Assessment of Copper Theft in Caltrans District 7 Electrical Systems

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Project 2368
January 2024

Introduction

In today's intricate web of transportation systems, electrical infrastructure plays a pivotal role in ensuring safety, efficiency, and connectivity. At the core of these electrical systems lies a precious metal—copper, prized for its conductivity and intrinsic value. However, the vulnerability of these systems to theft and vandalism has emerged as a growing threat to transportation infrastructure integrity.

This study delves into the pervasive issue of wire theft within the electrical systems of California Department of Transportation (Caltrans) District 7 (D7), exploring the extent, geographic distribution, and impact of wire theft incidents during fiscal years 2020 to 2022. Moreover, this research investigates the most affected electrical systems and equipment, and meticulously analyzes the financial costs incurred due to wire theft. By exploring these facets, the study aims to provide a thorough understanding of the wire theft problem in D7, shedding light on the financial and operational implications for Caltrans infrastructure and operations.

Although District 7 records the location, repair cost, and equipment damaged for every wire theft incident, there has been no cross-cutting analysis of the records to explore whether there are patterns in terms of the specific electrical systems targeted, key cost components in the repairs, and/or geographic locations of theft. Going beyond the quantification of financial losses, the study pinpoints the precise electrical systems and equipment most susceptible to theft. Additionally, through geospatial analysis, it uncovers distinct geographic patterns in the concentration of wire theft incidents, allowing for targeted preventive measures. In essence, this study acts as a bridge, closing knowledge gaps and equipping the Department of Transportation (DOT) with invaluable data to formulate more effective strategies in the ongoing battle against wire theft. These strategies, in turn, aim to fortify electrical systems, ensuring the continued safety and reliability of transportation networks for the benefit of the community.

To achieve these objectives, this study analyzed data on wire-theft-related repairs logged in the Integrated Maintenance Management System (IMMS), a software system utilized by Caltrans to manage and maintain the extensive transportation infrastructure throughout the state. This rich dataset included details such as the cost of repairs, type of equipment damaged, work order number, fiscal year work order filed, date of repair, and locations for each reported wire theft incident. It also allowed for an in-depth analysis of cost trends over time and identified the equipment most frequently impacted by theft. Additionally, a geospatial analysis was conducted, utilizing precise location data and supplementary information on metal recycling businesses and poverty levels to generate visualizations and geographical maps. This comprehensive approach provided a holistic understanding of the impact of wire theft on Caltrans D7 electrical systems.

This paper is organized into several sections. The next section explores insights derived from a literature review, highlighting the critical role of copper in the State Highway System (SHS) and the rationale behind its extensive use. Following that, the paper delves into the factors that make copper a prime target for theft and the preventive measures implemented by Caltrans. The subsequent section elaborates on the evaluation methods. In the following section, titled 'Findings,' the research outcomes are scrutinized, and recurring themes are identified. Finally, in the concluding section, the key findings are summarized, and tailored recommendations for Caltrans are presented.

How is Copper Used in the State Highway System and Why?

Caltrans District 7, like the rest of the state highway system, uses copper wire throughout the electrical systems that ensure the safety, efficiency, and functionality of transportation infrastructure. Copper is used so widely because its exceptional conductivity and durability make it an ideal choice for establishing connections within these systems. Copper's prominence stems from its unique attributes as an exceptional conductor of electricity and heat, its malleability, resistance to corrosion, and cost-effectiveness compared to peers within the metal category. Consequently, copper is the metal of choice for establishing connections within all Caltrans electrical systems. Indeed, copper—and to a limited extent, aluminum—constitutes the backbone of electrical systems.[1]

Copper is omnipresent in roadway infrastructure, appearing in electrical systems that illuminate highways and tunnels, collect data, manage traffic flow, and disseminate information to motorists (see Figure 1). For example, it is extensively used in electrically conductive elements such as wires and cables, which enables the transmission of electricity and data, electrical signals, and power distribution. Furthermore, copper's versatility and conductivity are critical in systems such as Traffic Management Systems (TMS) and Intelligent Transportation Systems (ITS), which rely on copper wiring buried underground within conduits to ensure seamless traffic control and management. Figure 2 illustrates the use of copper wire at just one freeway on-ramp—the wire is found in sign lighting system, roadway lighting system, and ramp metering system that includes a controller cabinet, traffic signal heads, meter-on heads, and loop detectors embedded in the roadway.

1 Benjamin F. Stickle, *Metal Scrappers and Thieves: Scavenging for Survival and Profit* (Murfreesboro, TN: Springer International Publishing, 2017), 82, accessed October 29, 2022, http://link.springer.com/10.1007/978-3-319-57502-5.

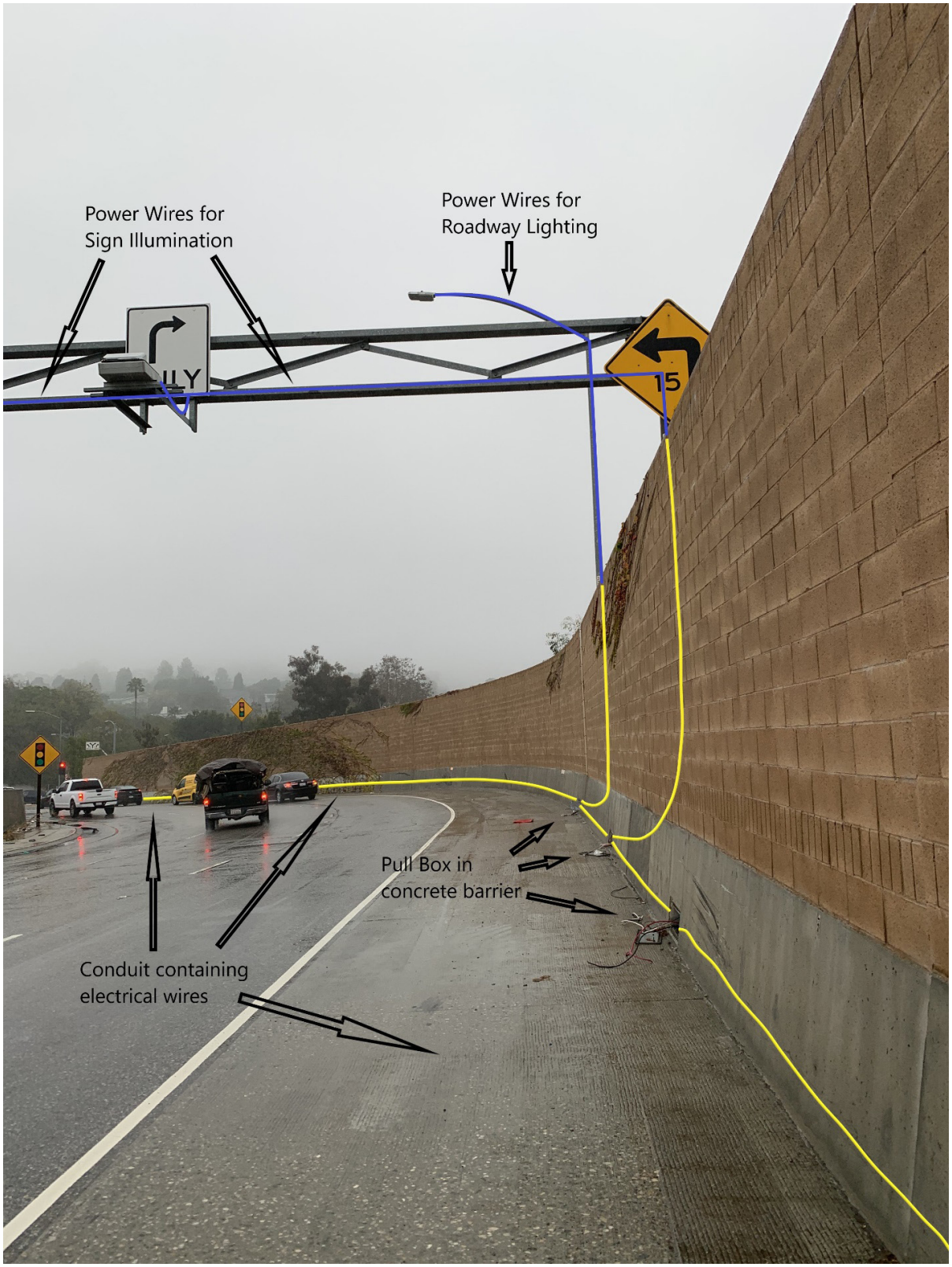

Figure 1. Illustration of Copper Wire Use in Roadways -- Northbound Route 405 Sunset Blvd Off-Ramp. Yellow and blue lines represent copper wire in the infrastructure.

Source: Author. November 7, 2022.

Figure 2. Illustration of Copper Wire Use in Roadways -- Santa Monica Blvd on-ramp to Route 405 northbound. Yellow lines represent copper wire in the infrastructure.

Source: Author. May 18, 2017.

Although copper wire has a long history in roadway infrastructure, its use has skyrocketed in recent decades with the growth of Traffic Management Systems (TMS) and Intelligent Transportation Systems (ITS) used to manage traffic congestion.[2] These systems critically rely on copper wiring buried underground within conduits, passing through in-ground pull boxes (PBs), which can be spliced as needed. Typically, these PBs are spaced no more than 200 feet apart, creating multiple access points and vulnerability to theft along most stretches of roadway.[3]

Why is Copper Stolen and What Preventive Measures has Caltrans Implemented?

Copper theft has surged in recent years due to the increasing demand for this valuable metal coupled with a diminishing supply. This dynamic has driven up the market value of copper, making it an attractive target for theft.[4] Both the United States and emerging economies like China and

2 Nirav Shah et al., "Optimization Models for Assessing the Peak Capacity Utilization of Intelligent Transportation Systems," *European Journal of Operational Research* 216, no. 1 (January 2012): 239.

3 California Department of Transportation, *Electrical Systems Design Manual*, 1st ed. (Sacramento, CA: California Department of Transportation, 2020), 9.

4 Stickle, *Metal Scrappers and Thieves: Scavenging for Survival and Profit*.

India exhibit a growing appetite for copper. Furthermore, copper holds immense value and utility in society, making it a sought-after commodity even in the black market.[5] This supply-demand imbalance plays a pivotal role in the rampant theft of copper wire, with thieves gaining easy access to PBs, electrolier handholes, and cabinets (see Figures 3 and 4). This surge in theft has inflicted adverse consequences on transportation agencies, including Caltrans.[6]

Figure 3. Two vandalized tamper resistant pull boxes at Branford St. on-ramp to Southbound CA I-5 Fwy.

Source: Photograph by Yaser Alatrakchi, taken on October 19, 2022.

Figure 4. Vandalized emergency power feeder at CA I-5 Fwy., Southbound CA-14 truck lane tunnels.

Source: Photograph by Yaser Alatrakchi, taken on August 8, 2022.

Recognizing the urgent need to protect its assets against theft and vandalism, Caltrans embarked on a journey to experiment with and implement more robust preventive measures. In a significant move, on December 19, 2014, Caltrans introduced Directive DD-113, which mandated the incorporation of all practical theft prevention methods across all project phases, encompassing initiation, construction, and maintenance.[7] This directive was aligned with the Director's Policy (DP-25) titled "Best Practices," which had been in effect since 2007, encouraging Caltrans staff to seek, learn, and implement national and global best practices.[8]

5 Eamon C. Francis and Odhran P. Shelley, "Copper Wire Theft and High Voltage Electrical Burns," *International Journal of Burns and Trauma* 4, no. 2 (October 30, 2014): 59–61.

6 Frances L. Edwards and Daniel C. Goodrich, *Introduction to Transportation Security* (Boca Raton, FL: Taylor & Francis Group, 2012), 5.

7 Kome Ajise, "Wire Theft Prevention" (California Department of Transportation, December 19, 2014).

8 Will Kempton, "DP-25 Best Practices" (California Department of Transportation, January 1, 2007).

Building on these efforts, in 2017 Caltrans took additional steps by publishing updated "Guidelines of Effective and Practical Wire Theft Prevention Methods" as part of DD-113.[9] The primary goal of these guidelines is to mitigate damage to the State Highway System (SHS) by instituting practical, multi-layered protective measures. Caltrans has been implementing these measures, but wire theft and vandalism have persisted, necessitating extensive repair work within the Construction and Maintenance divisions (see Figure 5). The relentless nature of copper theft underscores the need for ongoing vigilance and continuous adaptation of preventive measures to safeguard Caltrans's critical electrical systems and infrastructure.

Figure 5. Latest tamper resistant pull box that requires proprietary tool to open, located at southbound Pearblossom Hwy to southbound CA-14 Hwy gore area.

Source: Photograph by Yaser Alatrakchi, taken on August 10, 2021.

Evaluation Methody

To conduct the study, a dataset was created by drawing from the IMMS, a software system used by Caltrans to efficiently manage California's extensive transportation infrastructure. IMMS is designed to streamline maintenance activities, work orders, asset tracking, and reporting for the state's vast network of roads, bridges, and transportation infrastructure. Data is compiled from various sources, including field inspections, work orders, geographic information systems (GIS), inventory management, cost records, asset information systems, sensor data, historical records, data entry, and external sources. This provides a comprehensive dataset covering asset conditions, work orders, resource allocation, maintenance history, cost data, safety and compliance information, and geographical details, making it invaluable for analysis.

9 Kevin Riley, *Guidelines of Effective and Practical Wire Theft Prevention Methods* (Sacramento, CA: California Department of Transportation, 2017).

The study focused on wire theft incidents reported from fiscal years 2020 to 2022, chosen for data quality and practicality. The wire theft-related data was filtered and exported to an Excel spreadsheet, which included essential details about each incident:

- Description of damages: The “comments” column contained essential details about impacted systems and repair work.
- The cost of repairs: The IMMS breaks out cost into four components of labor, material, vehicle, and other expenses.
- Dates of repairs: Repair dates were found in the “comments” column.
- Location: Incidents were identified using the standard Caltrans format of ‘District-County-Route-Postmile.’

The financial data from the recorded incidents were systematically aggregated and visually represented using Excel, providing valuable insights into the financial implications of wire theft.

To make the IMMS records accessible for analysis and to identify the most affected systems and equipment, a structured approach was adopted. Based on the content of the “comments” column, each event was coded to find out the affected system or equipment. Subsequently, total values were calculated for each coded item.

Furthermore, a geospatial analysis was conducted using precise location data and additional information on metal recycling businesses and poverty levels. This allowed the generation of visualizations and geographical maps, enriching the study with spatial insights.

Findings

The study findings cover three key areas that provide insight into the nature and impact of wire theft within the Caltrans D7 transportation infrastructure: the financial ramifications, the systems and equipment most adversely affected, and the areas most frequently subject to theft.

Financial Impact of Wire Theft

Figure 6 presents the financial impact of wire theft within Caltrans D7. Total costs are presented, along with the breakdown for labor, equipment, material, and miscellaneous costs.

The cost of wire theft repairs more than doubled from 2020 to 2022. In 2020, the total cost of wire theft repairs for Caltrans D7 was approximately $507K, significantly lower than the subsequent years: $696K in 2021 and $1,232K in 2022. Repair costs rose 37% between 2020 and 2021, followed by a surge in costs of 143% in 2020 and 2022.

Costs for each category also surged between 2020 and 2022. Labor costs for wire theft repairs escalated by 120% during this period, from $261K to $576K. Equipment expenses nearly tripled over the same timeframe, with a 175% increase. Material costs exhibited a comparable rise, surging by 182%.

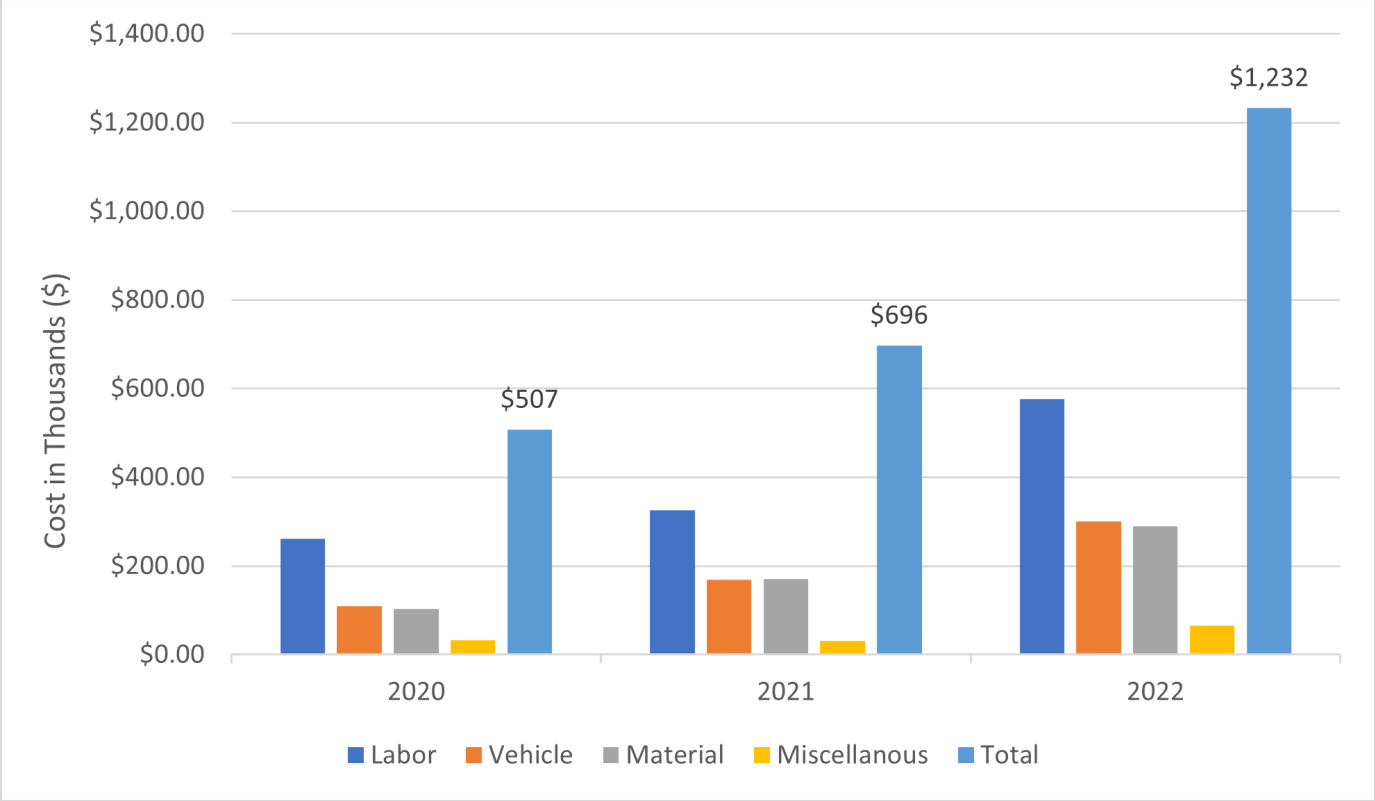

Figure 6. The costs of repairing wire theft are rising.

Source: Raw data from Caltrans IMMS.

Most Impacted Systems and Equipment

Figure 7 presents the number of systems impacted by wire theft, cataloged by fiscal year. The system by far the most severely impacted by wire theft between 2020 and 2022 has been highway lighting.[10] Subsequently, in descending order of occurrences, ramp metering systems, sign lighting, traffic signals, and communication systems have also been subject to wire theft. For example, in 2022, wire theft incidents related to highway lighting were 1536% more frequent than the second most impacted system, ramp metering (229 incidents compared to 14).

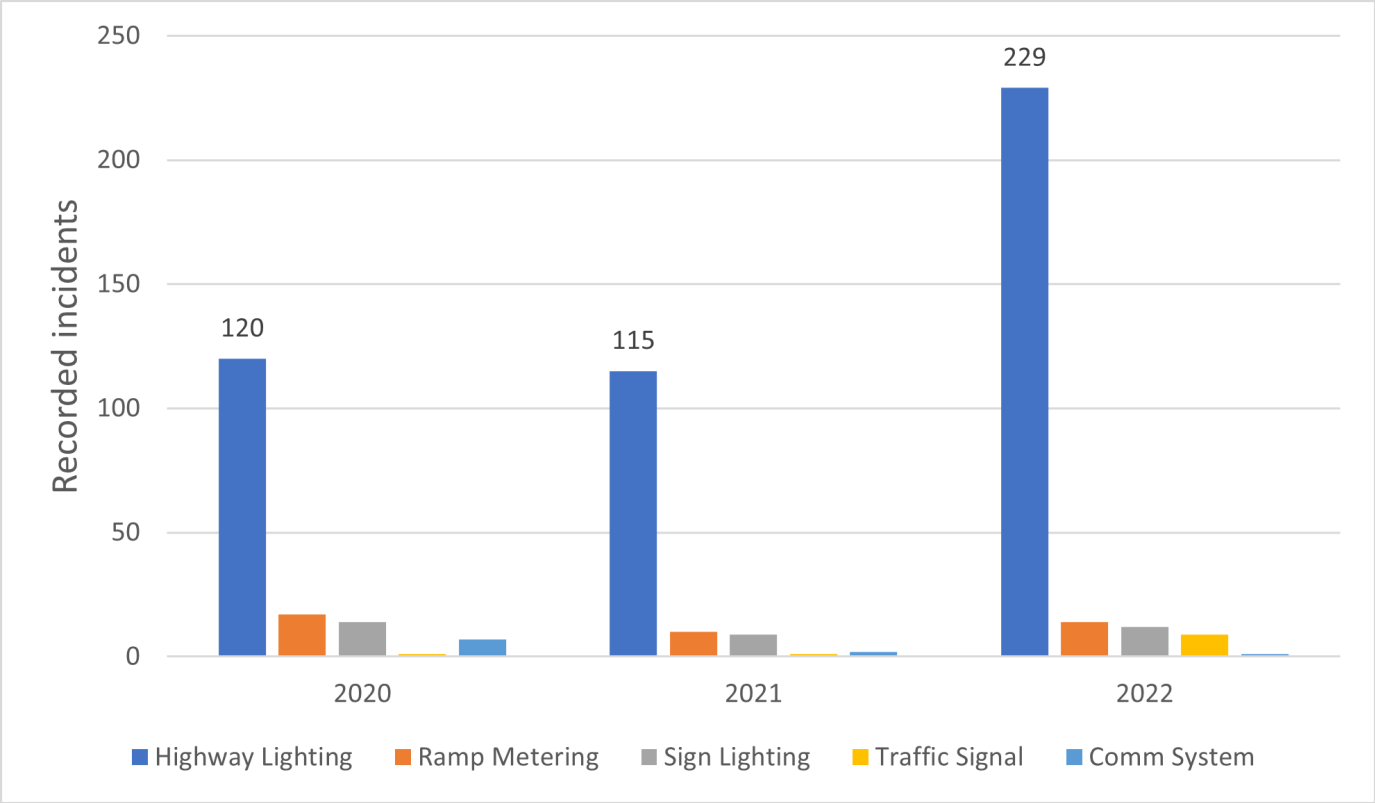

Figure 7. The highway lighting system is the most impacted electrical system.

10 Tunnel and street lighting were also considered as parts of highway lighting for this project.

Furthermore, the total number of systems affected by wire theft in 2022 reached the highest point in the last three years. To illustrate, the total number of impacted systems in 2022 almost doubled compared to 2021.

The number of equipment items impacted by wire theft is classified by fiscal year and exhibited in Figure 8. Vandalism and theft primarily targeted wire, followed by pull boxes (PB), service cabinets, fiber optic cables, controller cabinets, and conduit between 2020 and 2022. For instance, in 2022, theft incidents involving wire exceeded the second most impacted equipment, PB, by 226% (290 incidents compared to 89).

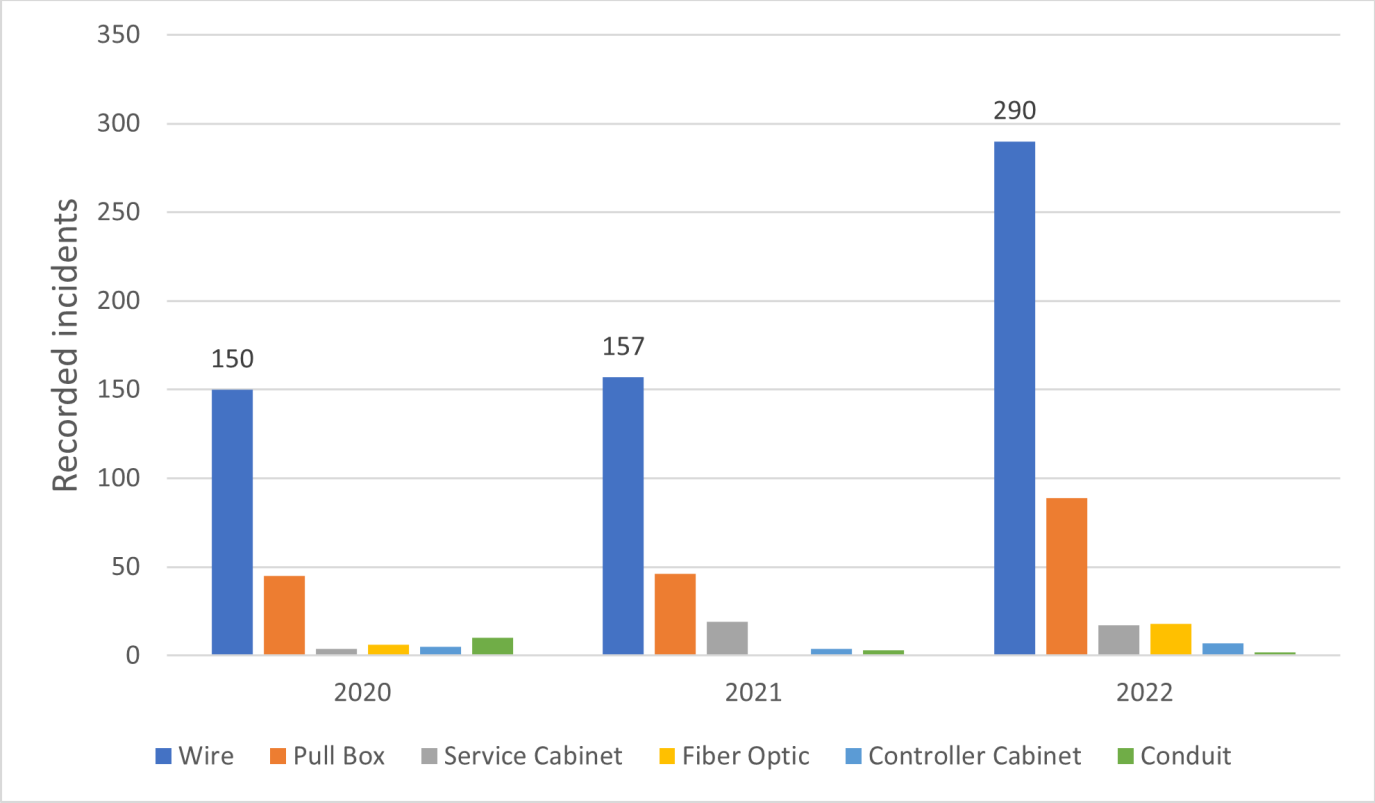

Figure 8. Copper wire is the most stolen equipment.

Additionally, the total number of equipment items impacted by theft in 2022 surpassed the numbers in the preceding two years. The total number of impacted equipment items in 2022 was nearly double the figure for 2021.

Geographical Distribution and the Contributing Factors

Figure 9 displays the results of the geospatial analysis as a heat map.[11] This heat map vividly illustrates that wire theft incidents between 2020 and 2022 predominantly concentrated in Downtown Los Angeles and Hollywood neighborhoods. Specifically, Boyle Heights, Lincoln Heights, Pico-Union, Elysian Park, and Hollywood Hills recorded the highest frequencies of wire theft incidents. Nonetheless, it's noteworthy that other neighborhoods also witnessed wire theft, albeit to a lesser degree. Notable examples include Pacoima, Inglewood, Carson, Compton, and San Pedro, which reported substantial wire theft during the same period.

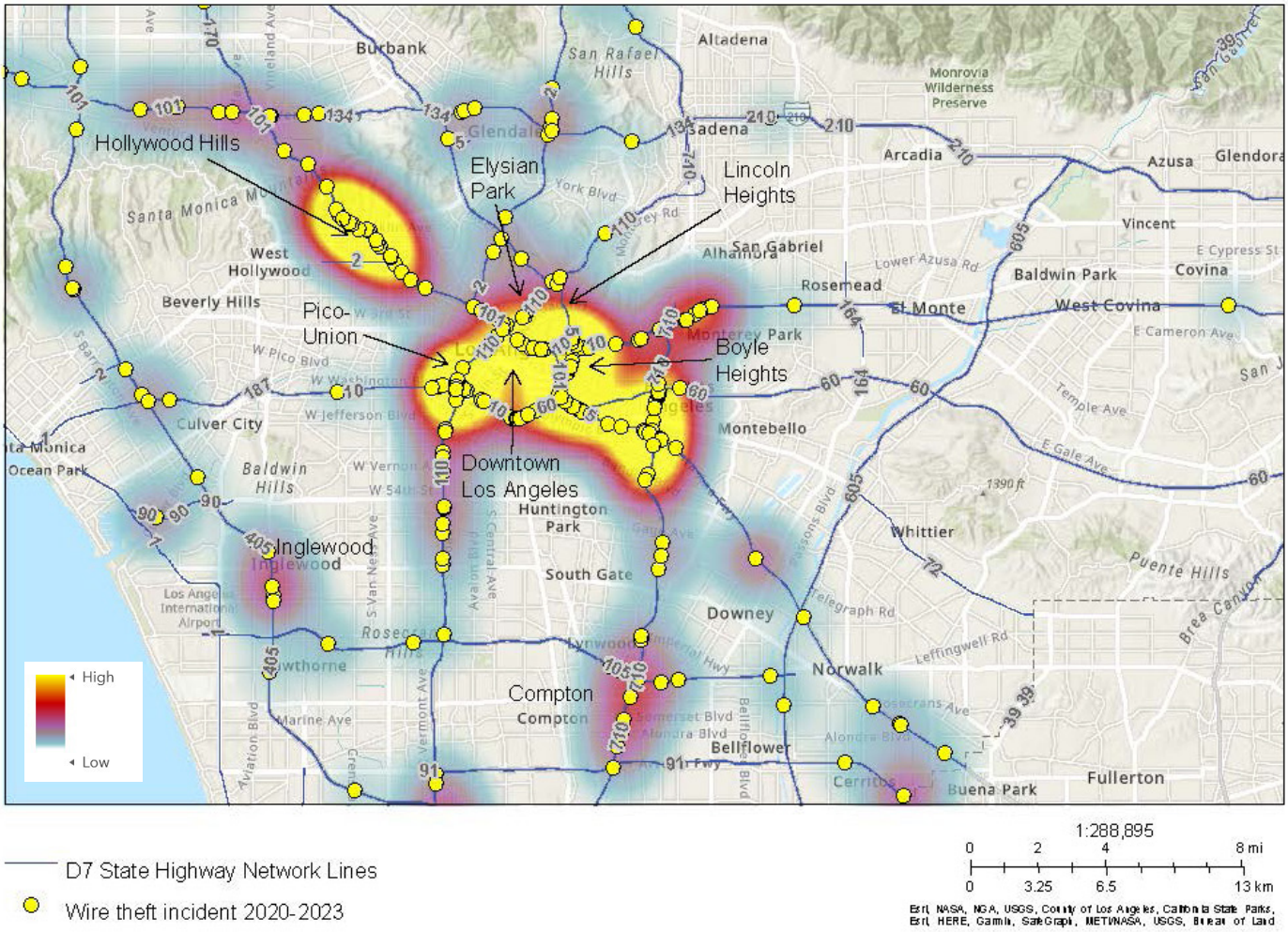

Figure 9. Downtown Los Angeles and Hollywood are the most impacted areas. Caltrans D7 includes Los Angeles and Ventura counties. Only the most impacted part of D7 is shown.

11 A heat map is a visual representation of data where different colors are used to depict varying levels of intensity or concentration. It is commonly employed in geographic information systems (GIS) to visualize and analyze spatial data, helping to identify patterns, trends, and concentrations within a geographic area. Typically, warmer colors represent higher values or greater density, while cooler colors represent lower values or less density.

Utilizing ArcGIS Pro, two feature layers were created to gain deeper insights into wire theft within Caltrans D7. Figure 10 shows the location of scrapyards on the heat map. It becomes evident from the figure that the neighborhoods most heavily affected by wire theft are close to scrapyards. This correlation suggests that proximity to scrapyards could contribute to the wire theft problem since thieves have an immediate location to sell the stolen copper.

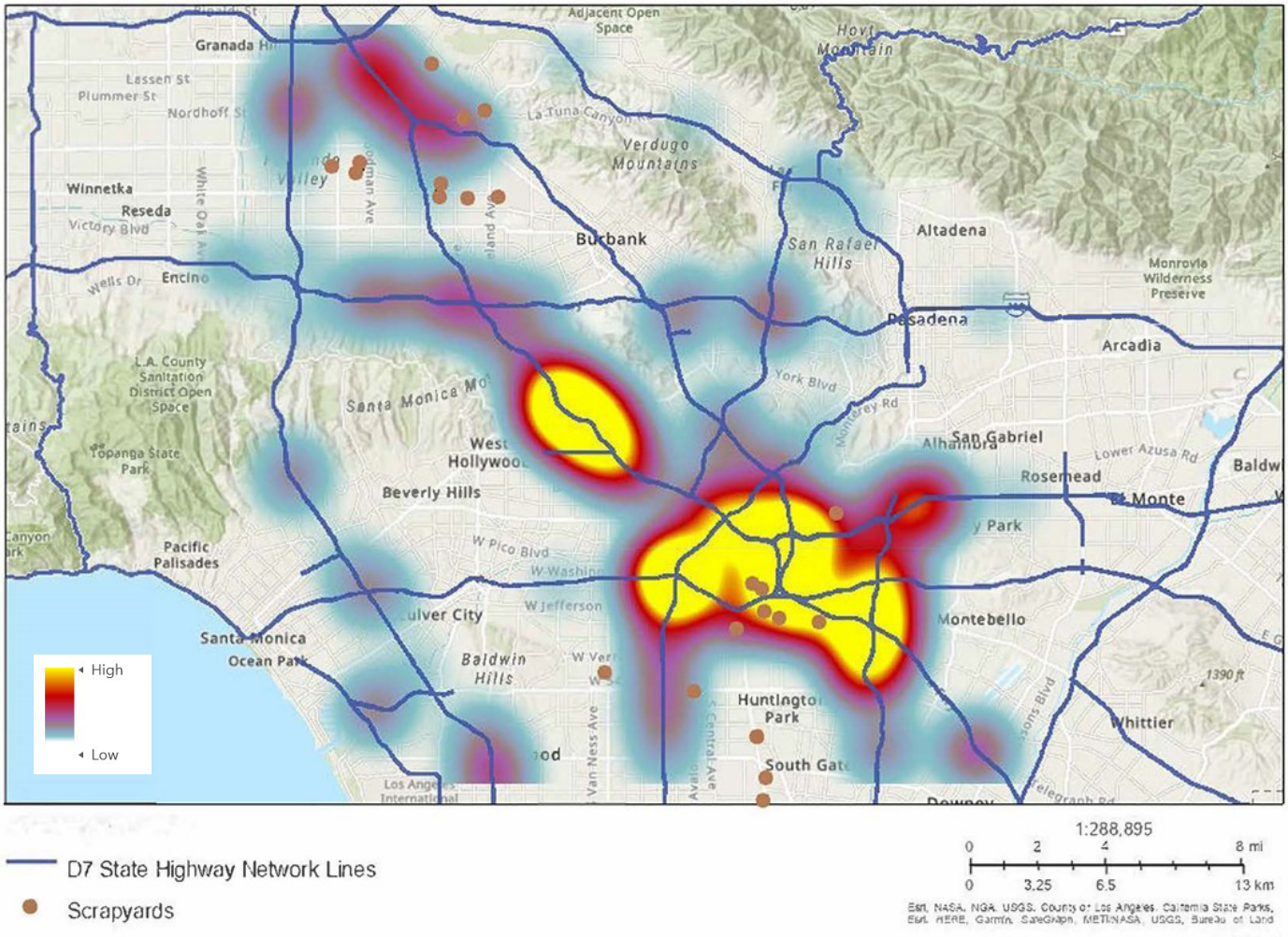

Figure 10. There are many metal recycler shops close to where more wire theft happens.

Figure 11 overlays data on neighborhood poverty onto the map of theft locations. Darker shades indicate higher poverty levels. This map makes it evident that neighborhoods with elevated poverty levels, including Boyle Heights, Lincoln Heights, Pico-Union, Elysian Park, and Hollywood Hills, also experience a high frequency of wire theft incidents.

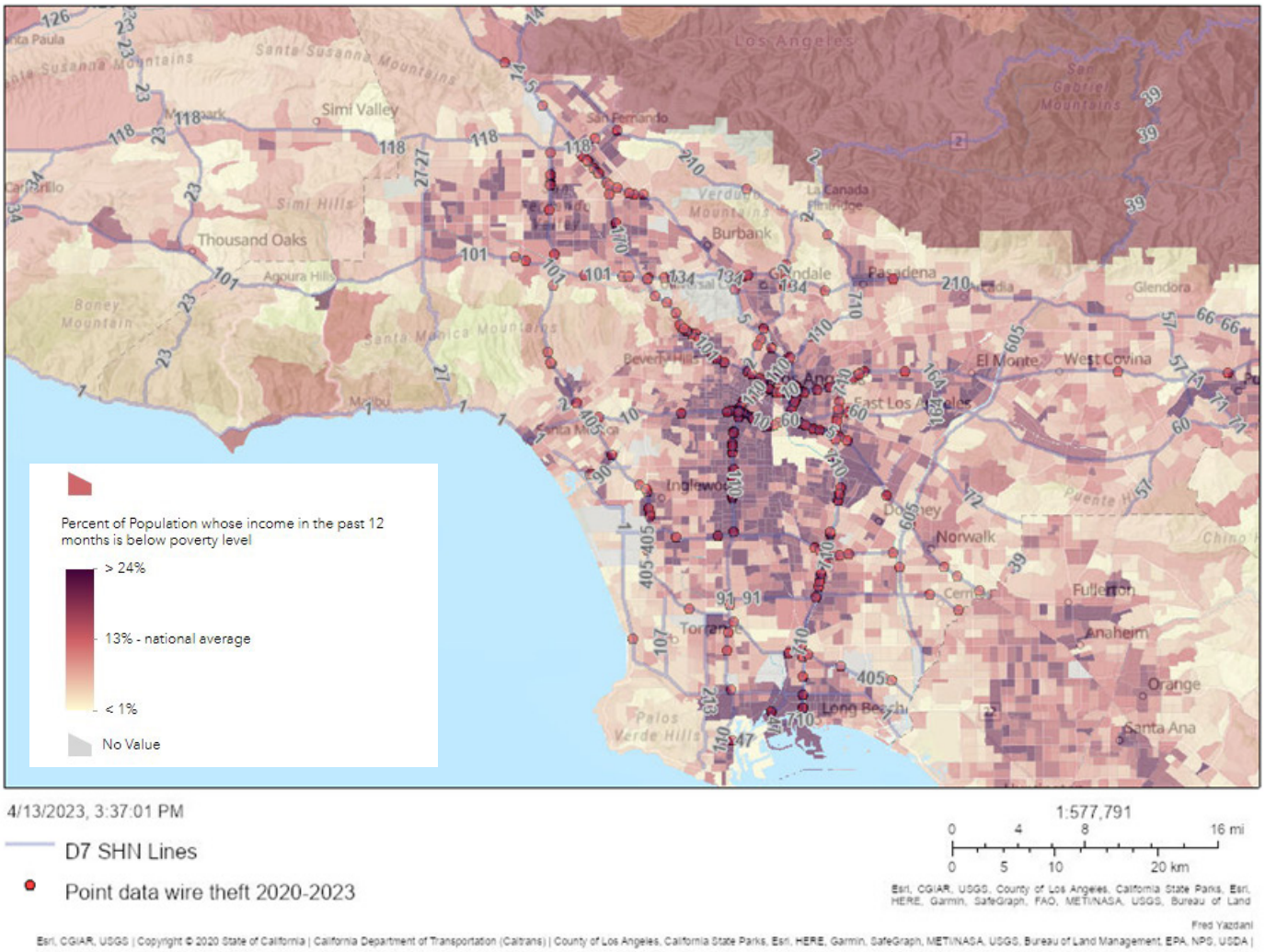

Figure 11. Density of wire theft points compared with poverty.

In conclusion, an analysis of wire theft repair costs over the past three years underscores the escalating problem of copper theft, posing a growing financial challenge for Caltrans. The qualitative analysis pinpointed highway lighting and wire as the most impacted systems and equipment, respectively. Furthermore, geospatial analysis using ArcGIS Pro unveiled Downtown Los Angeles and Hollywood neighborhoods as primary wire theft hotspots, with additional regions like Pacoima, Inglewood, Carson, Compton, and San Pedro also affected. Overlaying poverty and scrapyard data provided insights into potential contributing factors.[12] These findings emphasize the urgency of addressing wire theft in Caltrans D7 and implementing preventive measures to safeguard Caltrans infrastructure and finances.

12 Matthew P.J. Ashby and Kate J. Bowers, "Concentrations of Railway Metal Theft and the Locations of Scrap-Metal Dealers," *Applied Geography* 63 (September 2015): 288.

Conclusions and Recommendations

Summary of Findings

This study assessed the extent of wire theft within Caltrans D7 electrical systems and its financial ramifications between 2020 and 2022. The assessment revealed several key findings:

- Wire theft significantly burdened Caltrans D7 Division of Maintenance in the past three years. Repair costs, including labor, equipment, materials, and other expenses, surged by 143% in two years, rising from $507K to $1.23M. Labor costs, nearly double of the equipment or material expenses, were over $261K in 2020, increasing to $325K in 2021 and $575K in 2022. Equipment costs rose from $109K in 2020 to $301K in 2022, and material costs increased by 175%.

- Lighting systems suffered the most damage from copper wire theft, followed by ramp metering systems, sign lighting, traffic signals, and communication systems. Copper wire emerged as the most frequently stolen copper component, due to its prevalence and accessibility.

- Downtown Los Angeles and Hollywood were the primary targets, with Boyle Heights, Lincoln Heights, Pico-Union, Elysian Park, and Hollywood Hills following. Both are neighborhoods with high poverty rates and local scrapyards.

Recommendations

Based on these findings, the following recommendations can be made for further actions and research by Department of Transportation agencies:

1. **Expand on protecting other assets:** While various agencies have implemented security measures for highway lighting systems, this study revealed that ramp metering and sign lighting systems are also becoming targets. It is advisable for DOTs to extend protective measures to these assets.

2. **Enhance wire theft prevention measures:** Recognizing the urgency of wire theft challenges, agencies should take additional steps to strengthen wire theft prevention efforts:

    a. Agencies should engage in research to update or create comprehensive “Wire Theft Prevention Guidelines” that incorporate the latest and most effective prevention strategies. Collaboration among relevant divisions within the agency is crucial for implementing these strategies.

    b. DOTs can explore innovative approaches, such as digitally documenting the geographic coordinates (latitude and longitude) of electrical conduits and pull boxes during construction and concealing them afterward. This method conceals assets, making them harder to locate and access. The city of Los Angeles has begun implementing this method, and its effectiveness should be closely monitored.

c. In regions with high theft rates, DOTs should consider alternative materials—such as using aluminum wire in place of copper, during routine maintenance, improvements, and responses to wire theft incidents.

3. **Standardize data collection:** The study's analysis identified challenges related to data quality, including inconsistent formats and missing information. Agencies are recommended to establish standardized data collection processes to facilitate future analysis. For example, data collection tools, such as mobile applications, can guide field personnel in recording relevant information based on the type of asset or system they are working on, ensuring completeness and consistency. The use of predefined categories in data collection forms or applications can encourage detailed and easily analyzed data collection. This standardized approach will improve data quality and enhance its reliability for future research and analysis.

4. **Document comprehensive project information:** Addressing theft-related issues is not limited to specific divisions within the agency. Construction projects are often initiated to address theft, and various projects may incorporate components for theft prevention. To ensure a comprehensive dataset for future studies, agencies should document vandalism-related information from project initiation to completion. Consistent and accurate project documentation will ensure that valuable data is readily available for analysis, providing a more comprehensive understanding of theft issues within the agency's infrastructure.

By implementing these recommendations, Department of Transportation agencies can proactively address challenges related to copper wire theft, enhance data quality, and strengthen the resilience of their infrastructure. These measures will contribute to cost savings, improved infrastructure security, and more efficient maintenance processes in the long run.

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Acknowledgements

I would like to express my sincere gratitude to my family for their unwavering support throughout my journey in the MSTM program. Without their encouragement and assistance, this study would not have been possible.

I also extend my heartfelt appreciation to the dedicated team at the Mineta Transportation Institute, particularly MSTM Education Director Ms. Asha Weinstein Agrawal, for their guidance and contributions to my academic growth.

Furthermore, I want to thank Christina Prosperi for her invaluable expertise in utilizing the ArcGIS Pro software, which greatly enhanced the analysis of this study. Special thanks also go to the Caltrans Division of Maintenance Electrical Managers for providing the crucial data necessary for the successful completion of this research. Your support has been instrumental in this endeavor.

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