MEMORANDUM

Date:	04/25/2025	Project Number:	872.17.55
To:	Lawrence Henriquez, Senior Engineer, City of South San Francisco		
From:	Debaroti Ghosh, PhD and Margot Yapp, PE		
Subject:	Final Memo-Financial Impact of Heavy Construction Vehicles on City's Street		

Background

Construction traffic due to residential, commercial or public development can significantly impact pavement conditions. The construction introduces heavy equipment and material delivery vehicles, accelerating deterioration and worsening pavement condition. The City's objective is to identify the impacts of heavy construction vehicles and develop fees to recoup the damage they cause on City streets. Consequently, Nichols Consulting Engineers, Chtd. (NCE), conducted this study to quantify these impacts in financial terms. The following sections describe the technical approach used and presents the study's results.

Vehicle Impacts

To determine the number of trips that construction of a new unit would generate, the trip requirements for construction equipment, building materials, and home appliance deliveries were estimated. In the case of an undeveloped lot requiring grading and concrete slab placement, the large construction equipment traveling to the site would include an excavator, mini excavator, and a skid steer/forklift, totaling approximately 5 truck round trips. Material delivery was estimated at approximately 10-15 truck round trips (depending on type of units), including off-haul/infill material, foundation concrete pouring, lumber deliveries, drywall delivery, plumbing fixtures, HVAC fixtures and venting, roofing materials, landscaping materials, flooring materials, windows, counters, doors, street utility materials, driveway installation (concrete/asphalt truck or paver delivery), conditioned street improvement materials (asphalt and concrete), and general home appliances.

After consultation with Public Works Staff and based on previous studies related to the impact of heavy construction vehicles, NCE made the following assumptions below. Assumptions are based on Engineering Department's staff experiences with development construction projects. To keep the analysis straightforward, the City used a conservative estimate of travelling 6 miles one way to a dumpsite in Brisbane, rather than a more distant location.

- The average size of units in the City are assumed to be:
  - Single-family residential unit -2,000 square feet (sf)
  - Multi-family residential unit- 10,000 square feet (sf)
  - Commercial/Industrial unit- 25,000 square feet (sf)
- The average number of heavy construction vehicles based on experiences in inspecting developments of the single family and multi-family type required are assumed to be:
  - Single-family unit- 15
  - Multi-family/ commercial/ industrial unit- 20
- Construction vehicles travel an average of 6 miles roundtrip on residentials and 10 miles roundtrip on arterials/collectors to access the project site.

The detailed analysis of the financial impact of heavy construction vehicles is presented in Appendix A. It is important to note that heavy construction vehicles do not travel City streets with the same regularity and the route is dependent on the development sites. Therefore, the damage cost for heavy construction vehicles was estimated according to the approach described below:

1. Calculate the average damage cost per heavy vehicle $950 for residentials and $66 for arterials/collectors. Please see Appendix A for the technical approach on how these damage costs were determined.
2. Calculate the damage cost associated with the construction of residential and non-residential units based on the estimated number of vehicle trips and miles traveled.
3. Convert the damage cost to the following units and compare with neighboring agencies:
   a. Per unit – residential
   b. Per square foot of construction - residential/non-residential

Results

Table 1 shows the proposed heavy construction vehicle impact fee options.

Table 1. Proposed Construction Vehicle Impact Fees for City of South San Francisco

Option	Residential Unit Fee*	Non-Residential Unit Fee*	Unit
	Single Family	Multi-Family/commercial/ industrial	
1	$1,300	$1,000	per unit
2	$1.00	$0.50	per square foot

*Fee in 2024 dollars

For comparison, Table 2 summarizes heavy vehicle impact fees for several cities throughout California. These fees typically represent transportation costs associated with construction of new developments and are collected by agencies as part of a development impact fee. Many of the agencies have different fees based on the type of construction (residential vs. non-residential). The residential fees are predominantly flat fees, but some are also based on square footage or vehicle mileage. The non-residential fees are based on the square footage of the building being constructed.

The estimated per-unit fee for residential construction in the City is similar to the fees for many of the other agencies listed in Table 2. However, in terms of square footage, the proposed impact fees are lower than for most other agencies. Since the proposed fees were derived based on construction trips for an average size, single-family unit, NCE recommends implementing the fee on a per-square-foot basis to enable appropriate scaling for multi-family developments. Additionally, it is important to adjust the fee annually to account for inflation.

Table 2. Summary of Other Agencies' Construction Vehicle Impact Fees

Agency	Criteria	Fee	Reference
Anaheim	Single Family Unit	$2,029 per unit	City of Anaheim 2020
	Multi-Family	$1,297 per unit	
	Commercial/Industrial	-	
Citrus Heights	Single Family Unit	$1,434.12 per unit	City of Citrus Heights 2021
	Multi-Family	$1,312.74 per unit	
	Commercial/Industrial	$4.45 per sf	
San Bruno	Single Family Unit	$4,615 per unit	Economic & Planning Systems, Inc., 2019
	Multi-Family	$2610 per unit	
	Commercial/Industrial	$6.95 per sf	
San Francisco	Single Family Unit	-	City of San Francisco 2021
	Multi-Family	$9.95 per sf	
	Commercial/Industrial	$19.48 per sf	
San Mateo	Single Family Unit	$5003.76 per unit	City of San Mateo 2021
	Multi-Family	$3,071.42 per unit	
	Commercial/Industrial	$5.40 per sf	
Santa Cruz County	Single Family Unit	$697 per mile	NCE 2015
	Multi-Family		
	Commercial/Industrial	-	
	Multi-Family		
Pacifica	Single Family Unit	$2,126/Unit $1.18/sf	NCE 2021
	Multi-family/Commercial/Industrial Unit	$1.18/sf	

APPENDIX A

Appendix A

Heavy Vehicle Impact Study

City of South San Francisco

City of South San Francisco

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April 2025

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NCE Project No. 872.17.55

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1 Technical Approach

1.1 Background

The damage a particular vehicle imposes on a pavement depends on the condition and structure of the pavement and the load and axle configuration of the vehicle. In general, the damage to a pavement structure increases exponentially as the load increases (Huang 2003). As pavement conditions worsen, the damage caused by a given load increase. Additionally, the damage caused by a given load is less for a thicker pavement structure than it is for a thinner pavement structure.

Pavements do not deteriorate linearly. A newly constructed pavement starts out in excellent condition and deteriorates slowly for approximately 60 percent of its life. After that, the pavement deteriorates more rapidly, until it is considered failed. A pavement's total service life is the time it takes for it to deteriorate from excellent to failed condition. The remaining service life (RSL) is equivalent to the time it will take to deteriorate from its current condition to failed condition.

The structural impact of a vehicle on a pavement depends on the vehicle's load and axle configuration. An 18,000 lb load on a single axle is commonly used as the standard to which all other axle configurations and loads are compared. An Equivalent Single Axle Load (ESAL) describes the damage to a pavement caused by an 18,000 lb load on a single axle (Huang 2003). As axle load increases, the damage caused increases exponentially. For perspective, an average 4,000 lb passenger car has an ESAL equivalent of 0.0004 ESALs, while an 80,000 lb 5-axle tractor-semitrailer has an ESAL equivalent of 2.37 ESALs.

Since damage to a pavement is typically quantified in terms of ESALs, it is appropriate and common to also describe a pavement's structural capacity in terms of ESALs to allow for direct comparison.

1.2 Methodology

NCE developed a methodology combining elements from the California Department of Transportation (Caltrans) Highway Design Manual (HDM) (Caltrans 2019) and the American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures (AASHTO 1993). Both methods were employed to 1) incorporate the standard design practice for local California agencies, 2) represent traffic demands more accurately, and 3) incorporate the effect of pavement conditions. Ultimately, the analysis compared the estimated traffic demand associated with the heavy vehicles to the average remaining structural capacity of the agency's pavement network. The resulting impact was then integrated with a financial analysis.

Figure 1 presents a simplified flow chart of damage cost calculation using the methodology and assumptions described in the following subsections. It is important to note that the analysis distinguishes between two functional groups: 1) residential streets and 2) arterials and collectors. This differentiation allows us to account for variation in pavement structure and traffic demands.

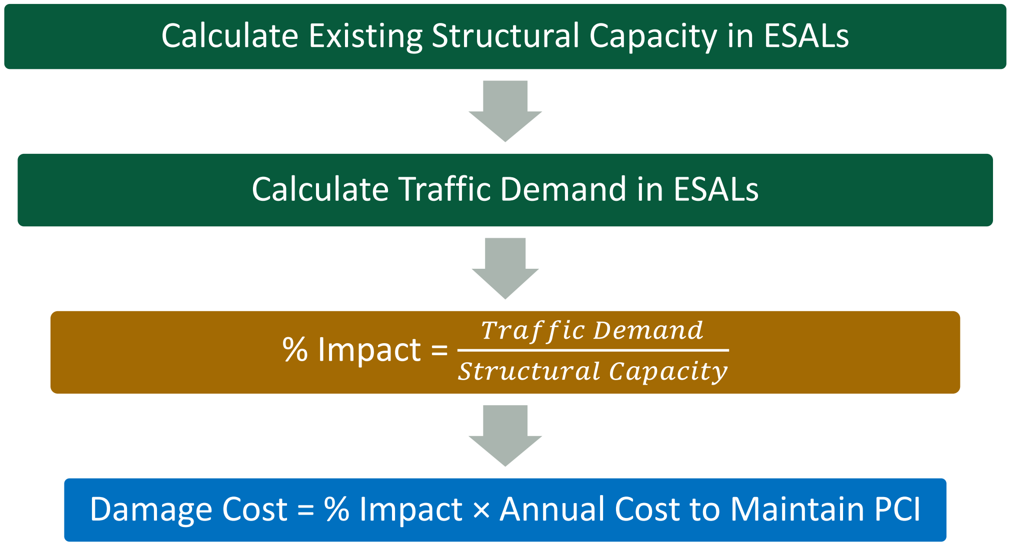

Figure 1. Flow Chart of Damage Cost Calculation

1.3 Pavement Condition

Pavement condition is typically quantified in terms of the pavement condition index, or PCI, which ranges from 0 to 100. The PCI scale is divided into 5 condition categories: “Excellent” (PCI of 85 or greater), “Good” (PCI of 70 – 84), “Fair” (PCI of 50 – 69), “Poor” (PCI of 25 – 49) and “Failed” (PCI of less than 25) (Table 1).

The network pavement condition breakdown by functional group was obtained from the City’s StreetSaver® database and is based on the results of recent condition surveys. The total service life of each functional class group was estimated from the StreetSaver® family deterioration curves for asphalt concrete (AC) pavement. The percentage RSL was also estimated using the StreetSaver® family deterioration curves for AC pavement.

The City’s network is in “Good” condition with an average PCI of 76 as of September 2024. Table 1 summarizes the portion of the City’s network in each condition category by functional class. More than half of the network is in “Excellent” to “Good” condition.

Table 1. Pavement Condition Breakdown by Functional Class

Condition Category	PCI Range	Pavement Condition Breakdown (% Area)*	
		Residentials	Arterials/Collectors
Excellent	85 – 100	39.2%	45.9%
Good	70 – 84	36.4%	29.2%
Fair	50 – 69	18.9%	11.9%
Poor	25 – 49	4.1%	7.7%
Failed	0 – 24	1.4%	5.3%

*Condition data obtained from StreetSaver® in September 2024.

For each condition category, the corresponding percent RSL was estimated from the family deterioration curves based on the mid-range PCI value. The deterioration curves, illustrated in Figure 2, are customized (using historical condition surveys) within StreetSaver® to match the typical performance of City streets. A pavement’s RSL reaches zero when it falls into failed condition (has a PCI less than 25). City residentials have a total service life of approximately 35 years, while City arterials/collectors have a total service life of approximately 30 years (Figure 2). Table 2 shows the estimated percent RSL for each condition category and functional class.

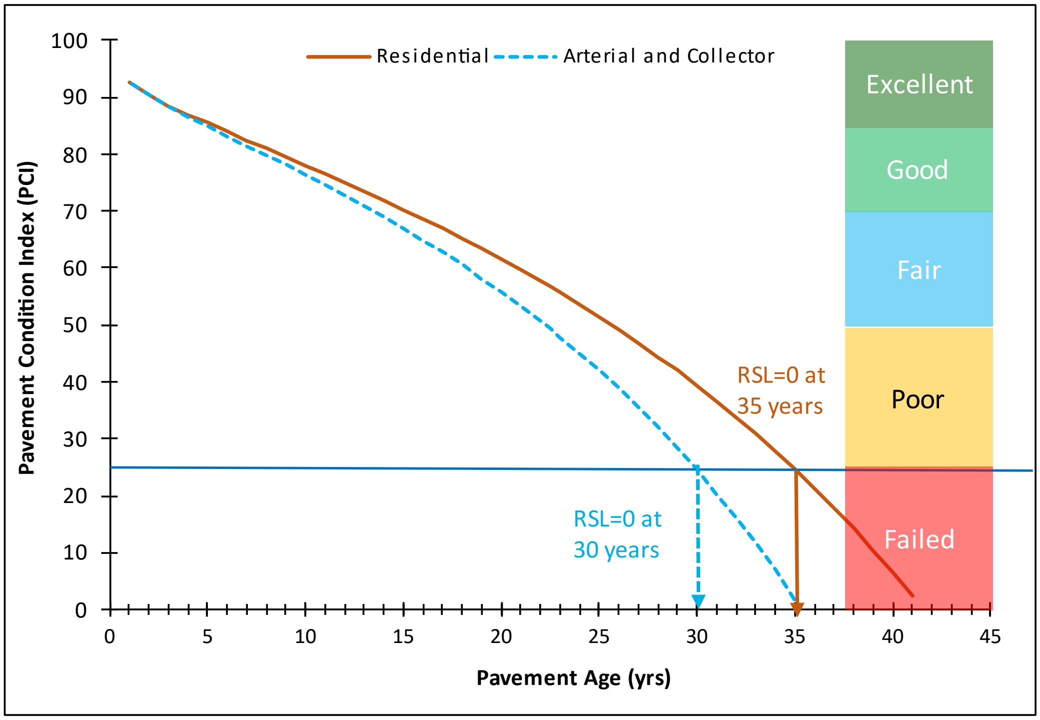

Figure 2. Family Deterioration Curves by Functional Class

Table 2. Remaining Service Life by Functional Class

Condition Category	PCI Range	Average Remaining Service Life (%)	
		Residentials	Arterials/Collectors
Excellent	85 - 100	96.8%	96.4%
Good	70 - 84	64.5%	70.9%
Fair	50 - 69	32.3%	45.5%
Poor	25 - 49	6.5%	18.2%
Failed	0 - 24	0.0%	0.0%

1.4 Structural Capacity

A pavement's capacity to carry traffic loads depends on the pavement structure and condition. Typical pavement structures were assumed to meet the City's design traffic index (TI) values, per the Caltrans HDM (CalTrans 2019), for each functional class group.

Traffic data analysis from various design projects, along with discussions with the City, revealed that residential areas are typically designed to achieve a TI of 5.0, while arterials and collectors are generally designed to meet a TI of 7.5. This was verified by the Public Works Staff. The corresponding ESALs for the design TI values were estimated according to the Caltrans HDM using a subgrade R-value of 25 (based on discussion with the City). To meet their respective TIs, residentials were assumed to have 3.0 inches of AC over 6.5 inches of aggregate base and arterials and collectors were assumed to have 4.5 inches of AC over 12 inches of aggregate base.

Design ESALs represent the capacity that a pavement structure has at the time of construction. For a TI of 5.0, the design ESALs are 7,161. For a TI of 7.5, the design ESALs are 216,093. The number of ESALs remaining based on condition category were estimated for each functional class by multiplying the design ESALs by the percent RSL (Table 3).

Table 3. Structural Capacity: ESALs Remaining by Functional Class

Condition Category	PCI Range	ESALs Remaining	
		Residentials (TI = 5.0)	Arterials/Collectors (TI = 7.5)
New Pavement		7,161	216,093
Excellent	85 – 100	6,931	208,313
Very Good	70 – 84	4,619	153,210
Good	50 – 69	2,313	98,322
Poor	25 – 49	465	39,329
Failed	0 – 24	0	0

1.5 Traffic Demand

After calculating the structural capacity of the pavement network, the traffic demand in ESALs for one heavy vehicle was estimated as AASHTO's load equivalency factor (LEF). LEFs describe the equivalent damage caused by various axle loads and configurations given the condition of the pavement. LEFs are a function of axle load and configuration, structural number (SN), and terminal serviceability. The sum of all LEFs for a given vehicle is the ESAL value for that vehicle.

An SN expresses the existing structural strength of a pavement and depends on pavement layer types and thicknesses, drainage, and condition. SN values range from 1 to 7, where 7 represents the greatest structural capacity. The SN values for the residential and arterial/collector pavement structures were calculated per the AASHTO pavement design guide (AASHTO 1993) according to Equation 1.

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3 + \cdots + a_nD_nm_n \quad \text{(Equation 1)}$$

where:

a_n: n^{th} layer coefficient

D_n: n^{th} layer thickness

m_n: n^{th} layer drainage coefficient

Representative layer coefficients were selected based on pavement condition from AASHTO Tables 2.4 and 5.2 (AASHTO 1993) and a drainage coefficient of 1 was assumed. Table 4 summarizes the calculated SNs based on condition category and functional class.

Table 4. Structural Number by Functional Class

Condition Category	PCI Range	Structural Number	
		Residentials	Arterials/Collectors
Excellent	85 – 100	2.4	4.0
Very Good	70 – 84	1.7	2.9
Good	50 – 69	1.6	2.7
Poor	25 – 49	1.1	1.8
Failed	0 – 24	0.8	1.3

For heavy vehicle axle configuration (single or tandem) and loading (empty or full), an LEF was estimated using the SNs and an assumed terminal serviceability of 2.5. The LEFs for one heavy vehicle axle loading were then summed to estimate the total ESALs for an empty and a full heavy vehicle.

The empty and full heavy vehicle ESAL values were combined in a weighted average according to Equation 2 to account for variability in loading along a route.

$$ESAL_{WeightedAve} = (2/3) \times ESAL_{Full} + (1/3) \times ESAL_{Empty} \qquad \text{(Equation 2)}$$

The weighted average ESALs were then multiplied by the vehicle frequencies (trips per year) to estimate the ESAL demand per year based on pavement condition and functional class group.

The next subsections present the traffic demand of heavy vehicles depending on pavement functional class and condition. In general, heavy vehicles will typically do more damage to thinner pavement sections (residential streets) than to thicker pavement sections (arterials/collectors). Similarly, heavy vehicles will do slightly more damage to pavements in worse conditions than to pavements in better condition.

1.5.1 Heavy Vehicle ESALs

Heavy vehicles used in construction typically include a variety of trucks and equipment designed for moving materials, lifting heavy loads, and performing various tasks on construction sites. Below are some of the common types of heavy vehicles used in construction, along with their typical gross vehicle weight (GVW) or empty vehicle weight (depending on the type):

1. Dump Trucks -GVW: 20,000 to 80,000 lbs, depending on size and capacity.
2. Concrete Mixers- GVW: 30,000 to 60,000 lbs.
3. Cranes- GVW: 40,000 to 200,000 lbs, depending on the crane's size and lifting capacity.
4. Bulldozers- Operating Weight: 15,000 to 80,000 lbs, depending on the size and model.
5. Excavators- Operating Weight: 20,000 to 100,000 lbs, depending on size.
6. Backhoe Loaders- Operating Weight: 14,000 to 24,000 lbs.
7. Loaders (Wheel Loaders or Skid Steer Loaders)- Operating Weight: 5,000 to 80,000 lbs, depending on the size.
8. Flatbed Trucks- GVW: 30,000 to 80,000 lbs (13,608 to 36,287 kg).
9. Tractor-Trailers (Semi-trucks)- GVW: 60,000 to 80,000 lbs or more, depending on the load and axle configuration.

10. Scrapers- Operating Weight: 30,000 to 100,000 lbs.
11. Pavers (Asphalt or Concrete Pavers)- Operating Weight: 20,000 to 40,000 lbs.

As discussed above, the weight of construction vehicles can vary significantly depending on their type and function. On average, heavy construction vehicles like dump trucks, cranes, and excavators typically have a gross vehicle weight (GVW) ranging from 20,000 to 80,000 lbs. The axle configuration of these vehicles also depends on their type, intended use, and weight distribution requirements. For example, medium-duty dump trucks, concrete mixers, and smaller flatbed trucks, which are commonly used in construction projects, typically feature a single front axle and a tandem rear axle.

It's important to note that the types and number of heavy vehicles used in construction projects can vary widely depending on the type of construction, the contracted company, and the project's timeline. To simplify the analysis, the following representative categories were used when reviewing the GVW and axle configurations of various heavy construction vehicles:

- Single front axle and a tandem rear axle
- Gross vehicle weight of approximately 60,000 lbs, with a tare weight of about 35,000 lbs.

The empty and full heavy vehicle ESALs were combined in a weighted average according to Equation 2 to account for variation in loading throughout a route. Empty heavy vehicles were estimated to have ESALs ranging from 0.434 to 0.544 depending on pavement condition and functional class. Full heavy vehicles were estimated to have ESALs ranging from 3.500 to 3.730 depending on pavement condition and functional class. The weighted average ESALs values per heavy vehicle are provided in the Table 5 below.

Table 5. Heavy Vehicle Traffic Demand on City Streets by Condition Category

Functional Class	Condition Category	Average Weighted ESALs/Vehicle
Residential	Excellent	2.592
	Very Good	2.592
	Good	2.612
	Poor	2.612
	Failed	2.612
Arterial/ Collector	Excellent	2.488
	Very Good	2.534
	Good	2.553
	Poor	2.631
	Failed	2.631

1.6 Financial Analysis

The City's network is in "Good" condition, with an average PCI of 76 as of September 2024. City residentials have a PCI of 77 and arterials/collectors have a PCI of 75. The City's existing annual budget of $4 million is not sufficient to maintain the current pavement condition for the next 10 years, therefore, in our analysis, the City's goal was set to at least maintain the individual PCIs of both residentials (77) and arterials/collectors (75) for the next 10 years. To estimate the financial commitment required to accomplish these goals, a budget analysis was performed in StreetSaver® using the City's existing decision tree with an inflation rate of 4 percent and an analysis period of 10 years.

The 10-year total funding needed to accomplish these goals is approximately $60 million ($19 million for residentials and $41 million for arterials/collectors), or $6.0 million per year. Figure 3 and Figure 4 illustrate the projected condition breakdown for residential and arterial/collector pavement sections as of September 2024, respectively, for in the analysis period.

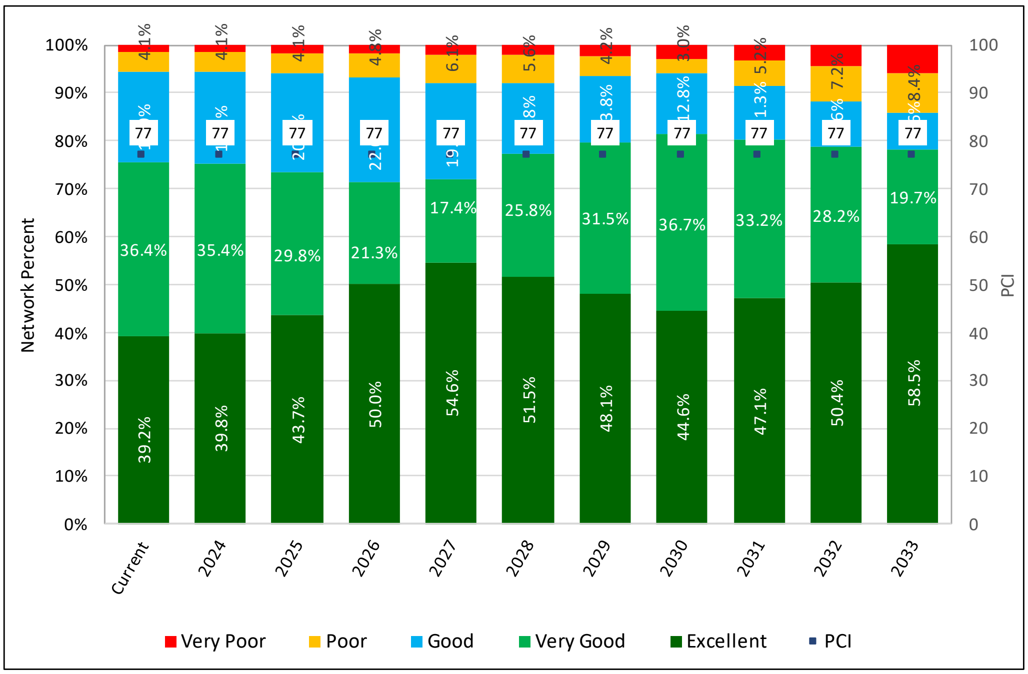

Figure 3. Projected Pavement Condition Breakdown for Residential Pavement Sections

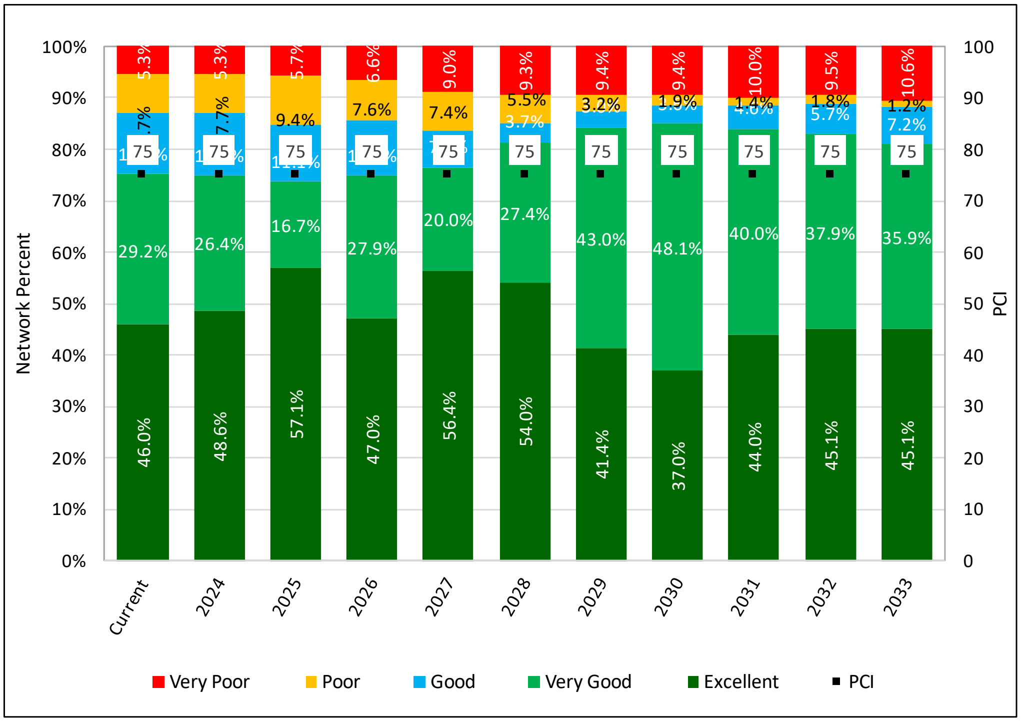

Figure 4. Projected Pavement Condition Breakdown for Arterial/Collector Pavement Sections

1.7 Vehicle Impact Analysis

The process to determine the impact of heavy vehicle damage to City streets is described in the following steps:

1. Calculate the weighted average structural capacity (ESALs) remaining for each. This was performed by multiplying the ESALs remaining in each condition category (Table 3) by the pavement condition breakdown for each year from the StreetSaver® analysis (Figure 3 and Figure 4) and summing the resulting products. This value represents the average structural capacity remaining on any given street in the City at the time of the analysis.
2. Calculate the weighted average traffic demand (ESALs) per heavy vehicle. This was performed by multiplying the weighted average ESALs per vehicle (Table 5) by the pavement condition breakdown for each year resulting from the StreetSaver® analysis (Figure 3 and Figure 4) and summing the resulting products. This value represents the average heavy vehicle traffic demand per vehicle in ESALs on any given street in the City.
3. Calculate the percentage of RSL used by one heavy vehicle. This was performed by dividing the demand for a given heavy vehicle (from Step 2) by the weighted average structural capacity remaining (from Step 1).
4. Calculate the damage cost each year associated with one heavy vehicle. This was done by multiplying the percentage RSL used for one heavy vehicle (Step 3) by financial commitment per year by functional class.
5. Calculate the average percentage RSL used by one heavy vehicle (average of Step 3).

6. Calculate the average damage cost for one heavy vehicle (average of Step 4).

The results are summarized in Chapter 2.

2 Results

On average, one heavy vehicle uses 0.05 percent of a residential pavement's capacity or RSL and 0.002 percent of arterial/collector pavement's capacity. This would result in average damage cost per heavy vehicle to be $950 for residentials and $66 for arterials/collectors. The Table 6 below shows the calculation steps for fee development per unit or per SF.

Table 6. Calculation Steps for Fee Development

Row No.	Heavy Vehicle Fee Estimate	Art/Col	Residential		Calculation Steps
		Commercial/ Industrial Unit	Single Family Unit	Multi-Family Unit	
1	Average Damage ($/Veh)	$ 66	$ 950		Calculated
2	Pavement Area (SF)	14,268,204	11,104,324		StreetSaver®
3	Total Centerline Miles	72	68		StreetSaver®
4	Average Pavement Width, ft	38	31		Row 1 / Row 3
5	Average Damage ($/Veh/SF Pvmt)	$ 0.00000	$ 0.00009		Row 1 / Row 2
6	Average $/Mi	$ 0.92	$ 13.97		Row 4 x Row 5 x 5280
7	No. of Heavy Vehicles/Unit SF	20	15	20	Input from City*
8	Average Route Distance Travelled (Mi)	10	6	6	Input from City*
9	Fee ($/SF Dvlpmt)	$ 0.01	$ 0.63	$ 0.17	Row 6 x Row 7 x Row 8 / Row 10
10	Typical Unit Area (SF)	25,000	2,000	10,000	Input from City*
11	Fee ($/unit SF Dvlpmt)	$ 183	$ 1,257	$ 1,676	Row 9 x Row 10

**Input from Public Works Staff - The Public Works Staff, including but not limited to staff from the Engineering Department provided input on Rows 7 and 8 regarding average number of heavy vehicles used, distance traveled, and typical unit areas. To keep the analysis straightforward, Public Works Staff used a conservative estimate of traveling 6 miles one way (12 miles round trip on major street) to dumpsite in Brisbane, rather than a more distant location."*

The fee Table 7 below summarizes two options, rounded to the nearest hundredth. The non-residential unit fee was calculated by averaging the fees for multi-family and commercial/industrial units.

Table 7. Proposed Construction Vehicle Impact Fees for City of South San Francisco

Option	Residential Unit Fee* Single Family	Non-Residential Unit Fee**	Unit
1	$ 1,300	$ 1,000	per unit
2	$ 1.00	$ 0.50	per square foot

*Fee in 2024 dollars

**Non-Residential Unit = Multi-family units/commercial/industrial

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