1 Traffic Signal Management System

Category	Subcategory	Grade
Overall Grade		C
Physical Health		
	Overall Condition	B
	Risk-Based Condition	A
Financial Health		
	Catch Up	F
	Keep Up	F

1.1 Background

1.1.1 What Services Do These Assets Provide?

Traffic signals provide critical services for traffic control of vehicular and pedestrian traffic by improving levels of service and enhancing safety at the intersection. They assign the right-of-way to the various traffic movements and thereby profoundly influence traffic flow. Traffic signals provide the orderly movement of traffic, increase the traffic-handling capacity of the intersection, and reduce the frequency and severity of certain types of crashes, especially right-angle collisions. Traffic signals along major streets are generally coordinated during peak commute periods to increase traffic flow efficiency.

1.1.2 *Who is Responsible?*

The City is fully responsible for traffic signals along City-managed streets. Intersections along state routes (e.g., Isabel Ave/CA-84, I-580 off/on ramps) are managed by the state and intersections outside city limits such as Tesla Rd at Mines Rd and Tesla Rd at Vasco Rd are operated by the County.

1.2 Asset Register

1.2.1 Asset Definition

An asset in the Traffic Signal Management System is defined as something of value that is owned and managed by the City. Each component of the traffic signal is designated as an asset, as shown in the following figures.

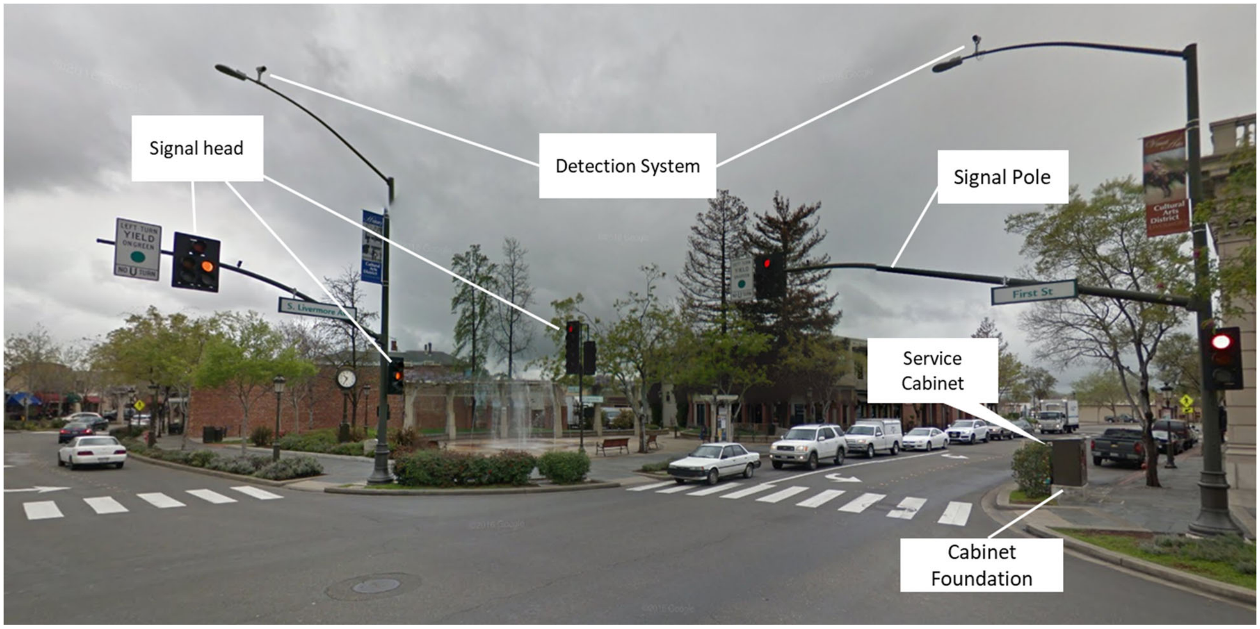

Figure 1-1 Traffic Signal Assets Example

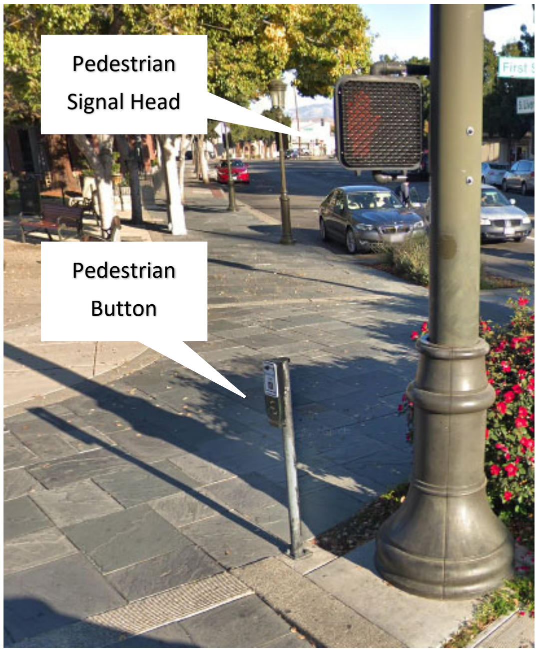

Figure 1-2 Traffic Signal Pedestrian Assets Sample

Any street lights at the traffic signals will be included in the Street Light Management System.

In addition to the signals themselves, the City manages the traffic signal network, which is vital to allow communication between the traffic signals on the street and the master controller in City Hall. The City utilizes different types of media to interconnect the traffic signals. Fiber optic cables, copper twisted pairs, and wireless (radio) are present in the City's traffic signal network. In addition, a managed Ethernet switch is required in each traffic signal cabinet to establish the communication. The interconnects run throughout the City, as shown in the following map.

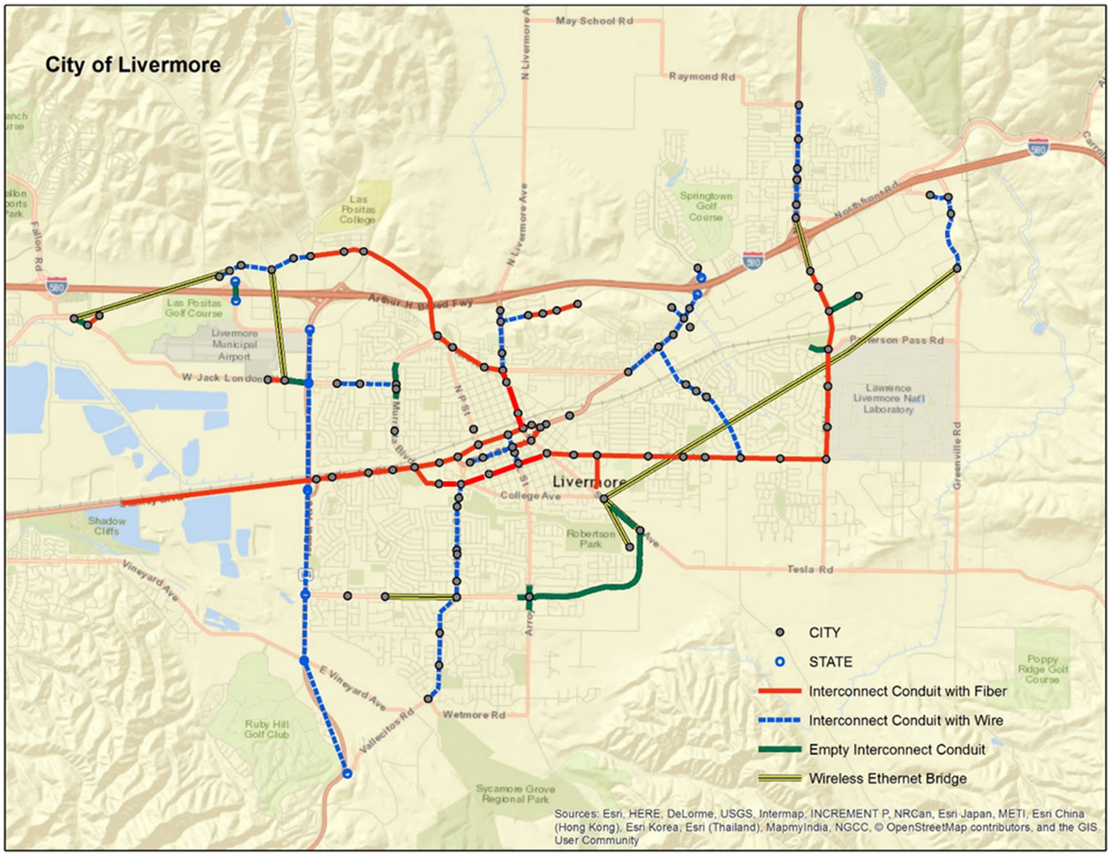

Figure 1-3 Map of Interconnects

1.2.2 Asset Class

Assets are grouped into classes to more efficiently model and manage the assets. An asset class generally refers to a group of assets that behave similarly (e.g., useful life, rehabilitation activities, maintenance needs). Grouping the assets into these classes allows easier modeling of life cycle behavior. Below is the list of the traffic signal asset classes.

- Signal Pole
- Signal Heads
- Detection System (camera/loop)
- Closed Circuit Television (CCTV)
- Pedestrian Push Buttons
- Pedestrian Signal Head
- Controller Cabinet
- Service Cabinet (with/without Battery Backup System)
- Cabinet Foundation
- Interconnect (Fiber/Copper/Wireless)
- Interconnect Conduit

1.2.3 Asset Hierarchy

The asset hierarchy for the Traffic Signal Management System is organized first by intersections and interconnects, then by specific signal at the intersection. The following figure illustrates the general asset hierarchy for City-owned

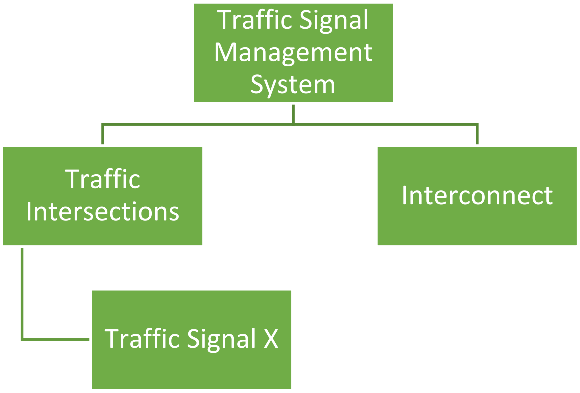

Figure 1-4 Traffic Signal Hierarchy

bridges.

1.2.4 Asset Inventory

Once the asset definition, hierarchy, and classes were set, the asset register was compiled. This process involved consolidating existing data from the City's information system (i.e., GIS) supplemented by desktop analysis (e.g., aerial imagery).

There are 108 signalized intersections owned/maintained by the City. Each signalized intersection can have several traffic signal-related assets. The number of signal heads, pedestrian signal heads, pedestrian push buttons, detection system, poles, and the type of poles can vary depending on the roadway width, number of lanes, number of legs at the intersection (e.g., Vasco at East Ave is 4-legged intersection, while Vasco at Dalton Ave is a 3-legged intersection). The more legs mean more direction of traffic to control and more equipment. More lanes mean more lanes to control, so more signal heads and longer mast arms are needed. Longer mast arms mean bigger poles. The same principle applies to the detection system, especially loop detection systems. More legs and more lanes mean more detector loops. For video detection systems, the number of cameras should typically match the number of legs in an intersection, so more legs mean more cameras. The number of pedestrian push buttons and number of pedestrian signal heads varies depending on the number of allowed pedestrian crossing locations at an intersection. Not all intersections have Close Circuit Television (CCTV) or Battery Backup System (BBS). In total, there are 6,449 assets in the Traffic Signal Asset Management Plan, as shown in the following table.

Table 1-1 Traffic Signal Asset Inventory

Asset Class	Quantity	Total Length (mi)
Signal Poles	736	
Signal Heads	1,705	
Pedestrian Signal Head	627	

Asset Class	Quantity	Total Length (mi)
Pedestrian Push Buttons	650	
Controller Cabinet	104	
Service Cabinet	30	
Service Cabinet with Battery Backup System	74	
Cabinet Foundation	104	
Detection System - Camera	102	
Detection System - Loops	2,226	
Closed Circuit Television	15	
Fiber Interconnect	13	14.0
Wire Interconnect	14	13.6
Interconnect Conduit	37	30.98
Wireless Interconnect Equipment	12	

1.2.5 Replacement Cost

Each traffic signal asset in the asset register was assigned an estimated replacement cost. As part of the asset replacement costs, an additional 30% markup was added to help account for project costs (e.g., design, engineering, permit fees, etc.).

The cost to replace a signalized traffic intersection is approximately $450,000 (in 2017 dollars with 30% project delivery costs). The sum of asset replacement cost for all traffic signal assets is approximately $54.1 million in 2017 dollars with 30% project delivery costs.

The breakdown of total replacement cost by asset class is shown in the following table.

Table 1-2 Traffic Signal Replacement Cost by Class

Asset Class	Replacement Cost
Signal Poles	$18,148,800
Signal Heads	$12,958,000
Pedestrian Signal Head	$1,906,080
Pedestrian Push Buttons	$1,976,000
Service Cabinet	$2,845,440
Controller Cabinet	$4,742,400
Cabinet Foundation	$474,240
Detection System - Camera	$775,200
Detection System - Loops	$2,706,816
Closed Circuit Television	$228,000

Asset Class	Replacement Cost
Fiber Interconnect	$663,633
Wire Interconnect	$358,915
Interconnect Conduit	$6,215,660
Wireless Interconnect Equipment	$127,680

1.2.6 Installation and Consumption Profile

The installation profile gives an indication of the age of the traffic signal assets. Installation year was determined based on historical data. Exact installation year from records for certain assets was incorporated whenever possible. The following figure shows the installation profile for the Traffic Signal Management System. The graph shows the City's historical facility investments represented in 2017 dollars.

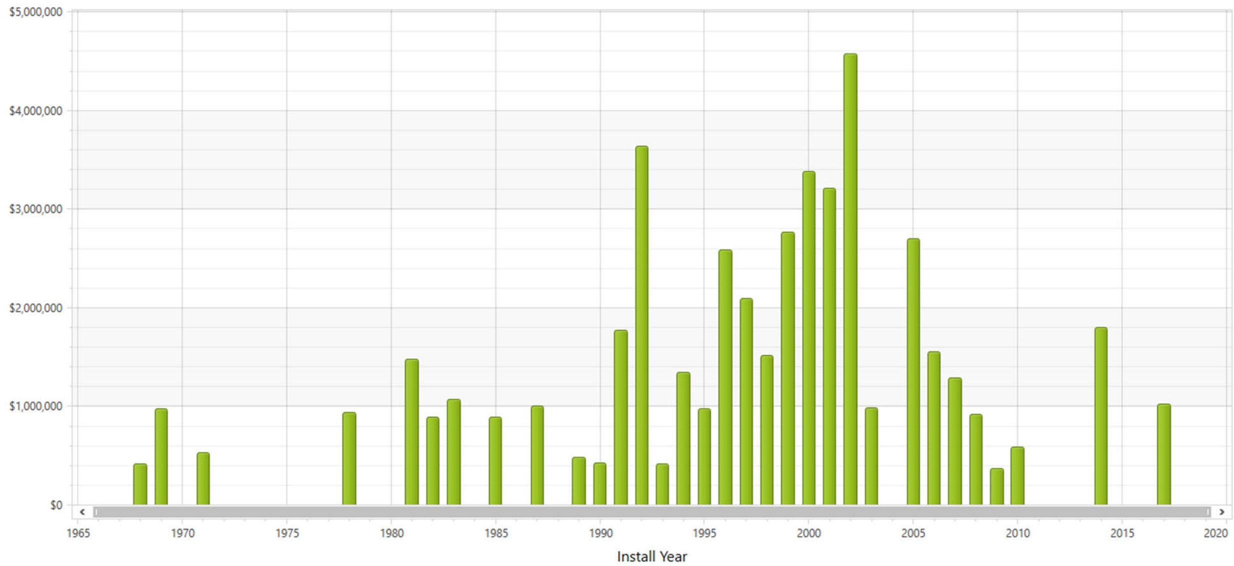

Figure 1-5 Installation Profile

More important than the installation data is the estimated current state or consumption of the assets. Consumption represents the percentage of an asset's expected life that it has used up or consumed. As illustrated in the following figure, most traffic signal assets have consumed approximately 70% or less of their useful lives. Although 70% may seem high, these assets may be in relatively good condition with years of life left, as explained in the next section. Another reason for the high consumption peak in the 70% was that many assets received a condition score of 3 (Good or As Expected Based on Age). An exponential decay curve was utilized to represent the deterioration of the asset, which roughly translated a condition assessment score of 3 to be 70% consumed. Discussion on the condition assessment rating scale is presented in the following section.

The following figure shows the consumption profile represented in 2017 dollars. Most of the assets are less than 70% consumed, and none of the assets are estimated to be fully consumed based on age, indicating that the system is in good condition overall.

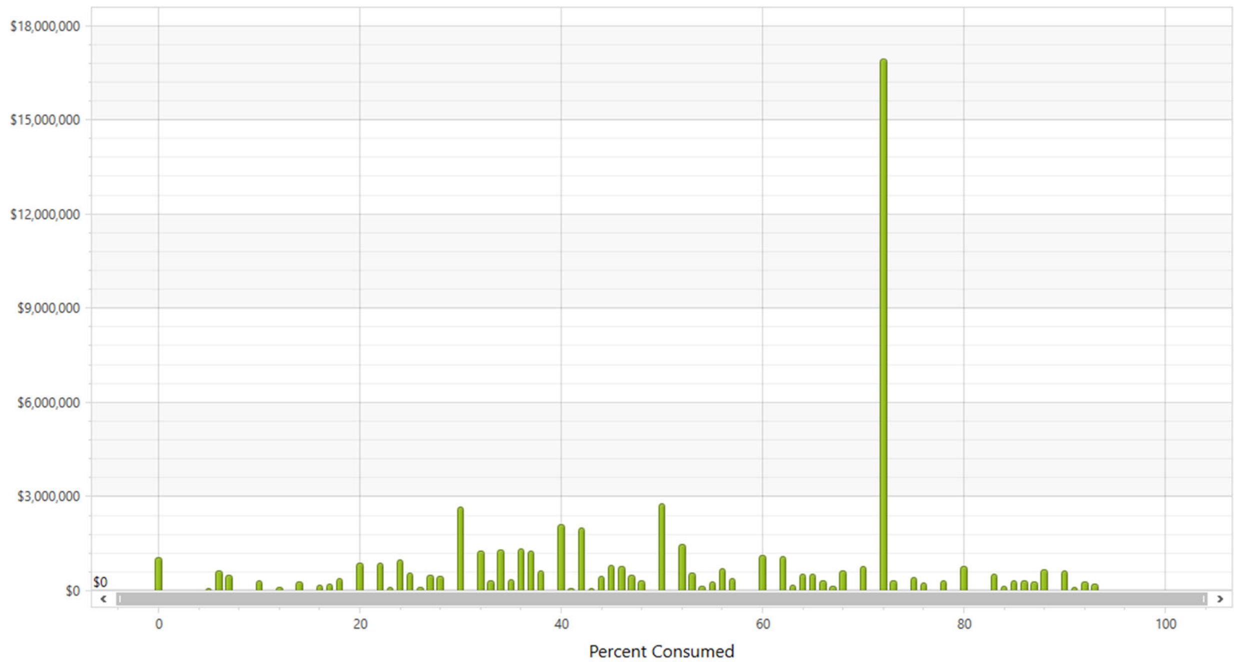

Figure 1-6 Consumption Profile

1.2.7 Condition Assessment

Because reliable age information was available for the traffic signals, the initial condition assessment for this system is based on age rather than on-site visual inspection. However, if an asset was considered to be in good condition relative to its age, a condition score of good was assigned to the asset. The condition was assessed based on the following condition scale. Condition information for each asset is available in the City's IRIS database. This information is too lengthy to include in this report.

Table 1-3 Condition Scale

Condition Score	Description
1	New or nearly new
2	Very good
3	Good or as expected based on age
4	Poor or recommended replacement within near-term
5	Failed or nearing failure, needs immediate attention

1.3 Risk Analysis

1.3.1 Probability of Failure

For the traffic signal assets, Probability of Failure (PoF) was calculated by comparing the installation year and the estimated useful life based on the City's historical usage, manufacturer's estimation, and/or other reputable resources (e.g., research results, ENR, neighboring cities). In the future, the PoF can be adjusted by assigning a condition score based on an inspection. PoF information for each asset is available in the City's IRIS database. This information is too lengthy to include in this report.

1.3.2 Consequence of Failure

The figure below presents the multi-tier logic Consequence of Failure (CoF) rating methodology developed for the Traffic Signal Management System. In the first tier, a criticality level was assessed at the traffic signal level based on the road class of the intersection, which was used to estimate the volume and speed of traffic at that intersection. The criticality was then assessed at the asset level based on how integral the asset class' function was to the traffic signal overall. CoF information for each asset is available in the City's IRIS database. This information would be too lengthy to include in this report.

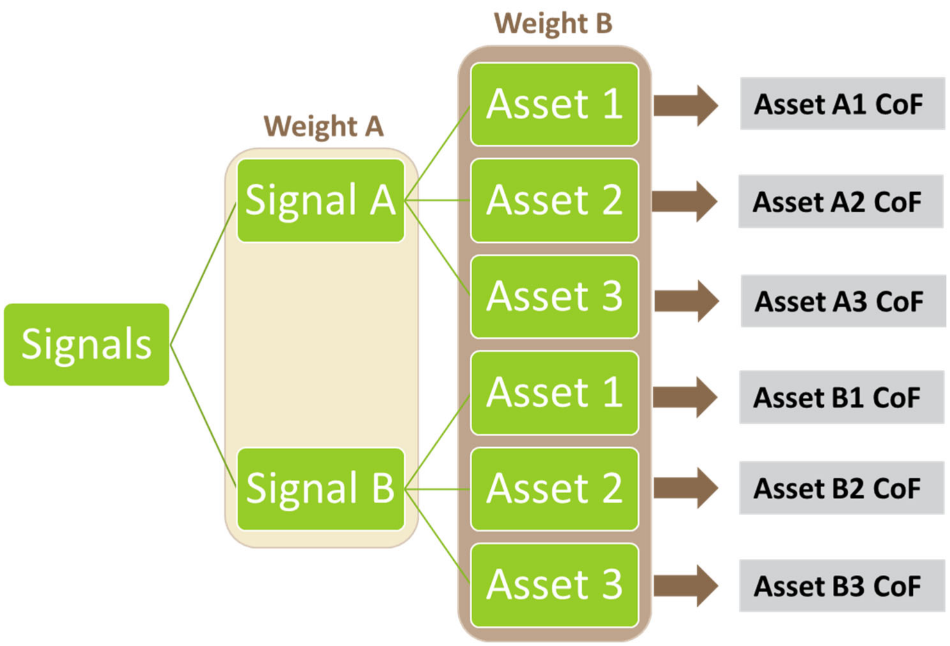

Figure 1-7 Multi-Tier Logic of CoF Rating Methodology

1.3.2.1 Signal and Asset Criticality Ratings

The intersections are prioritized based on a two-tier system where the first tier CoF rating is based on the usage and the second tier CoF rating is based on the importance of each asset in the intersection. In the first tier, the higher the volume and speed of traffic (e.g., arterial intersection), the higher the criticality of the intersection. The road class of all the intersection legs was considered when assigning criticality. For instance, a traffic signal at the intersection of two arterial roads was given a higher criticality than a traffic signal at the intersection of an arterial road and a collector road.

The ranking of the road class criticality is shown in the table below.

Table 1-4 Road Class Criticality

Criticality	Road Classes
Very High	Arterial/Arterial
High	Arterial/Collector
Medium	Arterial/Residential
Medium-Low	Collector/Collector
Low	Collector/Residential

In addition, each asset class was assigned a CoF score based on their criticality to the system as well as on safety and regulatory concerns. Assets that were critical to the function of the traffic signal (e.g., signal heads, signal poles) and were critical for safety (e.g., pedestrian signal heads) were given high criticality scores. Assets were rated on a scale of 5 (high criticality) to 1 (low criticality); due to the high regulatory and safety standards for traffic signals, assets were not given a criticality score lower than 3.

Table 1-5 Traffic Signal Class Criticality

Class/Type	Criticality
Signal Pole	5
Signal Heads	5
Controller Components	5
Pedestrian Signal Head	5
Pedestrian Push Buttons	5
Service Cabinet with Battery Backup System	5
Detection System (Loops, Camera)	4
Interconnect	4
Controller Cabinet	3
Cabinet Foundation	3
Service Cabinet	3
Closed Circuit Television	3

1.3.3 Risk Analysis Results

The following figure shows the resulting overall risk profile for City-owned and managed traffic signals. This profile incorporates both the PoF and CoF scores to prioritize the assets. The assets in the red zone of the risk matrix are the highest risk assets that have both a high probability and high consequence of failure. Assets with a risk score of 4 or higher were considered high risk assets.

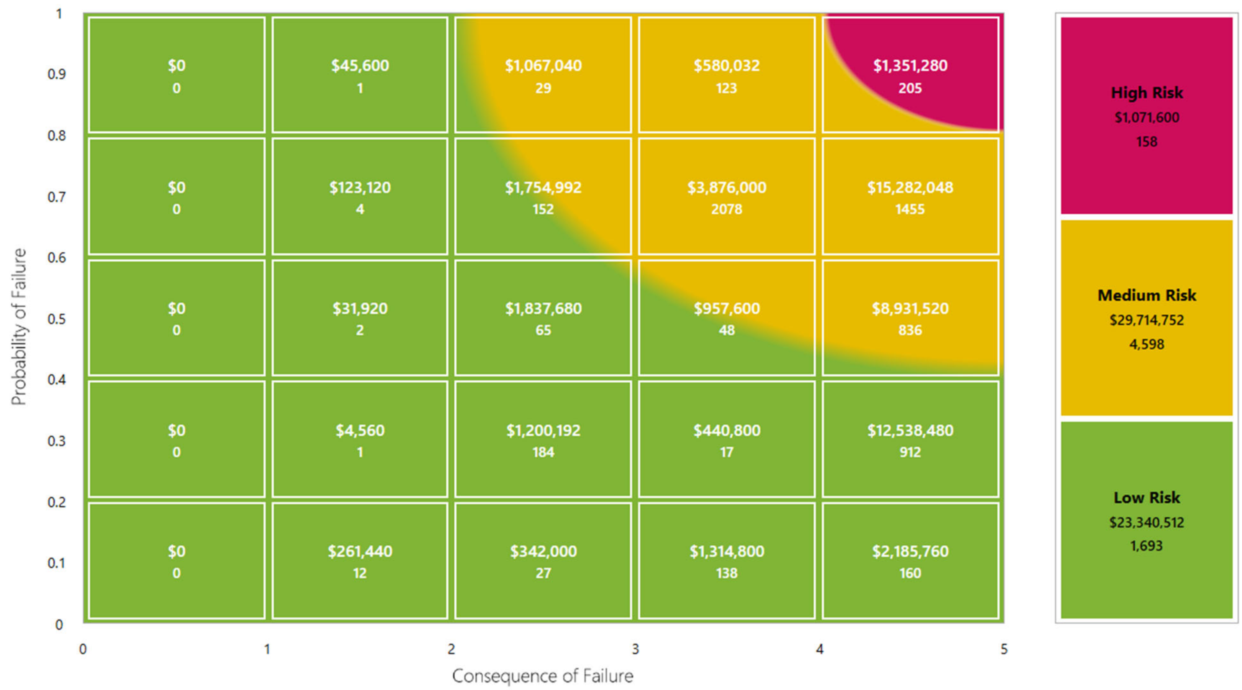

Figure 1-8 Traffic Signal Risk Matrix

There is approximately $1.1 million worth of assets in the high-risk zone. Most of these assets are signal heads and pedestrian signal heads that are estimated to be near the ends of their useful lives based on age. Because this analysis is based on age, a follow-up condition assessment may confirm that these assets are not in need of replacement, which would lower the red-zone cost estimate.

1.4 Future Needs

1.4.1 Life Cycle Cost Logic

Life cycle cost logic, also known as management strategies, were developed for the traffic signal assets. Each asset class was assigned a management strategy that includes the rehabilitation and replacement activities to best characterize the life cycle investment needs for the asset. Appendix A shows the management strategies for the traffic signal assets.

1.4.2 Long Range Replacement and Rehabilitation Profile

The following figures show the replacement and rehabilitation needs (including 30% for project delivery costs) for which the City is responsible over a 30-year span in 2017 dollars. Using a deterministic model (i.e. assets fail at the end of their useful lives), the average annual replacement and rehabilitation needs over the 30-year planning horizon is approximately $1.8 million.

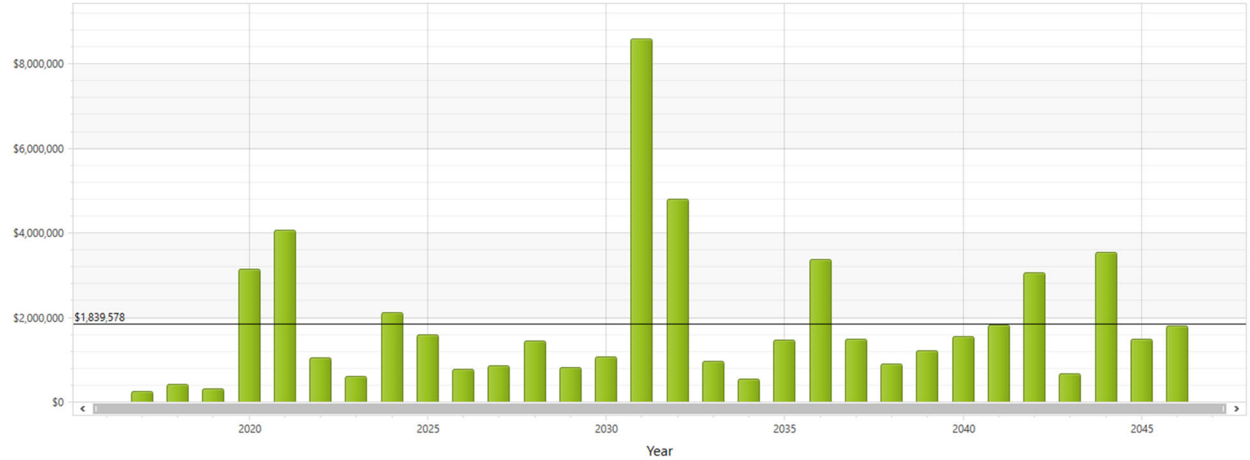

Figure 1-9 Traffic Signal 30-Year Replacement and Rehabilitation Profile (Deterministic)

The 30-year life cycle cost analysis was repeated utilizing a probabilistic model. In this model, asset failures were smoothed representing a more realistic expectation where assets may fail sooner or later than the expected useful lives (e.g., a pedestrian button could fail at 12 years rather than the expected 15 years); as such, this scenario may present a more realistic estimate of the future asset failures and funding needs. The probabilistic analysis incorporates the concept of randomness in that early or late asset failures are distributed randomly using the assigned standard deviation (i.e., 20%). The probabilistic model predicts the annual replacement and rehabilitation needs to be approximately $1.6 million.

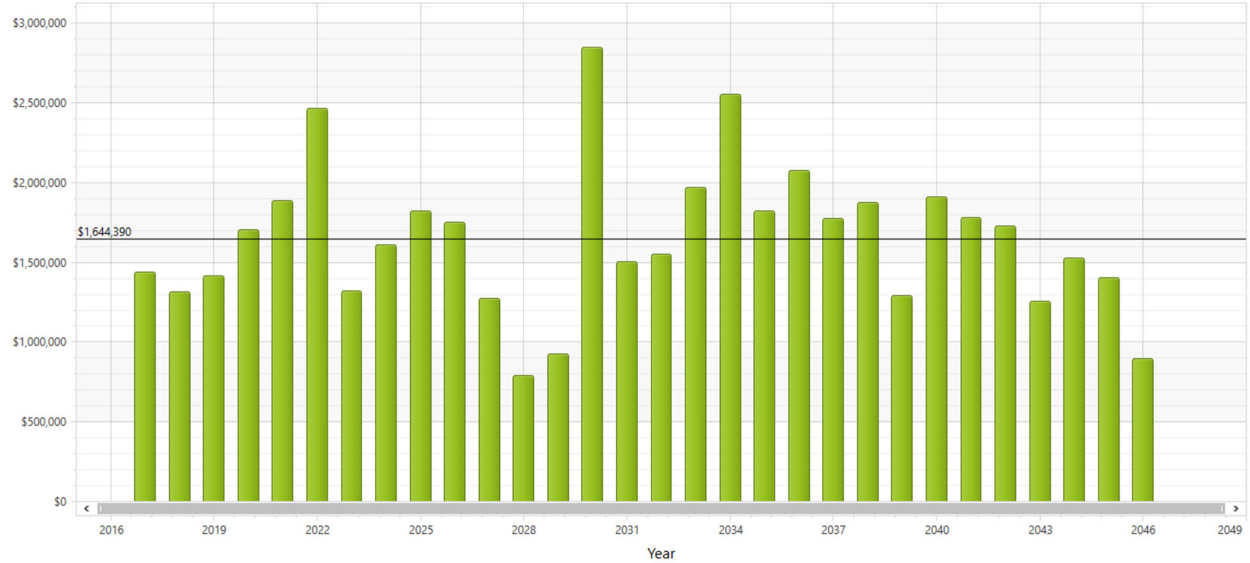

Figure 1-10 Traffic Signal 30-Year Replacement and Rehabilitation Profile (Probabilistic)

Both of the previous analyses represent results in 2017 dollars. Expecting the cost of construction will increase with time, a 3% annual inflation factor was utilized. With 3% inflation over the 30-year planning horizon, the projected annual investment need for the deterministic model jumped from $1.8 million per year to $3.0 million per year. Similarly, for the probabilistic model, the annual investment need increased from $1.6 million per year to $2.6 million per year. The results of these analyses are presented in the following figures.

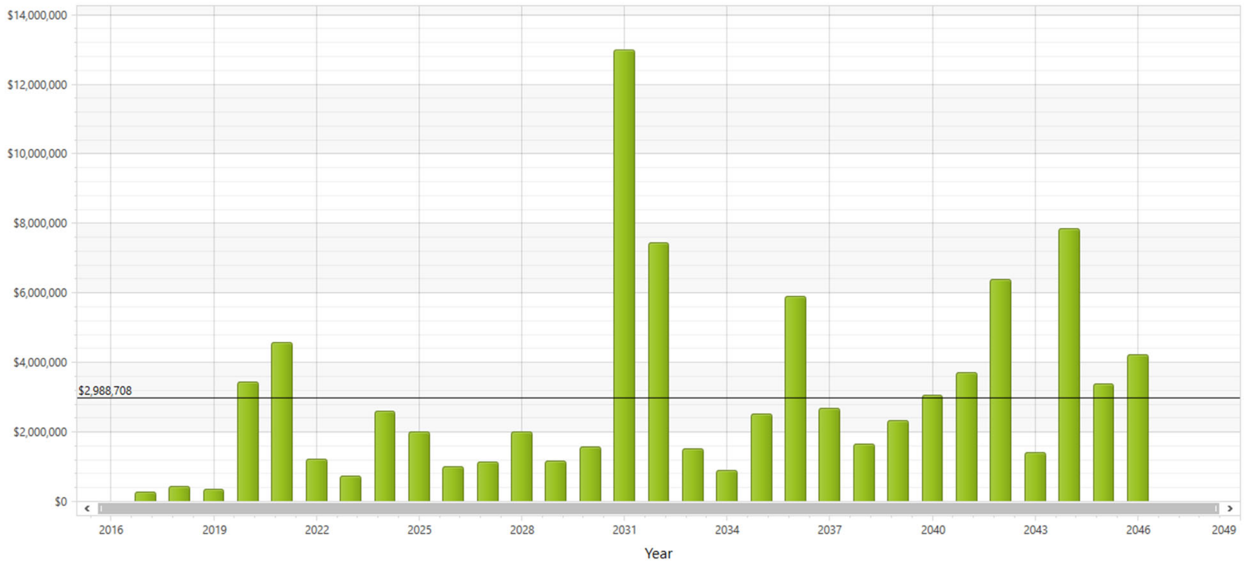

Figure 1-11 Traffic Signal 30-Year Replacement and Rehabilitation Profile (Deterministic, 3% Inflation)

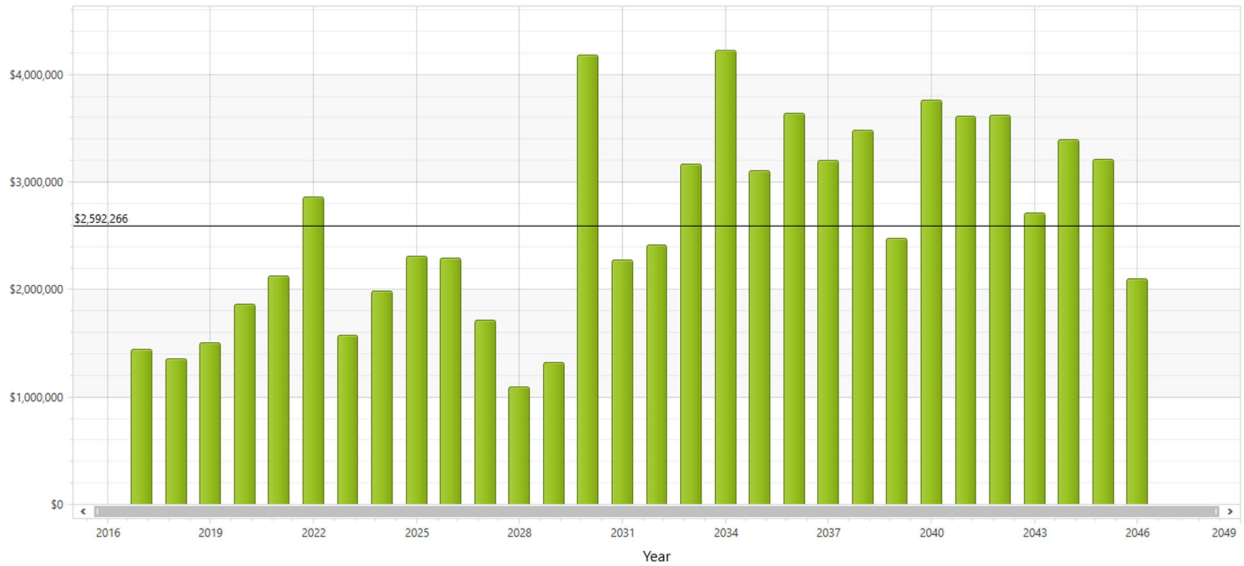

Figure 1-12 Traffic Signal 30-Year Replacement and Rehabilitation Profile (Probabilistic, 3% Inflation)

The following table summarizes the 30-year replacement and rehabilitation needs for the traffic signals.

Table 1-6 Replacement and Rehabilitation Profile 30 Year Summary

Analysis Type	R&R Average
Deterministic	$1.8 M/yr
Probabilistic	$1.6 M/yr
Deterministic with 3% Inflation	$3.0 M/yr
Probabilistic with 3% Inflation	$2.6 M/yr

1.4.3 Catch Up and Keep Up

When discussing replacement and rehabilitation, Catch Up describes all replacement and rehabilitation needs (e.g., assets fully consumed with condition score of 4 or 5) in the current year. Keep Up describes all replacement and rehabilitation needs in the remainder of a given planning horizon after the City has addressed the Catch Up needs. In the Catch Up and Keep Up analysis, the deterministic 30-year replacement and rehabilitation analysis is re-examined by bringing the high-risk assets (Catch Up needs) to the beginning of the planning horizon. The remaining replacement and rehabilitation needs are represented by the Keep Up. The following table displays the total Catch Up and the Keep Up for a 30-year planning horizon, both represented in 2017 dollars with 30% cost project delivery costs. As noted in the Risk section, although there are assets in the high-risk zone due to age, a condition assessment may provide updated data that would lower the risk for these assets.

Table 1-7 Catch Up and Keep Up Values (2017 Dollars)

	Cost
Catch Up	$ 1.1 million total
Keep Up	$ 1.8 million average per year

Overall, the Catch Up and Keep Up analysis provides a view of the future needs if the City were to focus solely on high-risk assets before addressing the other Keep Up needs. If the City were to fund the Catch Up ($1.1 million) in the immediate future, the Keep Up represents the annual average for the remaining repair and replacement needs in the 30-year planning horizon. As such, the Keep Up annual average should only be used as the future funding need estimate if the City has the budget to address all Catch Up needs in the immediate future. Again, it should be noted that in the case of the traffic signals, age was used to determine the PoF of the assets; if deemed necessary, a condition score can be assigned to these older assets, which could potentially lower the high-risk total and Catch Up cost.

1.5 Level of Service

1.5.1 Preferred Level of Service

The preferred level of service would be for the City to follow the rehabilitation and replacement cycles as outlined in the life cycle cost logic section of this report (i.e., full service). However, due to the City's limited budget the City may prioritize which traffic signal assets to rehabilitate or replace.

The estimated annual budget over a 30-year horizon for the preferred level of service is approximately $1.8 million or $3.0 million with 3% inflation.

1.5.2 Minimum Level of Service

Under the minimum level of service, only high-risk assets (i.e., CoF 4 and above), which are generally associated with high risk assets at high-risk intersections, would be rehabilitated and replaced. The following figure shows the high risk (e.g., 4 and above) 30-year replacement and rehabilitation needs. The annual average over a 30-year horizon is approximately $1.2 million or $2.0 million with 3% inflation.

1.6 Management System Score

1.6.1 Physical Health

The physical health of the Traffic Signal Management System was determined based on the ratio of poor condition assets and the red zone, high risk assets (as identified in Section 1.3) to the overall replacement cost of all system assets. These scores were used to assess the overall grade of the traffic signal management system. For these scores, the lower the percentage of poor condition (Overall Condition) and high risk (Risk-Based Condition) scores, the better.

Table 1-8 Traffic Signal Management System Physical Health Values and Scores

Category	Score	Grade
Overall Condition	8%	B
Risk-Based Condition	2%	A

As shown in the table, it is estimated that the Traffic Signal Management System is in good physical health.

1.6.2 Financial Health

The financial health of the Traffic Signal Management System was judged based on the ratio of the Catch Up and Keep Up values to the 2017 annual rehabilitation and replacement budget of approximately $500,000. The scores for each category are presented below. These scores were used to assess the overall grade of the management system.

Table 1-9 Traffic Signal Management System Financial Health Values and Scores

Category	Score	Grade
Catch Up Score	45%	F
Keep Up Score	28%	F

As shown in the table above, the financial health of the traffic signal management system is poor, with a score of F indicating the City's catch up needs. While the assets are currently in good condition as shown with a score of B in the physical health score (Table 1-8), the poor catch up score means that there may be insufficient funding dedicated to traffic signal rehabilitation and replacement to improve the condition of the current high-risk assets. The system also received a keep up grade of F; this implies that the system will not likely have the funding to keep up once it has caught up.

1.7 Policy

Due to the high regulatory and safety standards for traffic signals, all traffic signals should be replaced prior to failure.

1.8 Confidence Level

Confidence level factor weights are based on the City's specific goals for this phase of the asset management program development. Factors that were focused on during this phase of the asset management program development, such as asset inventory and condition assessment, were given higher weight. One of the City's particular goals was also to encourage buy-in on the part of its staff and stakeholders, so the Community Asset Management Program (CAMP) committee review was added to the general asset management program as a factor. On the other hand, factors that will be improved in future phases of the program development were given lower weight.

Table 1-10 Traffic Signal Confidence Level

Confidence Level Factor	Confidence Level Rating Score	Weighting Factor	Weighted Confidence Level Rating Score
Asset Inventory	70%	20%	14%
Data Quality	70%	15%	11%
Condition Assessment	75%	20%	15%
Asset Valuation	80%	10%	8%
Life-cycle Cost Logic	70%	10%	7%
Risk	85%	10%	9%
Staff Review	60%	5%	3%
CAMP Committee Review	100%	10%	10%
Total Score			**76%**

Asset Inventory (Unweighted Score - 70%)

Asset inventory was developed using desktop analysis (i.e., GIS, aerial imagery). Further use of the asset management system will determine whether the asset level was defined at the appropriate level.

Data Quality (Unweighted Score - 70%)

Asset inventory and attributes were developed from detailed data available in GIS. Further verification with staff will take place in the future.

Condition Assessment (Unweighted Score - 75%)

Condition assessment was generally based on age for the traffic signal assets; if an asset was considered to be in good condition relative to its age, a condition score of good was assigned to the asset. Further on-site verification in the future will increase the confidence level for the condition assessment.

Asset Valuation (Unweighted Score - 80%)

Replacement costs were estimated for each asset class. As assets are replaced in the future, the costs will be updated in the traffic signal management system.

Life-cycle Cost Logic (Unweighted Score - 70%)

Life-cycle cost logic was assigned to the assets.

Risk (Unweighted Score - 85%)

A robust CoF methodology was developed that incorporates the criticality of the traffic signal location, as well as the asset criticality relative to other traffic signal assets.

Staff Review (Unweighted Score - 60%)

Staff was involved in the development of the traffic signal management system. Continued review of the inventory and condition assessment should happen regularly.

CAMP Committee Review (Unweighted Score - 100%)

The CAMP committee reviewed, analyzed, and provided input on the results throughout the asset management plan process.

1.9 Next Steps

Asset Inventory

The asset inventory was created based on desktop analysis (i.e., GIS, aerial imagery). Further use of the asset management system will determine whether the asset level was defined at the appropriate level. In addition, on-site verification can take place as needed.

Condition Assessment

The initial condition assessment was based on a combination of age-based and assumed condition-based analysis. As the data is reviewed and on-site condition assessment is performed in the future, condition scores should be updated.

Appendix A – Traffic Signal Management Strategies

The following table shows the management strategies applied to the traffic signal assets.

Asset	Type	Useful Life	Replacement Cost	Rehab Activity 1	Frequency	Cost	Rehab Activity 2	Frequency	Cost
Signal Pole	1B	50	$15,200						
	TS – Small	50	$30,400						
	TS – Large	50	$45,600						
Signal Heads		40	$7,600	Replace LEDs	10	$1,000			
Controller Cabinet		30	$45,600	Update Internal compone nts	5	$4,000			
Cabinet Pedestal		60	$4,050						
Service Cabinet (no Battery Backup System)		40	$27,360 (Replace with BBS)	Replace batteries	3	$2,500	Replace BBS Controller	10	$3,000
Service Cabinet with Battery Backup System		30	$27,360	Replace batteries	3	$2,500	Replace BBS Controller	10	$3,000
Detection System	Loop	12	$1,216 per loop						
	Video	15	$7,600 per camera						
Pedestrian Buttons		15	$2,700						
Pedestrian Signal Head		25	$2,700	Replace LEDs	12	$1,000			
Closed Circuit Television		15	$15,200	Rehab	8	$1,000			

Asset	Cost	Useful Life
Interconnect Conduit	$38 per FT	50 years
Interconnect Fiber Cable	$9 per FT	25 years
Interconnect Wire Cable	$5 per FT	25 years
Ethernet Wireless	$10,640 per inspection	10 years