Smart Right-of-Way Permitting System for the City of Pittsburgh: coordination, pricing and enforcement

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Executive Summary

Public roads, streets, and sidewalks are managed by the City of Pittsburgh and those public space are used by all residents. The Department of Mobility and Infrastructure (DOMI) is responsible for issuing and enforcing permits for occupancy of the public right-of-way in the City of Pittsburgh, such as for construction projects and utility line repair and installation. A contractor must obtain the necessary permits from DOMI before obstructing or performing any construction activities within the public space.

Presently, DOMI charges limited administrative fees for each right-of-way permit, regardless of the work's impact on the social welfare. The impact of a right-of-way permit includes, but is not limited to, increasing the congestion level, hampering the accessibility of points of interest in the city, and reducing the availability of sidewalks for pedestrians (Hague, 2015). In fact, the impact of each right-of-way permit can vary significantly in terms of its location, time, and duration. From economics perspectives, these impacts can be viewed as the negative externality brought by a right-of-way permit (Suntory and Disciplines, 2019). Hence the permittees should be responsible for the externality by paying a corresponding fee serving the social welfare (Small, 1992). In the current flat-fee permitting system, the negative externality is not properly charged to the permittees. Therefore, current permitting system is not efficient enough to achieve optimal social welfare. As a result, it encourages suboptimal usage of public space to some extent.
Another issue in the permitting system is the lack of resources for supervising and enforcing the right-of-way permits. Permittees may obstruct the traffic for longer time than requested, or they may block the whole road instead of using one lane as per the requirements in the permit. Currently, the enforcement of the right-of-way permit is conducted by visual check of trained inspectors, hence it requires enormous human and equipment resources.

In 2018, there are in total 17,575 right-of-way permits issued by DOMI. The intensive use of public rights-of-way permits may cause tremendous social externalities and require a great number of resources for coordination, supervision and enforcement. Therefore, it is in great need for the city to build a smart right-of-way permitting system that: 1) properly evaluates the social impact of a right-of-way permit, with proper pricing to ensure social equity and social optimum; 2) intelligently supervises and enforces the permits given very limited human resources.

This project extracts key metrics from available data and develops cost models using analytical methods. The team focuses on two major neighborhoods in Pittsburgh: Shadyside and Oakland. In general, the total cost caused by a traffic obstruction permit (permit) is calculated by multiplying the duration of the permit with the inconvenience cost caused by the activity. The metrics supporting the cost model are categorized by the type of ROW users impacted:

Private Vehicle Speed and Volume: Used anomaly detection to identify features that characterize delays and predict delays caused by permits based on those features.
Public Transit Arrivals and Passenger Volume: Isolated delays from permits and use a decision tree to predict future delays.
Parking Revenue Loss: Measured seasonal variations in parking revenue and estimate loss based on the day of the week and location. (not studied in this project)
Bike and Pedestrian Volume: Extrapolated cyclist and pedestrian count in main corridor and non-corridor traffic based on Pittsburgh Count and Make My Trip Count survey data. (not studied in this project)

In addition, the team also develops **a prototype web application** to visualize the ROW permit information and their respective 'true social cost', alert locations that are likely to violate permits, and recommend routes and locations to inspectors for visual inspection and enforcement.

Issue at Hand

The City of Pittsburgh is responsible for permitting an increasingly complicated right-of-way. Numerous competing users, both fixed (parking, loading, pickup and drop off) and variable (temporary closures for construction projects) are trying to gain access to precious amounts of roadway, sidewalk, and curb, and those needs must be further evaluated against other public purposes, such as additional public space or dedicated transit or bike infrastructure. The City's fees for permits have not been updated in at least a decade, and the new permitting software coming online by the third quarter of 2019 provides a good window of opportunity to evaluate the "cost of curb" and set a consistent pricing strategy across the City that could serve as the underpinning of a dynamic pricing system.

Objective

The objective of this project is to 1) analyze current the Right-of-Way permitting fee structure for city of Pittsburgh, and introduce a dynamic pricing strategy that more accurately captures the marginal impact of social costs incurred; 2) develop a prototype web application for visualizing and analyzing ROW permits.

Approach

Figure 1 below represents the general approach the team took for this project. First, the team conducted a literature review to better understand the topic and investigate how other cities address the impact of ROW permits.

Figure 1 Process Flow Diagram of the Overall Approach

The team focused on two major neighborhoods in Pittsburgh: Shadyside and Oakland. Using available data sources, the team extracted key metrics and developed cost models using analytical methods in R and ArcGIS. With the synthesized cost model, the team developed an interactive pricing tool in Excel to provide to the City. Finally, a web application is developed to provide interactive interfaces and map-based visualization.

Literature review

The way a city structures its Right-of-Way permitting system can reflect its general approach to curbside management, the broader strategy of the two for cities to consider. By optimizing, re-allocating and streamlining curb space throughout a transportation network, a city aims to improve how it balances all users of the that particular network. Types of users include cars, trucks, public transit, bicyclists and pedestrians. Beneficiaries of efficiently balanced curb space are all who directly and indirectly rely upon it, such as local businesses, transportation companies, or citizens walking to work. Since curbside management is the broader strategy to accomplishing a more effective transit system for all parties, many insights can be drawn from the techniques used in developing those CM strategies that can be applied to improving a ROW permitting system. A few of those insights are listed below:

- *Important Role of Data Analysis in System Design:* The National Association of City Transportation Officials (NACTO) states that making the case for system changes with the many stakeholders of public transportation networks takes time and trust, and to effectively do so requires "choosing measurement over myths."[1] In CM, understanding how much of the population utilizes certain metered parking spaces or what intersections feature the highest rate of bus rider activity helps illustrate potential network pain points and highlight variability in network usage depending on certain exogenous variables, such as time and location. This can be achieved through asking the right questions, examining the data, and working to reveal insights from the newly synthesized information. While developing CM strategy includes analyzing ROW operations, it extends to a much broader set of studied attributes, like loading zone design, queuing-lane strategy, and metered parking spot placement. Still, the field's use of data to measure traffic trends has yielded much success for cities, such as Seattle.[2]

- *Establish Priorities before Planning:* In 2018, Seattle adopted a comprehensive CM plan that was to be implemented by the Office of Planning & Community Development that include the following policy goals for the best use of the streets (each directly cited)[3]:

Within the pedestrian realm, prioritize space to address safety concerns, network connectivity, and activation.

- Prioritize mobility needs in the street travel way based on safety concerns and then on the recommended networks and facilities identified in the respective modal plans.
- When mobility is needed only part of the day, design the space to accommodate other functions at other times.

These policies introduce time-variant considerations by acknowledging that some areas experience higher rush hour traffic than others (e.g., streets with parking lots or garage exits). Along with the more general, transferable policy priorities, Seattle's CM plan specifically articulated ROW priorities, which are listed below[4]:

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[1] "Curb Appeal: Curbside Management Strategies for Improving Transit Reliability." *NACTO Transit Leadership.* National Association of City Transportation Officials. November 2017.
https://nacto.org/wp-content/uploads/2017/11/NACTO-Curb-Appeal-Curbside-Management.pdf

[2] Zimbabwe, Sam. *Flex Zone/Curb Use Priorities in Seattle*. Seattle Department of Transportation, www.seattle.gov/transportation/projects-and-programs/programs/parking-program/parking-regulations/flex-zone/curb-use-priorities-in-seattle.

[3] "Seattle 2035 Comprehensive Plan: Managing Growth to Become an Equitable and Sustainable City" City of Seattle. December 2018. https://www.seattle.gov/Documents/Departments/OPCD/OngoingInitiatives/SeattlesComprehensivePlan/SeattleComprehensivePlanCouncilAdopted2018.pdf

[4] "Seattle 2035 Comprehensive Plan: Managing Growth to Become an Equitable and Sustainable City" City of Seattle. December 2018. https://www.seattle.gov/Documents/Departments/OPCD/OngoingInitiatives/SeattlesComprehensivePlan/SeattleComprehensivePlanCouncilAdopted2018.pdf

- Consider the assignment of space based upon shared-capacity potential and shorter-duration uses that emphasizes efficiency, and therefore, more value.

- Analyze the real estate composition to establish zones that each reflect different ROW-use priorities, as seen in the Use of Area priorities chart (Table 1 from Seattle's CM plan). Priority alignment can differ depending on the area make-up.

Table 1 Priorities for ROW "Flex Zone" by Predominant Use of Area

Priorities for Right-of-Way "Flex Zone" by Predominant Use of Area

Commercial/Mixed-Use Areas	Industrial Areas	Residential Areas
Modal plan priorities	Modal plan priorities	Modal plan priorities
Access for commerce	Access for commerce	Access for people
Access for people	Access for people	Access for commerce
Activation	Storage	Greening
Greening	Activation	Storage
Storage	Greening	Activation

- *Identify "Critical" Locations*: Depending on road capacity and traffic flow averages, it has become common practice to designate arterial classifications to roadways and even attach fee premiums and special plan considerations to them.

These are just a few of the many strategic approaches to developing a successful CM plan. Other considerations range from potential sources of congestion and equitable access to accounting for conflicting transportation options and economic incentives. But at the end of the day, priorities must be articulated and balanced, whether the focus is on accessibility, safety, social equity, infrastructure perseveration, or stakeholder satisfaction.[5]

Case Studies of ROW Permit Policies

There are number of cities that offer compelling policy insights into how ROW permits can be designed and priced in order to reflect more time- and location-based variation in ROW impact on public and private inconvenience. While none of the cities that were closely examined feature a truly data-driven, dynamic approach in measuring specific social cost incurred on all relevant stakeholders, some of them have aspects of their ROW fee structure that serve as basic proxies for variable social impact, which acknowledges the underlying potential for greater specificity in data collection and implementation. With that said, this paper investigates how well some of the leading cities in ROW permit procedure do in capturing the degree of social costs incurred by *delays in projects* (i.e., incentives to finish projects in timely manner), impact on *street-level congestion*, inconvenience for *pedestrians and bicyclists*, and decrease in potential *parking spot capacity*.

[5] "Seattle 2035 Comprehensive Plan: Managing Growth to Become an Equitable and Sustainable City" City of Seattle. December 2018. https://www.seattle.gov/Documents/Departments/OPCD/OngoingInitiatives/SeattlesComprehensivePlan/SeattleComprehensivePlanCouncilAdopted2018.pdf

Austin, TX

The city of Austin features on of the more advanced ROW permitting systems in terms of its permit-tracking infrastructure, while its fee structure is fairly baseline aside from some of the listed features below. To be clear, Austin does not charge permitting fees for its own city department and city works projects. Franchise companies, such as Texas Gas—which services all of Austin—are exempt from permit fees as well. Since fees are not accessed, the project timelines are often not precise so the ROW Management Division of Austin's Transportation Department will issue one-month long permits instead of day-rate based permits that are given to private contractors, decreasing the incentive to finish projects in a timelier manner.[6]

- *Time Consideration:* In order to incentivize private project timeliness, short-term permits (duration dependent on project-type) that have a non-renewable status. This means that is the project were to exceed the permit length, there is an additional fee assessed and the project manager must reapply for another permit. The city is currently working to improve its notification system so that project managers are automatically notified when their permit is close to its expiration date. The ROW division has found that the use of notifications has helped to increase the rate of on-time project completions.

- *Motorized Traffic Congestion*: The current permit fee structure does not account for specific effects on vehicle traffic since the city does not track traffic patterns at the street-specific level. Instead, its ROW Usage Fee includes a premium for projects that operate in more than one traffic lane. The assumption being made here is that there will be a greater impact on ROW traffic flows when more traffic lanes are being worked on. While the city has also designated the downtown area as the *Downtown Austin Project Coordination Zone (DAPCZ)* to acknowledge a greater level of activity, the zone does not mean additional ROW permit fees, only additional application requirements.

- *Pedestrian & Bike Inconveniences:* There is no additional fees incurred for sidewalk or bike lane permits aside from the baseline usage fee for sidewalk space. In other words, bicyclist and pedestrian volume counts are not considered.

- *Parking Revenues:* For both metered and unmetered parking lanes, there is a $35 application fee. Then, permits for unmetered parking lanes are charged by project length and square footage, while metered parking lanes are charged by calculating the loss of revenue for the respective meter rates of the permit location.

- *Additional notes on permitting structure:* The city includes a technology surcharge fee of four percent on all permits issued to private projects. According to Paloma Amayo-Ryan, Permit Review Analyst Manager at Austin's Transportation Department, the intention of the surcharge is to help allow for technology

[6] Amayo-Ryan, Permit Review Analysist Manager at Austin's Transportation Department. Interview. March 1, 2019

improvements and support a data and technology division. Through the additional revenue, the department has been able to fund an entire salary within the division. The city's investment in data-driven collection and capabilities is evident, especially considering their department's GIS tool, ROWPACT Project and Coordination Tool, which was built in-house.[7] The tool maps issued permits, color-codes them by the type of permit, and stores historic permit data as well. This allows for smoother permit coordination within the department when processing new permit requests. Currently, the goal is to provide a public-facing, real time coordination platform that notifies of upcoming projects and allows citizens to cross-register their commuting routes to see if they will be affected by any current ROW permitted projects. To make this happen, the city of Austin is working to implement AMANDA, a permitting and compliance platform provided by the private developer, CSDC Systems.[8] Other such cities that have implanted this platform included San Jose, Portland, Toronto, and Vancouver.

St. Paul, MN

The city of St. Paul's permit fee structure mirrors Pittsburgh's in that both a traffic obstruction permit and excavation permit are required for ROW work. What separates it from Pittsburgh is its thorough consideration of city-wide location differences in motorized traffic congestion patterns, as it charges more for higher traffic areas where ROW permits will have a disproportionate impact on traffic flow.

- *Time Consideration:* Currently, there is not an incentive structure built into the permit fee structure to ensure for more on-time project completions.

- *Motorized Traffic Congestion*: The city is a leading city in accounting for motorized traffic congestions patterns and its level of specificity in traffic volumes counts. First, the city distinguishes the permit rates for residential and downtown streets—charging more for downtown-street permits assuming a space closure will cause a greater inconvenience on the public. Second, the fees for Driving Lane Obstructions are subject to the type of street (i.e., Residential or Arterial), average daily traffic flow counts (i.e., Raw traffic count x Season Adjustment factor = Adjusted Count), number of lanes permit effects, and the time of day (i.e., 24 hours, 9am-3pm, 6pm-6am).[9] The city does benefit from the robust efforts made by the Minnesota Department of Transportation (MnDOT) to measure statewide traffic volumes through its Traffic Monitoring and Vehicle Classification Program.[10]

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[7] "ROWPACT: User Guide." *Right-of-Way Permitting and Coordination Tool.* City of Austin. http://www.austintexas.gov/Geocortex/Essentials/External/REST/sites/ROWPACT/VirtualDirectory/Viewers/ROWPACT/VirtualDirectory/Resources/Documents/ROWPACTUserGuide.pdf

[8] "Permitting and Compliance." *Amanda*, CSDC Systems , www.csdcsystems.com/solutions/permitting-and-compliance-solutions/?gclid=EAIaIQobChMI1uPB-vaL4gIVyIqzCh1GcQGeEAAYASABEgL2gfD_BwE.

[9] https://www.stpaul.gov/sites/default/files/Media%20Root/Public%20Works/2018%20Permit%20Rates.pdf

[10] *Traffic Forecasting & Analysis*. Minnesota Department of Transportation, www.dot.state.mn.us/traffic/data/coll-methods.html#TVP.

The traffic volume program allows counties and cities to track their own counts, St. Paul being one of those cities. To capture the average daily traffic flow counts, the city has automatic traffic count locations almost every block in the downtown area.[11]

- *Pedestrian & Bike Inconveniences:* St. Paul is unique in that its fee structure features a bike lane obstruction fee. This is unique because most U.S. city fee structures do not mention or consider bike lanes for their permit fees, which means the inconvenience for bicyclists generated by a potential lane obstruction is not being captured in the permit costs. Again, MnDOT's efforts to measure traffic counts has opened the door for someday creating fees based on pedestrian and bicyclist corridors that are distinguished by volume counts. Because of MnDOT's Minnesota Bicycle and Pedestrian Counting Initiative, there are two permanent index monitoring sites in the city of St. Paul.[12] That, paired with the St. Paul's annual city-wide, volunteer-based count initiative, has helped set baseline traffic flows for non-motorized modes of transit. In this paper, we propose a model that could operationalize such estimates for the city of Pittsburgh.

- *Parking Revenues:* The city's parking meter fees feature a more robust composition of fees than most cities. Included in the parking costs is a fixed labor and material charge (i.e., "hooding fee"), baseline permit fee, lost revenue count, and enforcement charges (for the hours of 8am to 10pm). This portfolio of charges still does not consider average parking volumes per meter area. Because of this fact, there is concern for the potentiality of disproportionally over charging for parking fees when comparing them to the permit's actual impact on parking.

Washington, D.C

The District of Columbia's permit fee structure also has similarities to Pittsburgh's in the baseline structure of the permitting procedure. What separates it from Pittsburgh is its articulated consideration for the value of public inconvenience during long permit projects.

- *Time Consideration[13]:* The typical length of a ROW permit is either 30 days or 45, depending on whether it is a surface permit or excavation permit being issued.[14] While the monthly period increments are larger than other cities' per-day or per-

[11] "Interactive Traffic Data Application." *MnDOT Traffic Data*, MN Department of Transportation, dotapp9.dot.state.mn.us/tfa/.

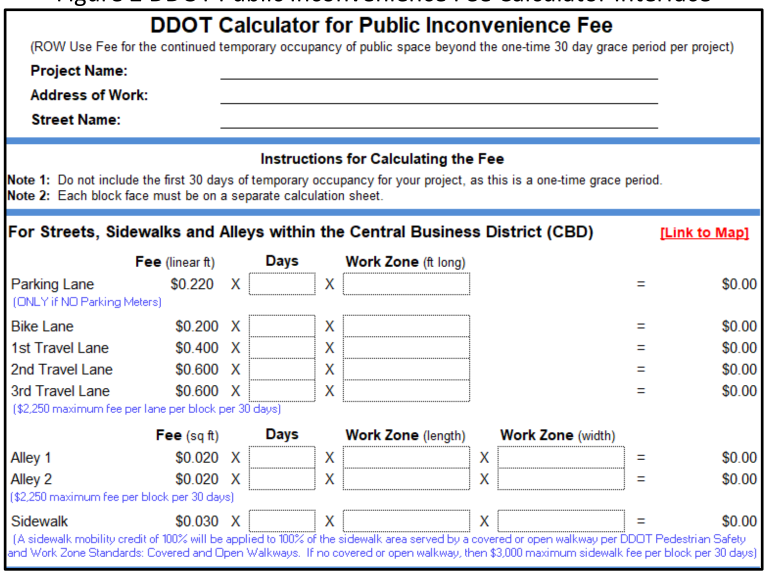
[12] "2015 - 2016 City of Saint Paul Bicycle and Pedestrian Count Report." *Department of Public Works.* Saint Paul, Minnesota. August 1st, 2017. https://www.stpaul.gov/sites/default/files/Media%20Root/Public%20Works/2015%20to%202016%20Bicycle%20and%20Pedestrian%20Count%20Report.pdf

[13] "Public Space Permit Fees." *District Department of Transportation*. Washington, D.C. https://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/ddot_public_space_permit_fees.pdf

[14] "Frequently Asked Questions on Permits." *District Department of Transportation*, Washington, D.C., ddot.dc.gov/page/frequently-asked-questions-permits.

week costing models, D.C. assesses a "Public Inconvenience Fee" (PIF) if the project needs to be extended beyond the original occupancy permit timeline and will be charged throughout the duration of the renewed period. The PIF is designed to be "an incentive to use public space more efficiently, enhance public mobility and return the use of the sidewalk, alley or roadway to the general public in a timely fashion."[15]

Figure 2 DDOT Public Inconvenience Fee Calculator Interface



DDOT Calculator for Public Inconvenience Fee

(ROW Use Fee for the continued temporary occupancy of public space beyond the one-time 30 day grace period per project)

Project Name:

Address of Work:

Street Name:

Instructions for Calculating the Fee

Note 1: Do not include the first 30 days of temporary occupancy for your project, as this is a one-time grace period.
Note 2: Each block face must be on a separate calculation sheet.

For Streets, Sidewalks and Alleys within the Central Business District (CBD) [Link to Map]

	Fee (linear ft)		**Days**		**Work Zone** (ft long)				
Parking Lane (ONLY if NO Parking Meters)	$0.220	X		X				=	$0.00
Bike Lane	$0.200	X		X				=	$0.00
1st Travel Lane	$0.400	X		X				=	$0.00
2nd Travel Lane	$0.600	X		X				=	$0.00
3rd Travel Lane	$0.600	X		X				=	$0.00

($2,250 maximum fee per lane per block per 30 days)

	Fee (sq ft)		**Days**		**Work Zone** (length)		**Work Zone** (width)		
Alley 1	$0.020	X		X		X		=	$0.00
Alley 2	$0.020	X		X		X		=	$0.00
($2,250 maximum fee per block per 30 days)									
Sidewalk	$0.030	X		X		X		=	$0.00

(A sidewalk mobility credit of 100% will be applied to 100% of the sidewalk area served by a covered or open walkway per DDOT Pedestrian Safety and Work Zone Standards: Covered and Open Walkways. If no covered or open walkway, then $3,000 maximum sidewalk fee per block per 30 days)

- *Motorized Traffic Congestion*: D.C.'s DOT (DDOT) takes into account differences on economic activity by distinguishing between the "Central Business District" (CBD) and the non-CBD in its pricing model. Again, this approach acknowledges the variation in motorized and non-motorized traffic within the defined areas. In addition to districting, the permit fees also consider the extra cost of working on additional traffic lanes.

- *Pedestrian & Bike Inconveniences:* By including sidewalks and bike lanes (considered travel lanes) in the PIF, the negative effects that permits can have on bicyclists and pedestrians is being acknowledged and captured, albeit rather crudely. There is also an incentive to maintain pedestrian mobility to the DDOT's "Pedestrian Safety and Work Zone Standards" that comes in the form of public mobility credits of 100% that will be applied towards sidewalk fee incurred from the PIF.[16]

- *Parking Revenues:* Aside from the application fee, only potential lost revenue is captured and charged for in the permit fee.

[15] "Frequently Asked Questions about the Public Inconvenience Fee." *District Department of Transportation*, Washington, D.C., 11 Apr. 2011, ddot.dc.gov/publication/frequently-asked-questions-about-public-inconvenience-fee.

[16] "Frequently Asked Questions about the Public Inconvenience Fee." *District Department of Transportation*, Washington, D.C., 11 Apr. 2011, ddot.dc.gov/publication/frequently-asked-questions-about-public-inconvenience-fee.

* While the District Department of Transportation does not charge a technology fee for its right-of-way permits, the act is not uncommon in D.C. For example, the Department of Consumer and Regulatory Affairs charges a 10% technology fee for all of its issued permits.

Other Policy Levers Utilized by Cities

1. Consideration of Permit Proximity to Traffic-influencing Attributes

In Cedar Rapids, Iowa, the ROW permit applications inquire about the permit location's proximity to certain objects, such as a traffic signal (see application excerpt below).[17] While the relevancy of this information concerns the permit procedure and application approval process, it brings up an interesting consideration. Understanding distances from other ROW features (i.e., environmental, model transportation, etc.) could prove informative for motorized and non-motorized traffic disruptions or delays.

Figure 3 ROW Permit application fields for Cedar Rapids, Iowa

Work will be done in: (select all that apply) ☐ Street* ☐ Alley ☐ ROW (between Street & Property Line) ☐ Easement ☐ Other
*Must complete Section 3 (Street Information) on page 2

Will any work be done within 10' of a tree in public right-of-way? ☐ YES (requires approval of City Arborist) ☐ NO

Will any work be done within 15' of a sidewalk ramp? ☐ YES ☐ NO Is ramp impacted? ☐ YES ☐ NO (if yes, provide drawing)

Will any work be done within 300' of traffic signal? ☐ YES (requires approval of Assistant City Traffic Engineer) ☐ NO

Surface Type: ☐ Concrete ☐ Asphalt ☐ Sealcoat ☐ Gravel ☐ Grass

Restoration of ROW by (select one): ☐ Applicant ☐ Property Owner ☐ Subcontractor: ____________

2. Use of Deposits (which include fee-withdrawal for additional source of income)

The use of deposits can serve as a commentary approach to utilizing bonds and liability insurance to securitize project completion and adherence to city project standards. It can also generate a new source of income. For example, the city of Toronto requires those who receive ROW construction permits to submit a Municipal Road Damage Deposit—$2,576.06 for Residential Applications, $6,539.28 for Commercial/Industrial Applications, and "a non-refundable fee of $66.03 deducted from the deposit at the time of the refund."[18] The bond is used to incentive the prevention of sidewalk, road or curb damage. Another example of bonds being used for this purpose is in Blue Springs, Missouri. Instead of requiring the deposit for ROW construction permits like in Toronto, Blue Springs applied the bonds to ROW street cuts—keeping approximately 1.3% of the deposit as a fee.[19] This demonstrates the versatility of such a policy tool designed to reinforce certain incentives at the discretion of the city.

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[17] "Right of Way Permits & Working in the Right of Way." *Public Works*, City of Cedar Rapids, www.cedar-rapids.org/local_government/departments_g_-_v/public_works/right_of_way_permits.php.

[18] "Municipal Road Damage Deposit Permit." *City of Toronto*, www.toronto.ca/services-payments/building-construction/infrastructure-city-construction/construction-standards-permits/construction-permits/municipal-road-damage-deposit-permit/.

[19] *Right-of-Way Permitting*. City of Blue Springs, MO, www.bluespringsgov.com/1796/Right-of-way-Permitting.

Traffic Obstruction Permits

Data Description

The City of Pittsburgh provided us with an excel document of traffic obstruction permits from 2016 to 2018. This document had 13593 permits in total with 124 features. The primary ID for each permit was "id" which indicated the year the permit was issued, not started, and a unique letter/number combination identifier. The following features from this dataset informed our model:

Geo.x and Geo.y: Latitude and Longitude coordinates for the location of the permit. Using GIS analysis we could ascertain the permit's neighborhood, closest street, and proximity to social cost metrics such as public bus stations or parking meters.
Description: A brief text description of the work being carried out. This field would sometimes indicate the right of way area that was being impacted by the work.

asis.Date.c.From. and asis.Date.c.To: The start and end date for the project indicated on the permit application. This gives us a rough estimate of the time period that will be impacted by the work. This is not the actual start and end date for work.

asis.Maintain.ca.cminimum.cof.cone.clane.cin.ceach.cdirection.cat.call.ctimes: Indicator variable if a minimum of one lane of traffic is open during the construction project. This makes it more likely for traffic delays due to construction.

asis.Off.1duty.cpolice.cofficer.crequired.cduring.cworking.chours.cto.cassist.cwith.ctraffic.ccontrol: Indicator variable if the permit requires an off-duty police officer to perform traffic control duties. Leads to a greater chance for traffic delay

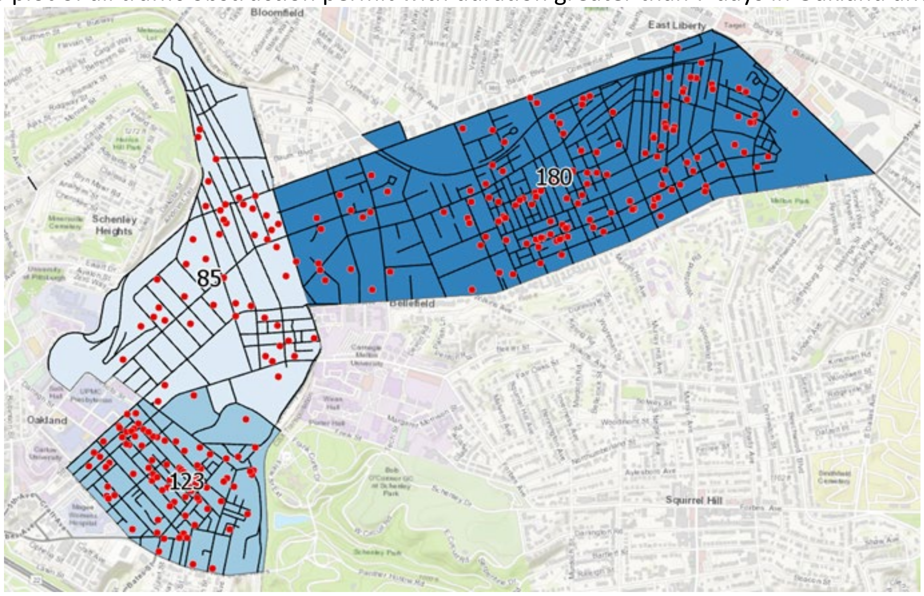
asis.Flagperson.crequired.cduring.cworking.chours.cto.cassist.cwith.ctraffic.ccontrol: Indicator variable if the permit requires a flagger to perform traffic control duties. Leads to a greater chance for traffic delay.

Scope

Based on our other datasets we narrowed the scope of the project to focus on permits in 2016 equal to or greater than 7 days that were in Central Oakland, North Oakland, or Shadyside.
2016 was the best year for us because most of our other datasets had data from that year, the parking revenue data was from 2015 but we felt it was representative of 2016. We used any permit that started or ended in 2016. This allowed us to have a period before the permit to measure normal delay and a period to measure the impact of the permit on delay. We ignored any permits that consisted of the whole year because we would not have a baseline "normal" delay.

We originally only looked at permits greater than 30 days to measure their long term impact on traffic. However, public bus data showed the effect plateaued after roughly a week. This illustrated individuals adapting to the permit and finding other routes. Therefore, we chose 7 days as the cutoff for permit length because it showed the true effect of the permit on traffic patterns. Figure 4 plots permits that occur for longer than 7 days in Oakland and Shadyside.

Figure 4 GIS plot of all traffic obstruction permit with duration greater than 7 days in Oakland and Shadyside



We chose to concentrate on Central Oakland, North Oakland, and Shadyside because we felt they represented Pittsburgh overall very well, they had enough permits to measure effect but not too many for large overlaps of effect. These communities are centrally located in Pittsburgh to have large amounts of traffic that would be impacted by permits.

Data Processing

Data processing was used to refine the year in which the permit occurred and the length of the permit. We created features for the start and end year to indicate what year the project started and ended. We then narrowed the permits down to only those that started or ended in 2016. For the length of the permit we subtracted the end date from the start date to get the total number of days of the project based on the permit.

Recommendations

The city should collect data on where on the right of way construction work will occur for each permit. This will allow any model used for social cost to be able to capture the difference in inconvenience cost based on whether work is in the road, sidewalk, bike lane, or parking lane. This will lead to a more dynamic model that will more accurately reflect what is going on in a work permit. The model outlined in this report does not take this factor into consideration when applying a social cost.

We also recommend indicating the area of the work zone instead of a point location. This will give a future model a better understanding of the area impacted by work. For instance a model would be able to count the number of parking meters affected by a work zone instead of an estimate. This model assumes that all area equidistant from the permit are affected equally within a threshold limit, such as 500 feet.

Public Transit

Data Description

To quantify the social impact of road obstructions on the public transportation, two datasets are mainly used: Public Transit Data and GTFS Transit Stop Data.

The Public Transit Data records every bus trip that arrives and departures from a bus stop in terms of the arrival time, departure time, the number of passengers on/off, travel distance, inbound / outbound, etc. The data spans from January 2016 to August 2016 and contains all routes within Oakland and Shadyside.

The GTFS Transit Stop Data contains the bus schedule and bus stop location information during the first quarter of 2016. The data maintains 152 stops within Oakland and Shadyside area.

The detour data has also been explored. It consists of records of broadcast on the bus detours, which are in text files. Most of these records were related to short-term permits, emergencies, or non-obstruction permits, which do not match with the long-term obstruction permits in this project. Besides, much of the detour information was recorded when Port Authority was informed of the detour temporarily, so it is not full data about all detours.

Methodology

Public vehicle inconvenience cost aims to assess the external impact on the public transit of permitting obstructions. The basic idea is that if a permitted obstruction causes road closure or traffic congestion to some extent, it might bring bus delays, extra emission, and some other negative externalities. In order to incorporate the social costs on public transit of a given permit, the two major costs -- **congestion cost and emission cost** -- are quantified in this project.

Congestion cost of a permit is measured by multiplying delay time per bus trip, the number of passengers affected and the value of time of passengers.

$$Congestion\ Cost\ =\ Delay\ Time\ \times\ Number\ of\ Passengers\ Affected\ \times\ Value\ of\ Time$$

Emission cost of a permit is calculated with extra emission per delayed trip, traffic volume and the price of emission. Since the major pollutant emitted by bus is carbon dioxide, its emission is measured in this project.

$$Emission\ Cost\ =\ Extra\ Emission\ \times\ Traffic\ Volume\ \times\ Price\ of\ Emission$$

The delay time per trip is measured by the difference between the average travel time of the bus each trip during the obstruction period and the normal travel time. Similarly, the extra emission of carbon dioxide is the difference between the average emission amount per trip during the permit period and the normal emission.

$$Delay\ Time\ =\ E(Travel\ Time\ during\ Permit)\ -\ E(Normal\ Travel\ Time)$$

$$Extra\ Emission\ =\ E(Emission\ during\ Permit)\ -\ E(Normal\ Emission)$$

Given the massive data sets and the need to assess to what extent the obstructions produce social costs, an exploratory data analysis, and predictive analysis have been done so as to have a general idea what kinds of permits might be associated to delay and extra emission based on historical data and build a prediction model for further pricing use.

Social Impact Assessment

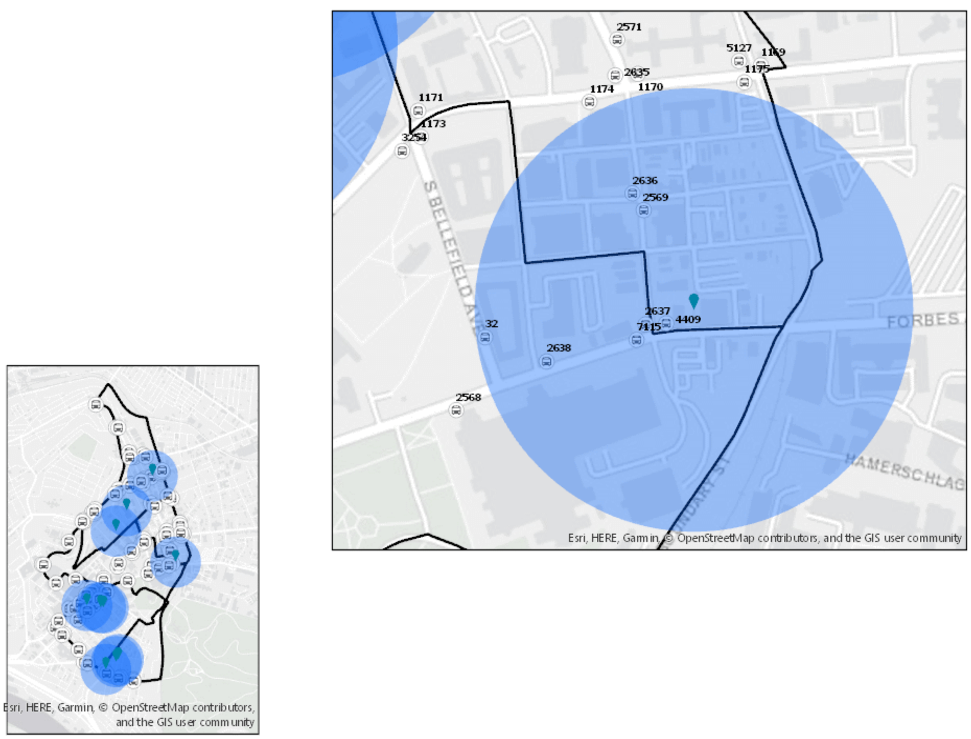
The primary goal of the exploratory analysis is to validate the methodology of quantifying the congestion cost and emission cost with the current datasets, as well as to construct a logical way of thinking - what other social features might associate with the road obstruction and cause varied levels of social effect.

Given the two formulas above, the key issue of calculating the congestion cost is to evaluate the time delay of a bus trip due to the road obstruction at the neighborhood. As for the emission cost, since we don't have direct record of the emission per bus trip, we measured the extra Carbon Dioxide (CO2) produced by vehicles due to the reduced speed caused by the congestion. According to the Energy Data Book[20], **there is a nonlinear relationship between fuel economy and average vehicle speed.**

Having had a high-level conception of the key features to be quantified, the next step is to define the scope of the social impact. And we made two key assumptions as below:

Assumption 1: In terms of the spatial range of the impact, **an obstruction mainly affect nearby bus stops**. We initially defined the impact area as a buffer area with a celcus of 150 meters centered on the location of the obstruction.

Figure 5 GIS plot of a permit and its impact area (shaded in blue)



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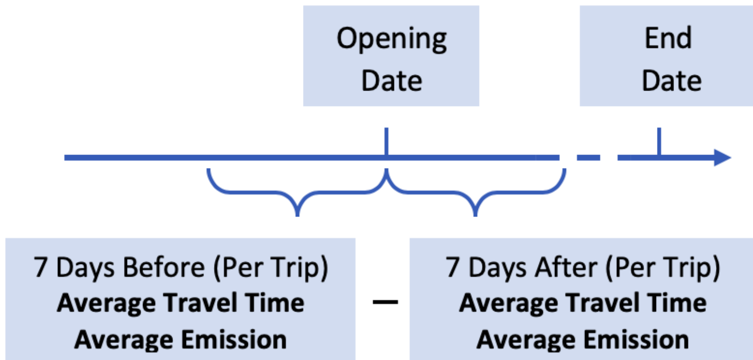
[20] Qian, Zhen(Sean), and H.Michael Zhang. "Journal of Transportation Engineering." *Full Closure or Partial Closure? Evaluation of Construction Plans for the I-5 Closure in Downtown Sacramento*, March 2013, 273-86. doi:10.1061/(ASCE)TE.1943-5436.0000502.

Assumption 2: In terms of the time range of the impact, **the beginning stage of an obstruction leads to a more significant time delay of the nearby bus trips**. Specifically, we assume the public transportation less than 7 days after the opening date of the obstruction will be notably affected.

Figure 6 Temporal representation of Permit activity impact diagram



Predictive Analysis

Given the two assumptions above, the delta travel time and delta emission are computed through comparing the average travel time and emission of the spatially affected bus trips during 7 days before and 7 days after the opening date of the obstruction. While the calculated results provide readers with a picture of what might be the social effect of road obstruction, the ultimate goal of the project is to support the decision making - In face with a new application of the road permit, how to decide a proper price to capture its true effect on the public transit? Thus, a predictive model is necessary to answer the question.

In order to measure the travel time and emission of trips near obstructions, each bus trip is splitted into intervals between adjacent stops. Thus, we only focus on the trip intervals near the permits, and calculate the travel time and speed per interval. The travel time per interval per trip is measured by the difference between the arrival time of the next stop and the departure time of the previous stop. The speed per interval is the distance between adjacent stops over the travel time.

Data Processing

The general idea of data processing is to match the public vehicle data, which consists of the Public Transit Data and GTFS Stop Data, with the permit data to detect the change of bus travel time and emission. Three steps are implemented to achieve the data integration:

Step 1: Join the permit data with GTFS Stop Data. Following the first assumption that the obstruction permit only affects bus stops within a certain distance, we used GIS to spatially join all the bus stops in a 150-meter-radius buffer with the permit centered on that buffer. Each row of the new data reflects a specific permit-stop pair.

Step 2: Join the new data with the Public Transit Data. Given the second assumption that the obstruction permit leads a significant difference in travel time / emission of the nearby bus stops between the pre 7-day period and post 7-day period of the permit, we joined each permit record with all public transit records that fall upon the corresponding time window. Each row of the joined data reflects a specific permit-bus trip pair.

Step 3: Aggregate the joined data to permit level. Since each permit is related to multiple bus trips that transit at the nearby stops, the last step is to average out the travel time and emission recorded by each single bus trips and conduct feature engineering to train the predictive model. After the data aggregation, each row reflects one unique permit obstruction and the average time delay and extra emission associated with that permit.

Step 4: Engineer features. To build the predictive analysis for incorporating future permits in pricing, characteristics of permits and bus trips that are likely to be associated with delay and extra emission are taken into account. Given the data in hand and referencing from other cities, 5 features are generated:

1. **Rush hour:** whether the working time of obstruction is in rush hour or not, rush hour is defined as hours between 7AM and 10AM, and between 4PM and 6PM;
2. **Closure:** whether the road is partially closed or fully closed due to the obstruction, which is marked as "checked" in the permit data if a road is fully closed;
3. **Duration**: the number of days an obstruction takes;
4. **Num_stop:** the number of bus stops near the permit, which is within the buffer;
5. **Passenger_vol:** the volume of passenger per bus stop per trip per nearby stop, which is the average total number of riders on and off the bus at each stop per trip.

For each permit, whether the road is fully closed, the duration and the number of stops nearby are fixed, but the travel time, emission amount and passenger volume vary across rush hours and non-rush hours. So when calculating travel time, emission and passenger volume, whether the obstruction work is in rush hour has been taken into account.

Model Definition
To better understand the how and to what extent how different factors affect the difference in bus travel time, a **decision tree** is built for visualizing purpose. After that, a **regression model** is built for more dynamic and accurate pricing purpose.

1) **Decision Tree**
A decision tree is a tree-like decision supporting model. It splits data into different groups by splitting on one feature that could provide most information towards the outcome at a time.

2) **Linear Regression Model**

Regression model for bus delays:

$$Delay\ Time\ per\ Trip = \alpha_0 + \alpha_1 closure + \alpha_2\ duration + \alpha_3 num\_stop + \alpha_4 passenger\_vol + \epsilon$$

Regression model for extra emission:

$$Extra\ Emission\ per\ Trip = \alpha_0 + \alpha_1 closure + \alpha_2\ duration + \alpha_3 num\_stop + \alpha_4 passenger\_vol + \alpha_5 base + emission + \epsilon$$

Model Interpretation & Conclusion

Congestion Cost

As shown below, duration is the most important feature related to whether a bus trip delays. Two other highly related factors are the number of stops near the permit, and the average passenger volume at each nearby stop. Based on historical data and the decision tree, 4 types of permits could be summarized to be associated with bus delays:

1. **Short-term permits:** the decision tree shows that the obstructions with a duration no more than 19 days could be seen as causing bus delays, and thus extra emission.
2. **Long-term permits with more bus stops nearby:** permits with on average more than 5.5 bus stop around but a duration more than 19 days may also be related to bus delays.
3. **Long-term permits with more higher passenger volume:** if a permit has a duration longer than 19 days and less than on average 5.5 bus stops nearby, but with average passenger volume larger than 2.8 per stop, it still has something to do with bus delays.
4. **Very-long-term permits with low passenger volume:** if a permit has a long duration as well as a small number of bus stops and passenger volume nearby, it probably would not cause any bus delay.

Based on the results of decision tree and regression model, permits with shorter duration, more stops nearby or higher passenger volume around are more likely to have an effect on the bus delay and extra emission.

Table 2 Results of the Regression Tree model on delay

	Permit Duration	Road Closure	Number of Stops	Passenger Volume
Rush Hour	-0.00123	-0.0005442	0.004632	0.00009306
Non-Rush Hour	-0.0009	-0.0185	0.0076	-0.0051

Emission Cost

Table 3 Results of the Emission Cost Prediction

	Permit Duration	Road Closure	Number of Stops	Passenger Volume
Rush Hour	-0.3394	-22.1288	-0.4155	4.0127
Non-Rush Hour	-0.3827	-8.5468	4.049	5.6564

Public Transit Inconvenience Cost Calculation

Given the delay time and extra emission per stop per trip, in order to calculate the overall effect a permit has, it should multiply by the average number of trips passing through each stops, and the average number of riders affected at each stop. However, it is very likely that the calculated delay time and extra emission are larger during non-rush hours, comparing with rush hours, and during the rush hours the delay time and extra emission is close to zero. The major reason is that during the rush hours, the congestion exists even when there is no obstruction nearby, and thus the buses have been delayed without the impact of permits. Hence delays caused by the permits during rush hours are not so significant in contrast with the delays during non-rush hours.

Recommendations

1. The information related to the road closure plan should be further confirmed. The accuracy of the feature “road closure” in the predictive models is not guaranteed given the challenge in judging whether the road is fully or partially closed from the permit data. The potential inaccuracy of the feature also poses a threat on the credibility of the model.

2. Detour data could be utilized to better quantify the congestion cost of road obstructions on the public transportation. Current parameters in this article are the average time delay and extra emission due to the reduction in travel speed. While these two parameters can be properly used to measure the congestion and emission cost if the road is partially closed, they still have limitations in assessing the social cost if the road is fully closed. Thus, detour data has greater potential in quantifying the externality given the road will be fully closed under a permit. Further work on information collection and validation from detour data and integration into the model should be highly considered.

3. Need further analysis to quantify the combined effect of multiple road obstruction permits which are spatially closed and have overlaid time period. The current model has muted the joint social impact of multiple permits. However, given the real world scenario, this impact cannot be measured by purely adding up the impact of each permit. Field research can be a good way to get more detailed insight to solve the problem.

Private Vehicle Inconvenience Cost

One of the Right of Way (ROW) impacted by the traffic obstruction permits are those who operate private vehicles. The current permitting structure does not account for (1) the inconvenience cost to drivers from delays caused by the work and (2) additional emissions cost resulting from extended travel times and congestion from the traffic obstruction work. The team's goal is to provide the city with a model that incorporates the two costs mentioned above.

Target Metrics

Driver Inconvenience Cost

Driver inconvenience cost captures the lost time caused by traffic obstruction permit activities. It is measured by multiplying delay caused by a permit activity, traffic volume, duration, and the value of time.

$$\text{Driver Inconvenice Cost} = \text{Travel Time Delay (minute)} \times \text{Number of Vehicles affected} \times \text{Value of Time}$$

Emission Cost

Emission cost represents the negative implications of increased vehicular travel times on the environment. It is calculated by multiplying the amount of increased emission due to increased travel times, traffic volume, and the cost of emission.

$$\text{Emission Cost} = \text{Increased Emission} \times \text{Number of Vehicles affected} \times \text{Cost of Emission}$$

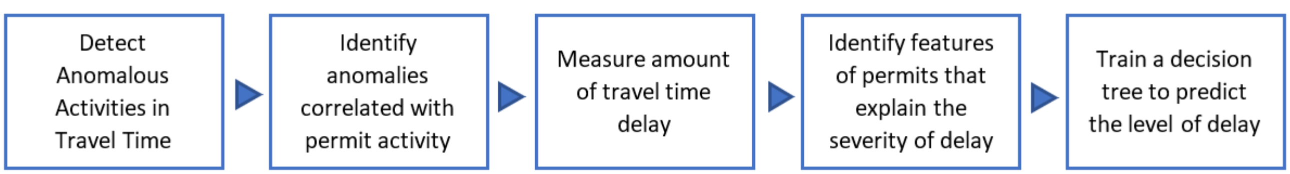
Data Description

There are two main data sources that the team utilized to synthesize metrics to measure the social impact of these obstruction permits: INRIX travel time and State Road Vehicle Volume.

Methodology

Approach

The process flow diagram below describes a five-fold approach to extract the travel time delays necessary to calculate social costs using the data sets mentioned above.



First step involves detecting anomalous activities in travel time. In other words, the purpose is to detect any deviation from average travel times that is not explained by seasonality or daily trends such as rush hour traffic. Once those anomalies have been detected, the next step is to identify anomalous travel times that is correlated with traffic obstruction permit activity. This is accomplished by matching (1) the start and end dates of the permit with the detected anomalies and (2) location of the permit and the TMC sensor locations. Such anomaly detection method then can be used to measure the average delay caused by the matched permit activity by subtracting the average travel time of anomalies from the average time of non-anomalies: (3)

Distinct fields in permit data helps explain the measured travel time delay and such features is used to train a decision tree that predicts the level of delay based on the permit details.

Key Assumptions

The following are key assumptions made while running this model.

1. Anomalous activity is explained by permit activity and permit activity alone.
2. The locations of the permit activity impact a portion of the road.
3. One permit can affect multiple roads.
4. One road can be affected by multiple permits.

Data Processing

Feature Engineering

With the provided permit data, the following features were engineered to be incorporated in building a model:

1. Delay significance: categorizes the amount of delay into four levels: None, Low, Moderate, and Major. Exact characterizations and values are displayed in the following Table 4:

Table 4 Classification of delay significance levels

Delay Significance Level	Amount of Time Delay
None	0 min
Low	$0 \text{ min} \leq \text{delay} < 5 \text{ min}$
Moderate	$5 \text{ min} \leq \text{delay} < 10 \text{ min}$
Major	$\text{delay} \geq 10 \text{ min}$

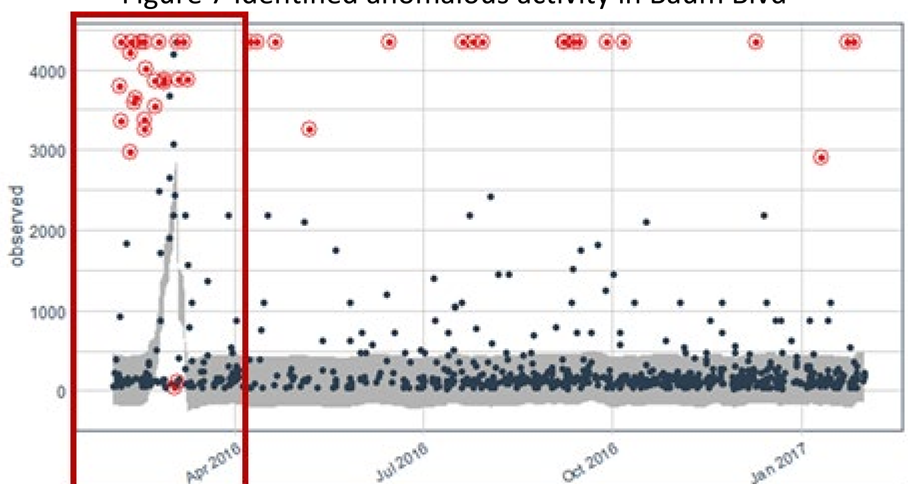
2. Weekday Work Hours: assigns weekday work hours into two categories (1) rush hour and (2) non rush hour based on time inputs provided by the original permit data;
3. Weekend Work Hours: assigns weekend work hours into two categories (1) continuous and (2) intermittent. Continuous work hours categorize entries in the original permit data;
4. Average Traffic Volume: the average number of vehicles on a given road. This feature is extracted from the traffic volume data set. Two values are calculated: the average volume during rush hour and non-rush hour.

Results

Anomaly Detection

The figure below plots the travel times of vehicles on Baum Blvd from February 2016 to January 2017. The red points indicate the detected anomalous travel times. There is a larger cluster of points identified as anomalous, as indicated by the red box. Comparing this result with the permit information, there is a vault installation occurring in Baum Blvd between February and April. With this information, it can be concluded that there is a high probability this permit activity is correlated with a delay in travel time.

Figure 7 Identified anomalous activity in Baum Blvd



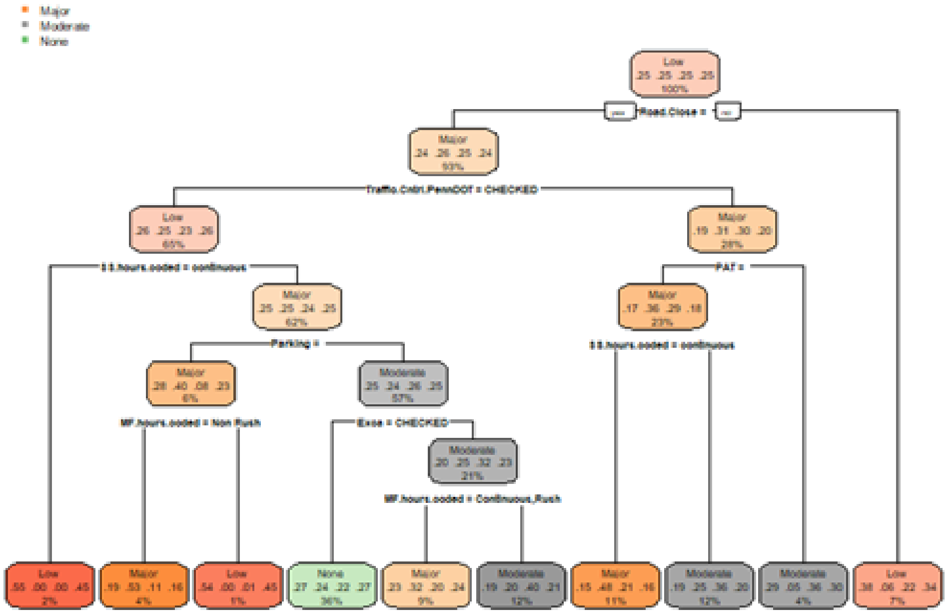
Permit ID	Permit Location	Description	Start Date	End Date
DPW1601084	0 BAUM BLVD	INSTALLING VERIZON VAULT	2/17/2016	4/2/2016

The above approach is implemented for all available travel time measurements.

Decision Tree Results

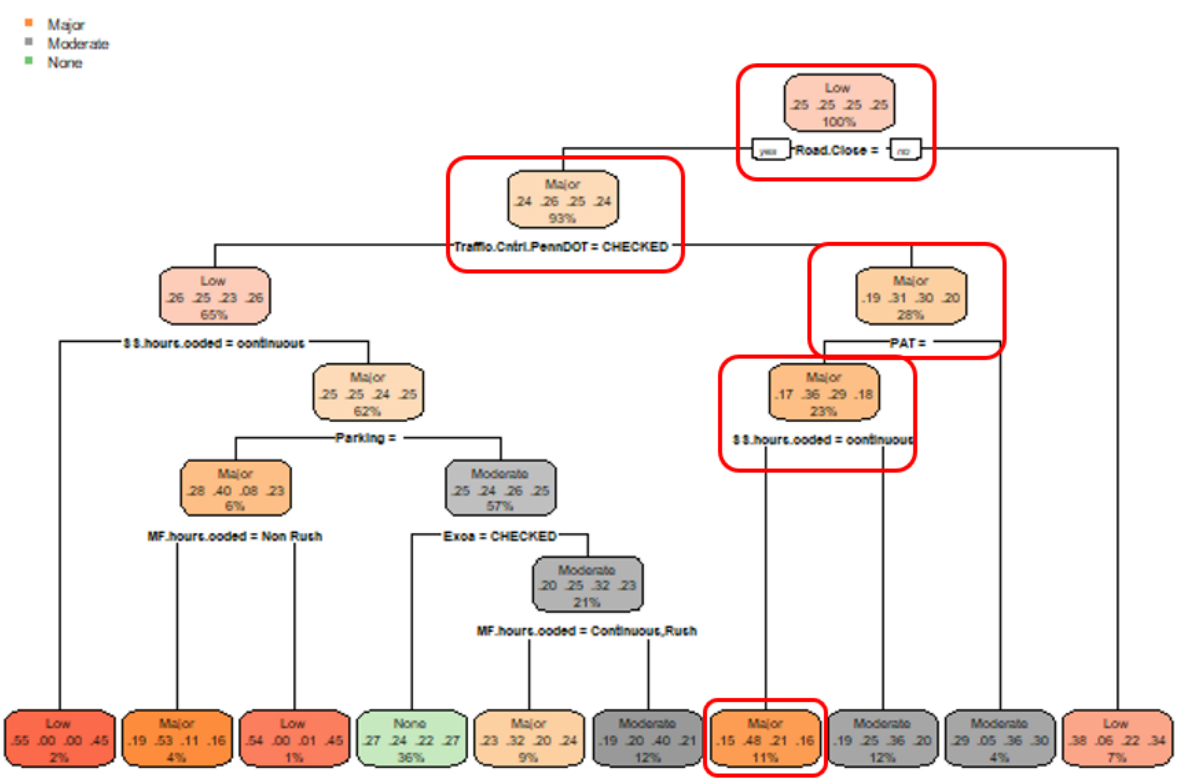
Decision Tree learning is a model that is trained to predict a certain value (e.g. estimated travel time delay) based on multiple input variables (features extracted from the permit data). This learning method is used to predict an estimate of travel time delay depending on the information contractors provide to the city. Figure 8 is a diagram of the decision tree learned for this project.

Figure 8 Trained decision tree model to predict travel time delays



For example, referencing the sequence of red boxes in the figure below, if the permit indicates that the full road closure field is left unchecked, a traffic control plan based on PennDOT's procedure is submitted, the Port Authority has not been notified and there is continuous work being done on weekends, the model predicts that the permit activity will most likely cause a major delay (over 10 min).

Figure 9 Sample Path of trained decision tree model to predict travel time delays



A prototype web application

In addition, the team also develops **a prototype web application** to visualize the ROW permit information and their respective 'true social cost', alert locations that are likely to violate permits, and recommend routes and locations to inspectors for visual inspection and enforcement. Figure 10 below shows a screenshot of the web application. It provides user interfaces to query and visualize any ROW permits of interest, reviewing their respective societal cost (quantified by the methods discussed above). It also is able to detect and warn any substantial societal costs induced by a new permit application, with a follow-up suggestion to change the timeline of this new permit.

The right-of-way permitting system would allow the city to efficiently manage and enforce permits, reduce labor costs, and improve revenue management It would also best allow permits over time and space using the pricing as the leverage, so as to improve city's mobility and safety.

Figure 10 A screenshot of the prototype ROW web application