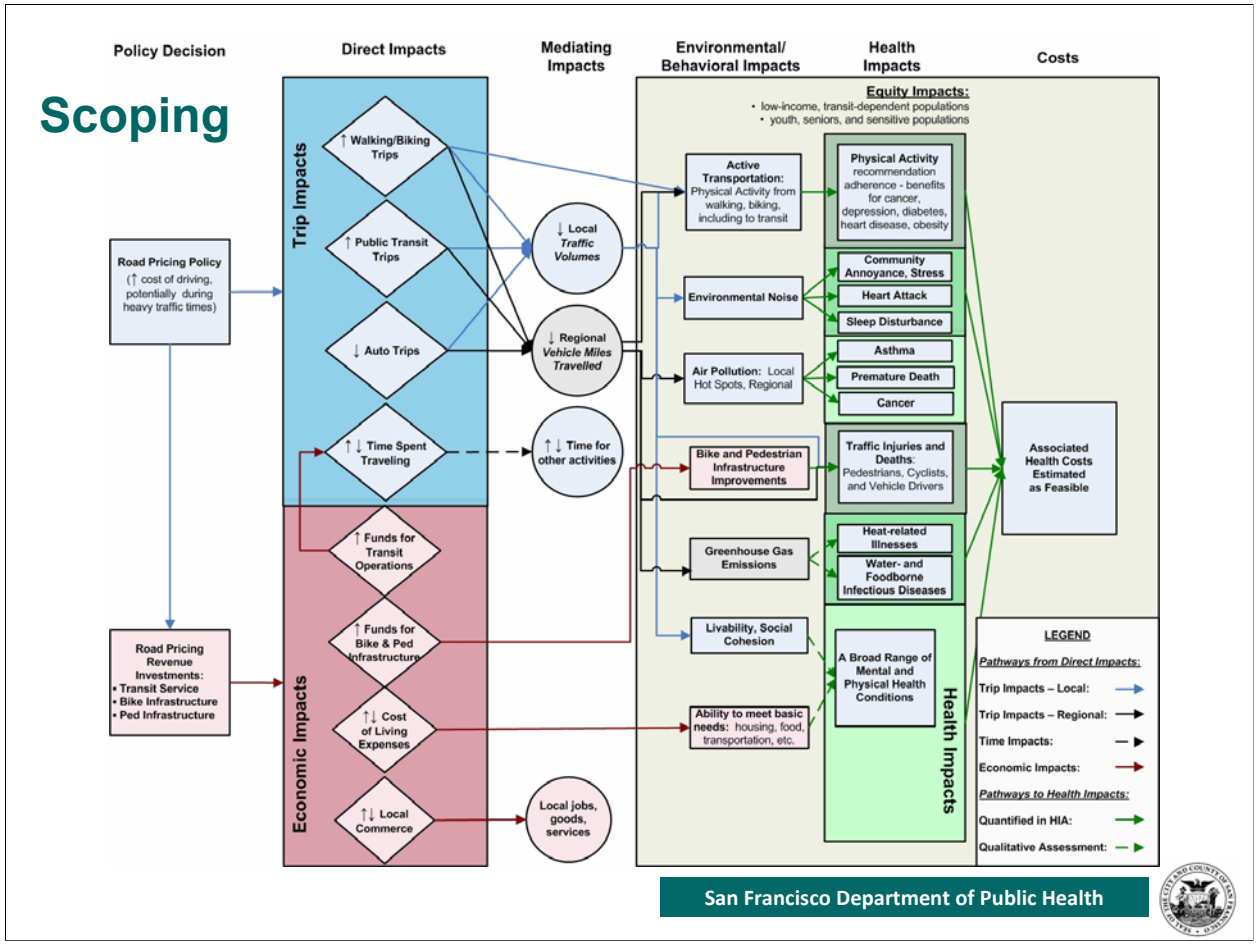
air pollution and proximity to heavy traffic resulting in reduced lung function, increased asthma hospitalizations, asthma symptoms, bronchitis symptoms, and medical visits; air toxics like diesel exhaust and benzene are carcinogens

Environmental justice, Equitable access:

for all populations and subgroups regardless of age, ethnicity, income, immigrant status, etc.

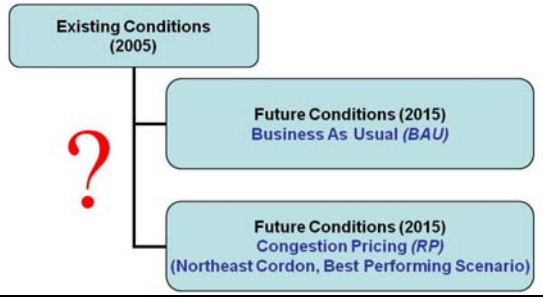
Screening: *HIA Valuable? Feasible?*

- Study area: large portion of San Francisco's land, existing and future residents, employees
- Policy being studied; health impacts not quantified
- Local/regional stakeholders concerned - air pollution, traffic hazards, equity
- Opportunity to build collaboration between transportation and health sectors
- Innovative, novel policy with many unanswered questions
- Analyses could inform policy design, revenue investments
- Tools available to assess the health impacts of transportation decisions
- HIA framework/approach could be applied to future transportation analyses



This pathway diagram depicts the multiple ways in which road pricing can have an impact on health. The pathways in the tan box on the right of the slide are the focus of the HIA. Stakeholder feedback informed our scope re: potential impacts via meetings, interviews, presentations and participation in public meetings, webinars, and technical advisory committee meetings led by the SFCTA. Concerned stakeholders include: community residents; local and regional transportation, planning, and health government agencies; local and regional NGOs focused on issues related to walking, biking, environmental policy, environmental justice and social equity; commerce; and freight. Simpler pathway diagrams for specific health pathways are included later in this presentation.

Assessment: Health impacts



Active Transportation by Age, Mortality Reductions *
Vehicle-Pedestrian Injury Collisions *
Air Pollution and Premature Mortality *
Noise and Sleep Disturbance, Annoyance, Myocardial Infarction *
Air Pollution and Noise Levels Near Schools
Vehicle-Cyclist Injury Collisions
Equity Analyses: Distribution of Health Impacts by Income, Age, Race
Cost Analyses: Air Pollution, Pedestrian and Cyclist Injury Collisions
Pedestrian Environmental Quality Assessment, Targeted Areas
Empirical Evidence Related to Transit Access, Climate Change, and Other Livability Impacts
**** Preliminary Results Presented in the Presentation***

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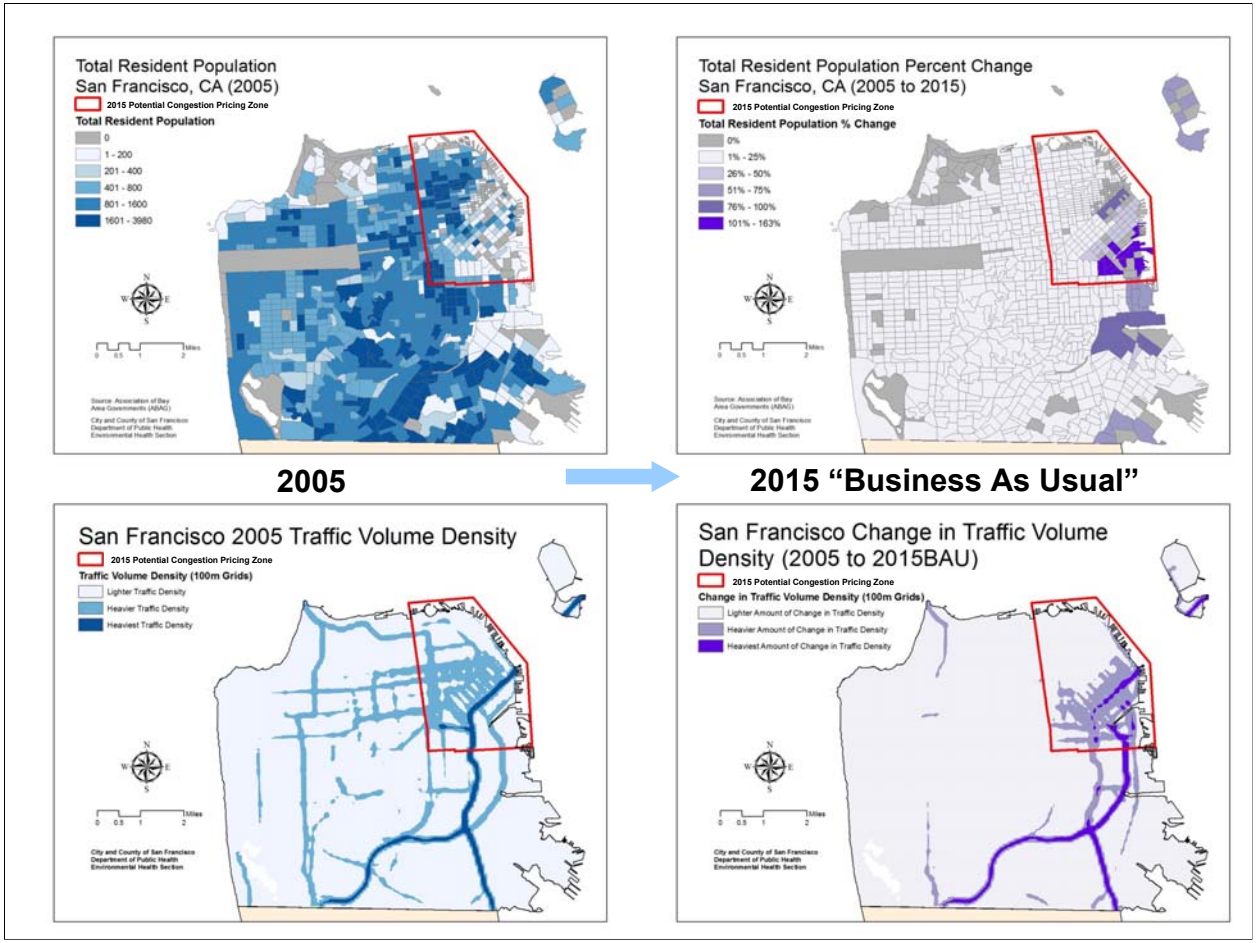
The HIA looks at health impacts and conditions in 2005 Existing Conditions (using the same baseline year as the San Francisco County Transportation Authority's analysis), comparing conditions and impacts in 2005 to 2015 under "Business as Usual" (BAU), and conditions and impacts in 2015 BAU compared to 2015 with Congestion Pricing (i.e., RP - Road Pricing) in the aforementioned Northeast Cordon scenario.

Key HIA inputs are SFCTA Transportation Model outputs for 2005, 2015 BAU, 2015 RP conditions, including:

- street-level vehicle traffic volumes and speeds (street-level volumes were aggregated for analysis purposes)
- district-level trips by mode (walk/bike/transit/driving), trip duration, and trip-maker district of residence (n=12 districts).



This slide further details 2005 Conditions compared to 2015 Business As Usual (BAU) in San Francisco with respect to increasing residents and increasing traffic. The cordon zone, outlined in red, includes a diversity of neighborhoods including the downtown business district, Union Square, North Beach, Chinatown, off/on ramps from the Bay Bridge, as well as South of Market, Mission Bay, and northern Potrero Hill.

Under BAU in San Francisco, we see increasing traffic and increasing residential population density, particularly in the cordon zone, and often in formerly industrial areas, near freeways and busy roadways.

Increasing Residents, Increasing Traffic			
	2005	2015 BAU	2005 - 2015 BAU (%)
TRAFFIC			
Citywide	80,032,000	85,431,000	7%
In Cordon	27,357,000	30,085,000	10%
RESIDENTS			
Citywide	796,000	824,000	4%
In Cordon	172,000	183,000	6%

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Continuing from the previous slide, as detailed in the table, new residential development – and associated increases in vehicle trips under BAU conditions - are more concentrated in the cordon zone ("In Cordon") that is the focus area for the congestion pricing study.

Results are preliminary and are undergoing technical review in Spring 2011.

	2005	2015 BAU	2015 RP	Change: 2005-2015 BAU	Change: 2015 BAU - 2015 RP	*Confidence In Preliminary Results Given Available Methods, Assumptions*
Air Pollution, PM 2.5-related Mortality (Ages 30 and up)				**N**	**N**	***High - Moderate***
Citywide	65	66	63	1	-3	
In Cordon	24	26	23	2	-3	
Noise, Highly Sleep Disturbed (Ages 25 and up)				**%**	**%**	***High***
Citywide	51,000	54,800	55,500	7%	1%	
In Cordon	18,600	21,200	20,000	14%	-6%	
Noise, High Annoyance (Ages 25 and up)				**%**	**%**	***High***
Citywide	92,500	100,400	101,600	9%	1%	
In Cordon	36,800	40,600	40,100	10%	-1%	
Noise, Associated Myocardial Infarction (Age 30 and up)				**N**	**N**	***Moderate***
Citywide	31	34	35	3	1	
In Cordon	18	20	20	2	0	
Active Transportation via Cycling - Lives Saved (Ages 25-64)				**N**	**N**	***High - Moderate***
Citywide	28	30	31	2	1	
Vehicle-Pedestrian Injury Collisions (Annual, N)				**%**	**%**	***High - Moderate***
Citywide	810	860	810	6%	-6%	
In Cordon	360	395	360	10%	-9%	

2015 BAU – 2015 RP:

- **decreases in air pollution-related mortality to below 2005 conditions;**
- **decreases in sleep disturbance and modest decrease in annoyance in the cordon;**
- **slight estimated increase in citywide sleep disturbance, annoyance and heart attack related to traffic noise;**
- **modest increase in lives saved from active transportation;**
- **notable reductions in vehicle-pedestrian injury collisions to 2005 levels.**

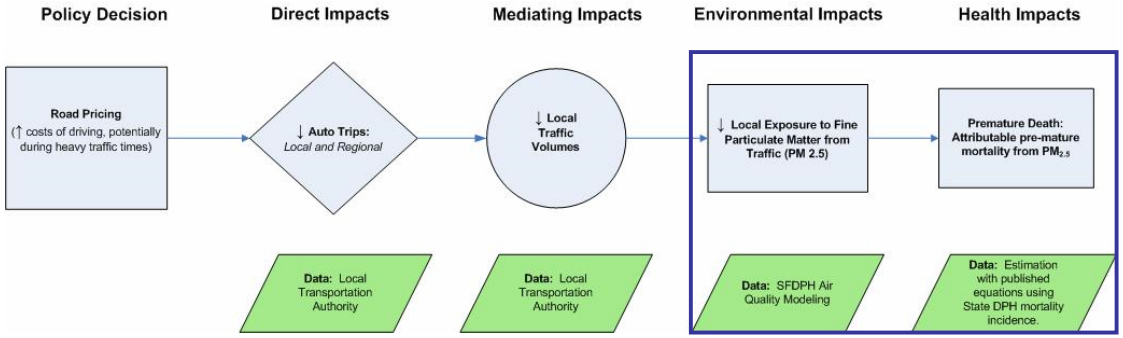
The preliminary HIA results are summarized below. Please note that results are preliminary and undergoing technical review in Spring 2011. Overall confidence in the preliminary results given the available estimation methods and assumptions is summarized in the far right column of the table on this slide. These methods and assumptions will be detailed in the HIA final report, which we anticipate posting online at the following link in Summer 2011 (http://www.sfphes.org/HIA_Road_Pricing.htm).

2005 – 2015 BAU (increasing residential density in areas with existing and increasing high traffic volumes): increases in premature mortality related to air pollution; increases in sleep disturbance, annoyance, and heart attacks associated with traffic noise; increases in vehicle-pedestrian injury collisions, particularly in the cordon area; modest increases in active transportation and associated lives saved from cycling.

2015 BAU – 2015 RP (Road Pricing with the Northeast Cordon Scenario): decreases in air pollution-related mortality to below 2005 conditions; decreases in sleep disturbance and modest decrease in annoyance in the cordon; slight estimated increase in citywide health impacts related to traffic noise; modest increase in lives saved from active transportation; notable reductions in vehicle-pedestrian injury collisions to 2005 levels.

In the rest of this presentation, we will “lift up the hood” of the HIA and explore the methods we used to arrive at these preliminary results in more detail.

Air Quality and Noise Health Impacts



Inputs - *Exposure Estimation:*

Air Quality: Traffic volumes and speeds; vehicle emissions rates; temperature and humidity; surface and upper air meteorology; receptors and exposure height

Noise: Traffic volumes, speeds, time of day; vehicle type; road surface type

Outputs – *Exposure Levels:*

Air Quality: Traffic-related fine particulate matter (PM 2.5) exposure levels

Noise: Traffic-related noise levels (decibels, Ldn)

Assumptions/Uncertainties include: High - moderate confidence in evidence for causal health impacts; moderate confidence in truck volume estimates; moderate confidence in precision of air quality dispersion modeling in an urban environment; exposure response functions do not take into account vulnerable populations; moderate confidence in exposure response function for noise-related heart attack (based on limited studies).

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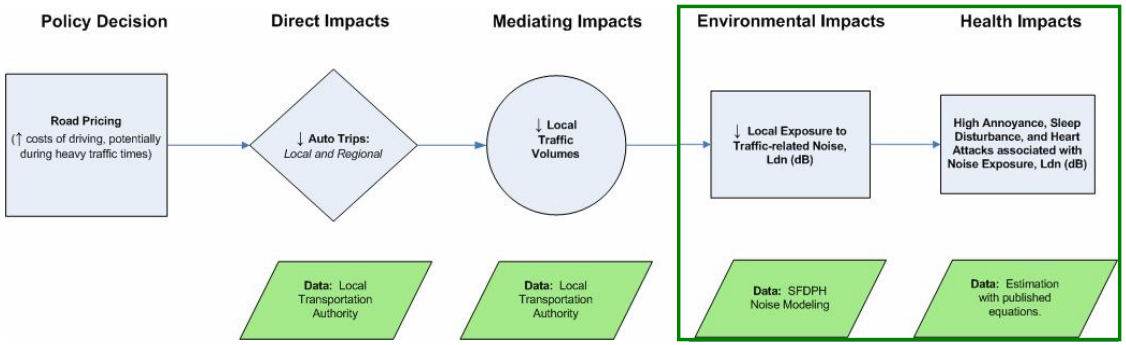
This diagram details the pathway through which road pricing policy contributes to decreases in auto trips, decreases in local traffic volumes, and estimated decreases traffic-related fine particulate matter (PM2.5) and its resulting health impacts.

The bottom left section of the slide describes the inputs into the air quality and noise exposure estimates.

We also include some of the assumptions and uncertainties we used to arrive at the HIA estimates – which as I mentioned will be further detailed in the final HIA report.

Air Quality and Noise Health Impacts



Inputs - *Exposure Estimation:*

Air Quality: Traffic volumes and speeds; vehicle emissions rates; temperature and humidity; surface and upper air meteorology; receptors and exposure height

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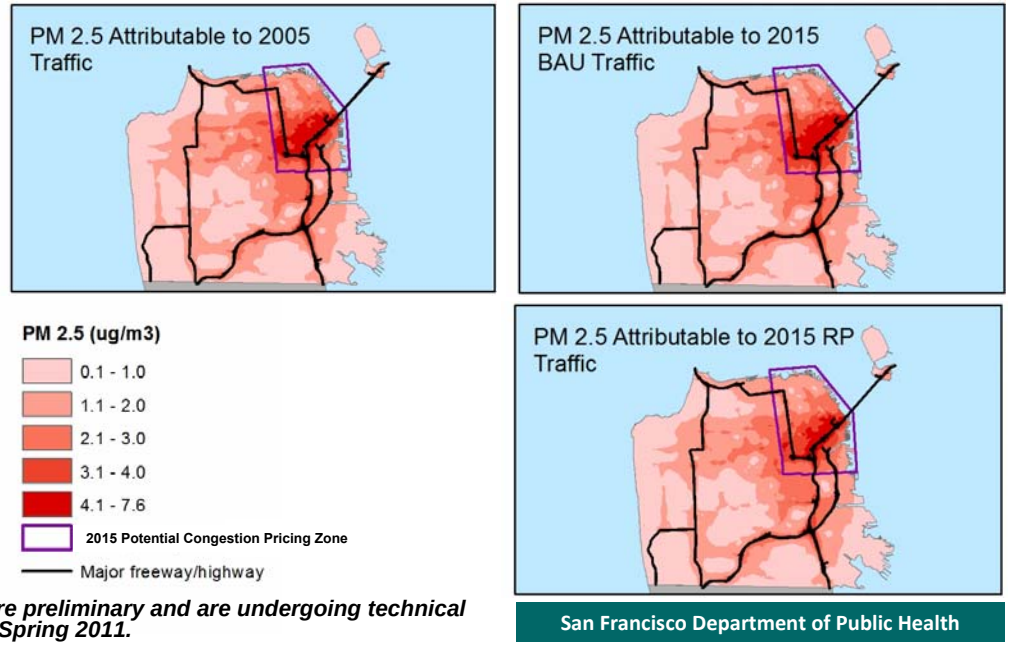
This diagram – very similar to that for air quality - details the pathway through which road pricing policy contributes to decreases in auto trips, decreases in local traffic volumes, and estimated decreases in traffic-related noise and its resulting health impacts.

The bottom left section of the slide describes the inputs into the air quality and noise exposure estimates.

We also include some of the assumptions and uncertainties we used to arrive at the HIA estimates – which as I mentioned will be further detailed in the final HIA report.

Air Quality Health Impacts

Change in PM 2.5 Emissions Attributable to Vehicle Traffic in San Francisco



Results are preliminary and are undergoing technical review in Spring 2011.

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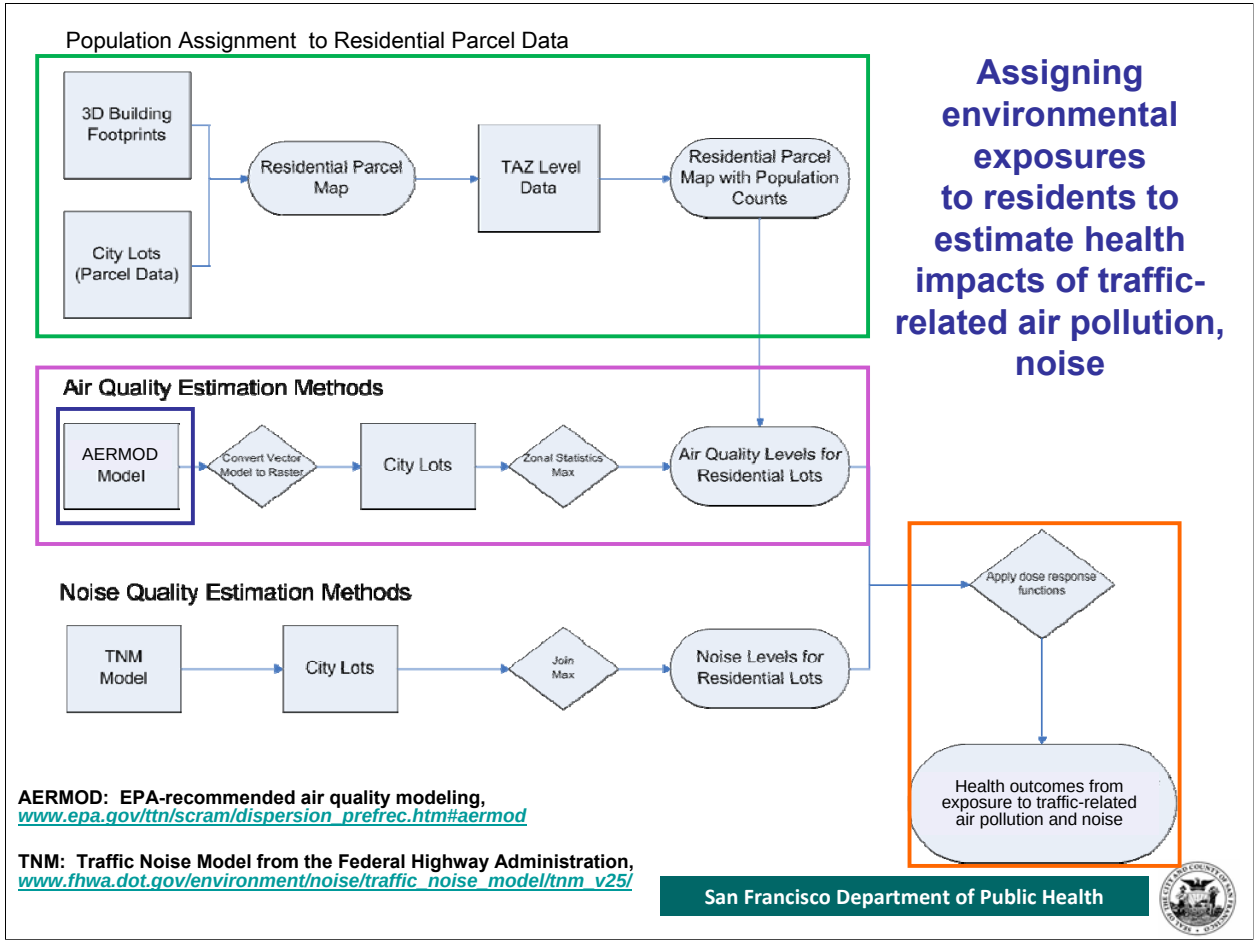
The maps in this slide depict changes in air quality from 2005 – 2015 BAU, and 2015 BAU to 2015 RP (Road Pricing, Northeast Cordon scenario) based on our preliminary results. Focusing particularly on the area inside the road pricing boundary and along the freeways and highways – we see increases in PM2.5 from 2005 (upper left) to 2015 BAU (upper right) and decreases in those same areas particularly along the freeways and highways when comparing 2015 BAU (upper right) to 2015 RP (lower right).

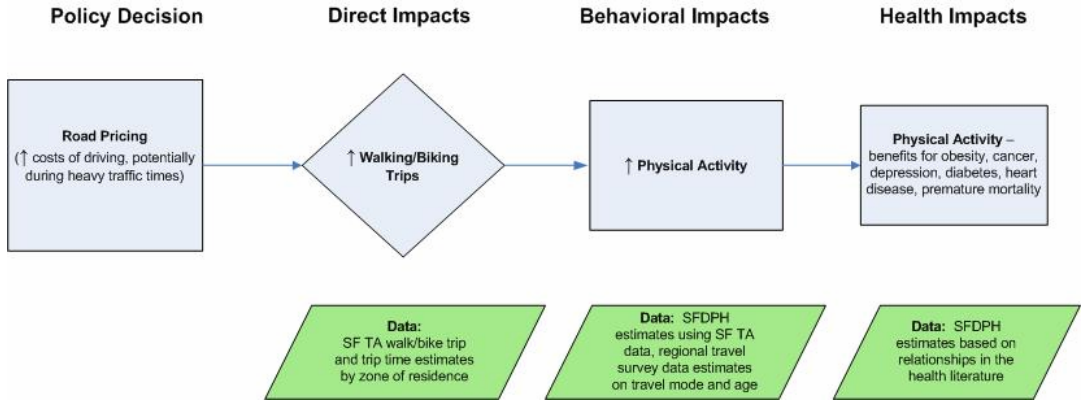
Please note that SFCTA traffic model assumptions do not include programmatic or off-model improvements to address/reduce potential neighborhood impacts.

The HIA analyses will help to inform design of the program mitigations and benefits as needed.



The previous slide detailed the output from the air quality exposure modeling, which is represented in the blue box on this slide. We use those exposure estimates to estimate exposure in San Francisco's residential lots – as represented in the purple box. In a parallel process (in the green box), we use spatial building footprint data and city lot data to assign the residential population estimates (accessed from the SFCTA at the TAZ (travel analysis zone) level) to specific locations. We repeat this process three times for the three HIA scenarios (2005, 2015 BAU, 2015 RP), to obtain estimates of the population exposure to varying levels of air pollution. We then apply dose-response functions from the empirical literature (from meta-analyses, when available) to estimate health outcomes associated with air pollution. We use a parallel processes to estimate noise-related health impacts, as described in the bottom pathway on this slide.

Active Transportation: *Assessment*



Existing and Future Conditions Data:

- Walk & Bike Trips, Times by Residence District (SFCTA Model)
- Residential Population, Age (SFCTA, census-based estimates)
- Weekday Trips and Trip Mode by Age Category (Bay Area Travel Survey)

Assumptions/Uncertainties include:
High confidence in evidence for health impacts, age estimates; moderate confidence in area-level trip estimation method by age; high-moderate confidence in mortality estimate.

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This diagram details the pathway through which road pricing policy impacts changes in walk and bike trips and therefore physical activity and related health impacts. We used existing and future conditions data from the SFCTA to assess walk and bike trips and trip times for trips made by residents living in 12 geographic districts in San Francisco that are used for transportation analyses. We also used data for existing and future conditions for area-level resident population and age. Because data was not available on trip making and travel mode by age in San Francisco, we estimated trip making by age and transportation mode based on the Bay Area Travel Survey data, assuming the proportion making weekday trips and transportation mode by age were similar across the Bay Area region. This slide also depicts some of the assumptions and uncertainties in the analyses, which will be further detailed in the HIA final report.

Active Transportation Impacts: Walking/Biking

	2005		2005 - 2015 BAU		2015 BAU - 2015 RP	
	Walk/Bike Trips Per Capita	Walk/Bike Minutes Per Capita	Walk/Bike Trips Per Capita	Walk/Bike Minutes Per Capita	Walk/Bike Trips Per Capita	Walk/Bike Minutes Per Capita
In The Zone						
Age Under 5	1.7	30	6%	7%		
Age 5-19	2.8	48	6%	8%		
Age 20-44	2.0	35	6%	7%		
Age 45-64	1.2	21	5%	6%		
Age 65 and Over	2.1	37	5%	6%		
TOTAL	***1.9***	***33***	***5%***	***7%***	***1%***	***2%***
On the Fringe						
Age Under 5	0.9	19	1%	1%		
Age 5-19	1.5	31	1%	1%		
Age 20-44	1.2	24	2%	2%		
Age 45-64	0.7	14	1%	1%		
Age 65 and Over	1.1	23	0%	1%		
TOTAL	***1.1***	***22***	***1%***	***1%***	***3%***	***3%***
Outer Districts						
Age Under 5	0.6	12	-1%	0%		
Age 5-19	1.0	20	0%	1%		
Age 20-44	0.8	15	0%	1%		
Age 45-64	0.4	9	-1%	0%		
Age 65 and Over	0.7	15	-1%	0%		
TOTAL	***0.7***	***14***	***-1%***	***0%***	***2%***	***2%***

Results are preliminary and are undergoing technical review in Spring 2011.

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While there is a lot of data included in this slide that we look forward to describing further in our final report, including breakdowns by age, for this presentation we want to focus on changes in walking and biking under BAU compared to RP.

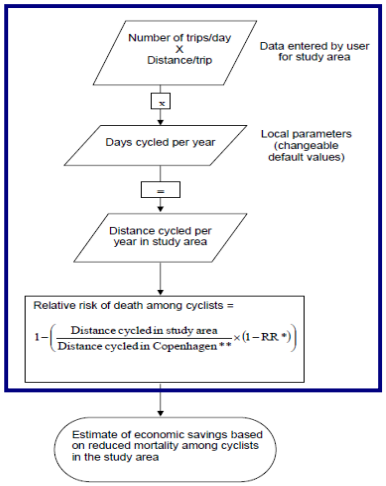
We collapsed the 12-districts in San Francisco into three districts for this analysis, defined with respect to their geographic location relative to the Northeast Cordon road pricing zone (depicted with a blue boundary on the map). The three zones are “In the Zone,” turquoise, comprised of the districts mostly in the cordon zone; “On the Fringe,” yellow/mustard, comprised of the districts just outside of the cordon zone; and the “Outer Districts,” those further away from the cordon zone in pink.

In 2005 – 2015 BAU, our preliminary results indicate increases in active transportation – but primarily only “In the Zone” (turquoise), explained by increases in residential populations in areas of SF with existing built environment factors, transit access, parking policies, etc. that are already the most conducive to walking and biking (as evidence in the 2005 existing conditions data summary).

However in 2015 BAU – 2015 RP, the preliminary results reveal additional, modest increases in active transportation across all zones as the cost of driving increases and people choose to take more trips by walking or biking across all districts. We see the largest proportional increases in active transportation “On the Fringe,” which makes intuitive sense as those residents likely have a higher proportion of shorter trips across the cordon boundary that they could make via walking and biking as the cost of driving increases.

Active Transport Impacts: Lives Saved from Cycling

Figure 1. Basic workings of the HEAT for cycling



*RR = relative risk of death in underlying study (0.72) (Andersen et al., 2000)

**Distance cycled in Copenhagen calculated based on 3 hours per week for estimated 36 weeks/year at estimated 14km/h

	2005	2015 BAU	2015 RP	*Confidence In Preliminary Results Given Available Methods, Assumptions*
Lives Saved Annually From Cycling (Ages 25-64)	28	30	31	***High - Moderate***

Using the Health Economic Assessment Tool (HEAT) for Cycling

Results are preliminary and are undergoing technical review in Spring 2011.

The HEAT was developed with support from the World Health Organization, and is available and downloadable online:

•*www.euro.who.int/en/what-we-do/health-topics/environmental-health/Transport-and-health/activities/promotion-of-safe-walking-and-cycling-in-urban-areas/quantifying-the-positive-health-effects-of-cycling-and-walking/health-economic-assessment-tool-heat-for-cycling*

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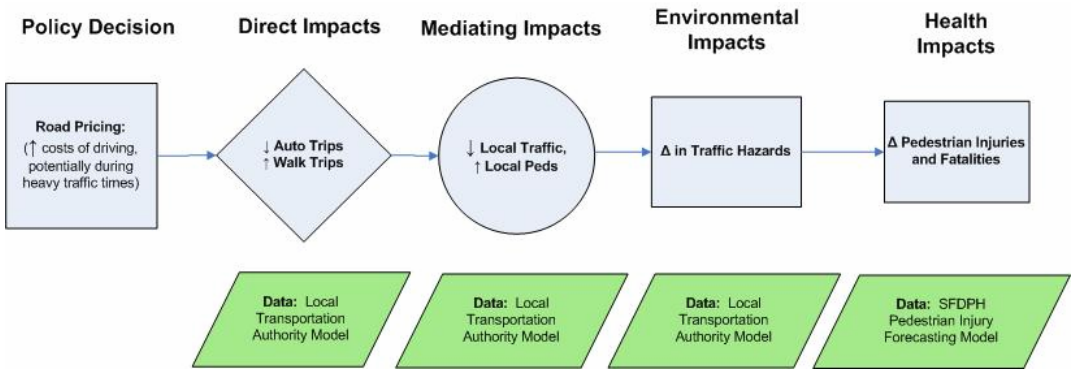
To quantify the health benefits from increases in cycling, we used the HEAT (Health Economic Assessment Tool) for Cycling. This tool was developed with support from the World Health Organization and is downloadable online from the link on the slide. We used the cycle trip and duration estimates for people aged 25-64 as the key inputs into the Tool, along with local data on mortality rates to estimate lives saved from cycling. Our preliminary results indicate that increases in cycling will save an additional 2 lives each year under 2015 "business as usual" compared to existing conditions, and one additional life each year beyond BAU with 2015 RP. We anticipate applying a similar approach to estimating the health benefits of increased walking. Notably, there are numerous other health benefits from active transportation; lives saved/reductions in mortality are the most severe among a spectrum of impacts (literally, the difference between life and death).

Pedestrian Injury Collision Impacts



SFDPH has developed a multivariate, linear area-level (census tract) regression model* to *predict the natural log of vehicle-pedestrian injury collisions in San Francisco's n=176 census tracts:*

$$\ln(\textit{Ped Injury Collisions}) = b_0 + \sum b_i X_i$$

Significant predictors of area-level collisions ($b_i X_i$):

- Traffic volume (+, ln)
- **Arterial streets (+) w/o surface transit**
- **Neighborhood commercial zoning (+)**
- Employees (+, ln)
- Residents (+)
- **Land area (-)**
- Below poverty level (+)
- Age 65 and over (-)

* Wier et al. (2009) *Accident Analysis & Prevention.*

Assumptions/Uncertainties include: High confidence in evidence for health impacts; high-moderate confidence in estimates of model predictors (includes pedestrian volume proxies); high-moderate confidence in forecasting approach.

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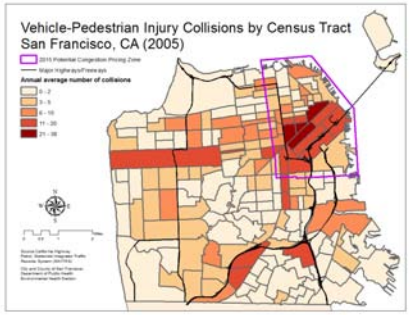
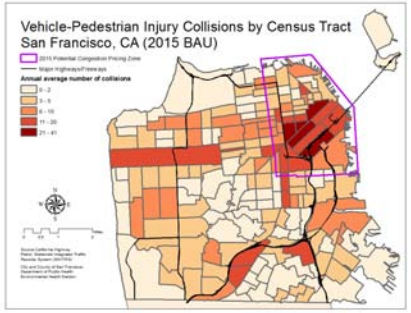
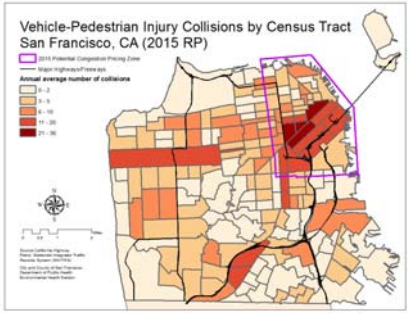
The diagram details the pathway through which road pricing policy impacts changes in trips and therefore traffic hazards and vehicle-pedestrian injury collisions. SFDPH developed a vehicle-pedestrian injury collision forecasting model to predict the number of collisions at the census tract level in San Francisco based on land use, transportation and socio-demographic factors. Significant predictors in the model are listed on the bottom left of the slide; variables for which we used estimates changes under future (2015) conditions are highlighted in turquoise. We used this model to estimate changes in collisions under 2005 vs. 2015 BAU and 2015 BAU vs. 2015 RP using existing and future conditions data from the SFCTA model on traffic volume as well as planning projections regarding changes in the number of employees, residents, income and age. This slide also depicts some of the assumptions and uncertainties in the analyses, which will be further detailed in the HIA final report.

Vehicle-Pedestrian Injury Collisions

	2005	2015 BAU	2015 RP	Change: 2005-2015 BAU	Change: 2015 BAU - 2015 RP	*Confidence In Preliminary Results Given Available Methods, Assumptions*
Vehicle-Pedestrian Injury Collisions (Annual, N)				**%**	**%**	***High - Moderate***
Citywide	810	860	810	6%	-6%	
In Cordon	360	395	360	10%	-9%	







Results are preliminary and are undergoing technical review in Spring 2011.

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The table summarizes changes in vehicle-pedestrian injury collisions citywide and in the cordon. While vehicle-pedestrian injury collisions increase from 2005 to 2015 BAU (as residential populations increase in the areas where there is the most traffic), there are comparable decreases from 2015 BAU to 2015 RP (back to 2005 existing conditions levels) both citywide and in the cordon zone. The maps at the bottom of this slide depict area-level changes in the annual average of vehicle-pedestrian injury collisions in 2005, 2015 BAU and 2015 RP conditions. We see increases in collisions under BAU – with increases most notable in areas in the road pricing zone as well as some tracts south of the zone near the freeway. In 2015 with RP, we see reductions in the road pricing zone relative to 2015 BAU conditions – explained by reductions in traffic volumes in those areas. Note that the highest category for the annual average number of collisions changes under 2015 BAU conditions.

Please note that the SFCTA traffic model assumptions do not include programmatic or off-model improvements to address/reduce potential neighborhood impacts. The HIA analyses will help to inform design of the program mitigations and benefits as needed. We anticipate conducting additional sensitivity analyses of these preliminary results in the coming months. It is notable that similar proportional decreases were seen with the introduction of congestion pricing in London.

Summary

Preliminary results:

2005 - 2015 BAU - ***Estimating the health impacts of "Business As Usual" (BAU)***

- Worsening of traffic-related health impacts, exacerbated in the cordon area:
  - increases in air pollution-related premature mortality (modest)
  - increases in sleep disturbance, annoyance, and heart attacks associated with traffic noise
  - increases in vehicle-pedestrian injury collisions, particularly in the cordon area
- Modest health benefits from increases in residents' active transportation and associated lives saved, concentrated in the cordon zone

2015 BAU – 2015 RP - ***Estimating the health impacts of congestion pricing on BAU***

- Health benefits from air pollution-related mortality reductions to below 2005 conditions
- Health benefits from decreases in sleep disturbance and a modest decrease in annoyance in the cordon
  - though very modest estimated increases in noise-related adverse health impacts citywide (additional analyses to inform targeted HIA recommendations)
- Modest health benefits from increases in active transportation and lives saved from cycling
- Health benefits from notable reductions in vehicle-pedestrian injury collisions to 2005 conditions

Results are preliminary and are undergoing technical review in Spring 2011.

Next Steps

Next steps and timeline:

- **February – April 2011:**
  - Technical review of preliminary results, detailed methods summary of assumptions, certainty
  - Additional assessment including equity (distribution of impacts), cost analyses for specific outcomes
  - Recommendations for policy design, revenue investment
- **May - June 2011:** Public report draft for review, conduct public outreach
- **July 2011:** HIA Report finalized, conduct additional public outreach

Project Website:

www.sfphes.org/HIA_Road_Pricing.htm

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