Chicago Region Traffic Signal Modernization

Prepared by
Chicago Metropolitan Agency for Planning

October, 2020 draft

Contents

List of Tables

Modernizing the region's traffic signals

This report proposes a modernization program for the Chicago region's highway traffic signals. The goals of this program are to maintain and improve arterial traffic flow, improve traveler safety, and improve system reliability, including reliability for the freight system. The report proposes to provide modern traffic signals at all signalized locations, with key locations and corridors prioritized for early upgrades. The report also prioritizes shared resources for signal management to enable economies in implementation.

Signalized arterials have a big impact on the region's daily travel. In northeastern Illinois, over half (58%) of vehicle miles traveled on state, tollway, county and township roads is on the arterial system.[1] Since so much of the region's traffic is on arterial roadways controlled by traffic signals, modernizing those signals is necessary for the region to meet the safety, congestion, and reliability performance goals set out in ON TO 2050, the region's long-range comprehensive plan. Indeed, ON TO 2050 recommended establishing a program to modernize traffic signals.

Improvements in the traffic signal system are necessary. Most of the region's signals need new controllers, since seventy-five percent are very old. About three-fourths of the region's signal controllers are no longer supported by vendors, and replacement parts are no longer manufactured. Improved communications are another key need. For example, while modern signals have continuous communication with a centralized system that assures the system is working properly, maintains coordination between signals, and collects intersection performance data, many of the region's signals rely on dispersed local systems with dial-up communications that might be monitored once a day, or just weekly for timing purposes. Most existing signal systems do not support automated traffic signal performance measures.

Here are some examples of traffic signal modernization activities that are necessary to support improved traffic flow, safety, and reliability:

- Replace outdated traffic signal controllers with controllers that are still manufactured and supported.
- Provide real-time, centralized traffic signal communications.
- Using those improved communications, implement automated traffic signal performance measures and signal timing improvements.

[1] "Illinois Highway Statistics Sheet 2018" (Illinois Department of Transportation Office of Highways Project Implementation, n.d.), http://idot.illinois.gov/Assets/uploads/files/Transportation-System/Reports/OP&P/Travel-Stats/2018%20Illinois%20Highway%20Statistics%20Sheet.pdf.

- Upgrade traffic signal controller cabinets to facilitate upgraded controllers and communications. Some existing cabinets cannot accommodate modern controllers, though replacing the cabinets can be more work than the controllers themselves.

- Upgrade the signals' physical supports (often called poles or standards), mast arms, lanterns, lenses, and visors. Sometimes the physical supports have rusted, while old lanterns can be replaced by more efficient LED signals. This will also require an updated inventory of signal-asset conditions.

- Modernize and maintain vehicle and pedestrian detection. The signal timing plans for many signals, particularly in the City of Chicago, are fixed, based on average traffic volumes and the time it takes for pedestrians and vehicles to clear the intersection. However, suburban signals generally rely on vehicle and pedestrian detection to allocate right-of-way (green-time) on a real-time basis. These systems often require maintenance. Detection of bicyclists also needs to be improved.

- Provide accessible pedestrian signals. Pedestrian signal accessibility for those with disabilities is an issue, as is providing no-touch systems to prevent the spread of disease.

- Signal timing plans in use outside the Chicago region could reduce delay if they were deployed in the Chicago region, but may require additional or modernized equipment.

In short, the region's traffic signal infrastructure and supporting management technologies have been underfunded for many years and require substantial and sustained modernization. But modernizing 8,000 signals operated by IDOT, county DOTs, the Chicago DOT and many municipalities will be a tremendous challenge financially and organizationally.

The case for modernization: signal timing

Improved signal timing, including coordination between signals, is a major benefit of signal modernization. Though highway agencies now have programs to maintain signal timing, better communications and data collection will improve the region's signal timing, thus reducing delay and improving safety.

Many regions have established traffic signal retiming programs, and northeastern Illinois agencies continue to perform "signal coordination and timing" studies. The cost of optimizing traffic signals is relatively low, $4,000 - $6,000 per signal, and "can produce benefit-cost ratios as high as 40 to 1," according to national reviews.[2] The high benefit-to cost-ratio results from the low cost of the project combined with the often high delay reduction for motorists.

[2] Federal Highway Administration Office of Operations. "Arterial Management" April, 2004. Posted at https://ops.fhwa.dot.gov/aboutus/one_pagers/arterial_mgmt.htm. Accessed October, 2020.

Local agencies have also demonstrated high reductions in motorist delay from signal retiming programs. For example, evaluations for the Lake County Division of Transportation have found substantial benefits from retiming projects on county highways. See Table 1.

Table 1. Lake County signal retiming evaluations

Year	Number of Corridors	Reduction in vehicle delay per day (hours)	Reduction in fuel consumption per day (gallons)	CO2 emissions avoided per year (metric tons)
2018	1	403	12	25.2
2016	5	591	404	749
2015	3	694	91	276
2013	6	1625	545	Not Available

Source: Lake County Division of Transportation. Signal coordination and timing study. Web page. Posted at https://www.lakecountyil.gov/3833/Signal-Coordination-and-Timing-Study.**Error! Bookmark not defined.** Accessed October, 2020.

Likewise, the Regional Transportation Authority has documented benefits for general traffic (non-transit vehicles) from retiming signals when transit-vehicle priority programs are implemented. Implementation of transit signal priority capabilities required updating signal equipment but also signal optimization before the transit signal priority installation. The benefits are shown in Table 2.

Table 2: Regional Transportation Authority signal retiming evaluations

Road name and segment	Change in travel times for general (non-transit) vehicles					
	AM Peak		Midday		PM Peak	
	NB or EB	SB or WB	NB or EB	SB or WB	NB or EB	SB or WB
Ashland from Cermak to 95th	-5%	-1%	-10%	-7%	-4%	-2%
Cicero from 87th to US 6	-10%	-13%	-2%	-9%	-9%	-17%
Milwaukee from Golf Mill to Jefferson Park CTA	-14%	-9%	-16%	-12%	-15%	-15%
Cermak from IL56 to 54th Ave	-12%	-17%	-14%	-12%	-28%	-6%
Dempster from Mannheim to Dodge	-10%	-16%	-22%	-15%	-14%	6%
Grand from Dilleys to Sheridan	-13%	-13%	-13%	-1%	-8%	-4%
95th from Roberts to Western	-19%	-12%	-14%	-18%	-26%	-28%
147th from Halsted to IL 83	-25%	-19%	-22%	-20%	-22%	-20%
159th from Park Center to IL 83	-1%	1%	-6%	-11%	-14%	-14%

Source: AECOM AECOM, “Evaluation Report for the Regional Transit Signal Priority Implementation Program (RTSPIP) Version 2.0” Prepared for Regional Transportation Authority. December 2019. Posted at https://stage-web1.rtams.org/sites/default/files/digital_documents/Evaluation%20Report%20for%20the%20Regional%20Transit%20Signal%20Priority%20Implementation%20Program%20%28RTSPIP%29.pdf. Accessed October, 2020.

Signal retiming programs usually depend on consultants hired to install temporary traffic counting equipment and collect a few days or hours of traffic flow data. Using traffic models, they generate a proposed optimal signal timing plan, install it on in the signal controller database, and monitor the results for any needed adjustments. After the retiming is complete, the consultant exits and the signal is left unmonitored until the next retiming is triggered by a project, complaint, or calendar. There is no way to identify signals that can benefit most from retiming because signal performance is unmonitored.

Another way to look at the results, however, is that the opportunity for travel time improvement existed prior to the signal retiming program. The signal timings and coordination shown in Table 1 and Table 2 were optimized and delay minimized the last time these locations were retimed, but the benefits eroded invisibly over time as traffic patterns changed. Without consistent signal performance monitoring, the opportunity was unknown so all vehicles using these roadways have been delayed more than necessary. The situation exists region-wide, and for the traveler traversing many road segments, delay is accumulated over the entire route.

Upgrading signal equipment and communications to modern standards is costly, but the cost to retime an intersection is similar to the cost of purchasing a new controller, and retiming is recommended every three to five years. Central traffic signal management systems can identify poorly performing signals so money isn't wasted evaluating signals that do not need attention. The cost and difficulty of frequently retiming signals is reduced because field traffic data collection can be eliminated and new signal plans can be designed and installed from the traffic management center. With performance measures for the new signal plan immediately available, adjustment and observation can be completed in a more timely and agile way from the management center.

The case for modernization: central signal systems and partnerships

Establishing communication with field equipment is useless without a central signal system software and operating staff. The City of Chicago, Lake County, DuPage County, and Kane County each have traffic management centers with central signal systems, along with several smaller municipalities. Any upgrades to these jurisdictions' signals can immediately be incorporated into an existing central system.

Cook County does not have a central signal system, but has partnered with Lake County to operate signals along Lake-Cook Road. Cook County signals along Lake-Cook Road communicate with the Lake County central signal system. Cook County signal operators have a computer terminal in Cook County to communicate with the Lake County system. This partnership can be expanded to include additional signals in Cook County. This is a good example of shared services, as recommended by ON TO 2050.

The Illinois Department of Transportation (IDOT) does not have a central signal system, although they have recently embarked on a study of a regional traffic management center in northeastern Illinois. IDOT traffic signals in Lake County are also connected to the Lake County central signal system, and IDOT has a desk and workspace in the Lake County office.

As a group, the signals under jurisdiction of Chicago DOT (39%), Cook County DOTH (5%), DuPage County DOT (5%), IDOT (44%), Kane County DOT (2%), and Lake County (3%) are 98% of the region's signals. Today these signals could be linked to either their own central signal systems, or to Lake County's.

While Lake County traffic signals have already been improved to a large degree, the county could invest in expanding its central signal system hardware and software using funding contributed by other agencies that share it. The modernization program could also be the source of funding that allows the Lake County central signal system to grow enough to accommodate other agencies and become a regional or multijurisdictional center. Since a central signal system is a computer system of hardware and software, sharing a single system is invisible to the operator. The difference is mainly whether the operator accesses software nearby or farther away. Advantages of a shared system include sharing of hardware and software purchases and maintenance, and easier inter-jurisdictional coordination.[3]

An analysis by the Lake County Division of Transportation found that moving to centralized communications and an automated traffic signal performance measures approach yielded a savings of about $6,000 per year over the traditional signal coordination and timing approach.[4] The Lake County analysis further found that the system could be extended through a partnership with other signal agencies in the region at a potential regional savings of $140,000 per year[5] (though more modern equipment would still be required for some agencies with or without such a partnership). The bottom line is that efficiencies from signal modernization can bring both better service to travelers and lower-cost operations to transportation agencies.

---

[3] TMCs do not need to involve large building construction projects or dedicated hardware systems. Virtual TMCs, communicating with existing DOT systems, are explored fully in the FHWA document *Guidelines for Virtual Transportation Management Center Development (2014)*, posted at https://ops.fhwa.dot.gov/publications/fhwahop14016/fhwahop14016.pdf.

[4] Justin Effinger, P.E. "Lake County Passage: Automated Traffic Signal Performance Measures, Lake County, Illinois." Presentation to IDOT Fall Planning Conference. October 3, 2019. Posted at http://www.idot.illinois.gov/Assets/uploads/files/About-IDOT/Pamphlets-&-Brochures/Events/Multi-Modal-Planning/Fall-Planning/2019/Lake%20County%20Innovations.pdf.

[5] Ibid.

Recommended traffic signal improvement approaches

The goal is to add communications, hardware, and software to traffic signals so they can be centrally monitored, controlled, and evaluated for performance. Since communications and monitoring costs are often treated separately from signal modernization costs, these two costs were evaluated separately.

Traffic signal modernization scope

We evaluated signal modernization costs at two levels. First, signal modernization may consist of:

- A new controller,
- A new cabinet; and
- accessible pedestrian signals.[6]

A second, higher level of investment would consist of complete reconstruction of the signal. Complete reconstruction involves the items above plus the following, as needed:

- Miscellaneous construction items (asphalt resurfacing, curb and gutter, traffic control, etc.);
- Pedestrian items (sidewalks, ramps, detectable warnings, etc.);
- Underground items (conduit, cable, handholes, etc.);
- Signal items (signal heads, posts, mast arms, power supplies, etc.);
- Signs and markings;
- Vehicle detection;
- Other intelligent transportation system elements (emergency and railroad preemption, transit priority, video feeds, switches); and
- Engineering.

[6] The United States Access Board's draft Public Rights-of-Way Accessibility Guidelines state that "For existing pedestrian signals, the proposed guidelines require accessible pedestrian signals and pedestrian pushbuttons to be provided when the signal controller and software are altered, or the signal head is replaced (see R209.2). Accessible pedestrian signals and pedestrian pushbuttons must comply with the referenced standards in the MUTCD and the technical requirements for operable parts in Chapter R4." "Accessible pedestrian signals and pedestrian pushbuttons." Web page. https://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/background/regulatory-assessment/accessible-pedestrian-signals-and-pedestrian-pushbuttons. Accessed October, 2020. Note that agencies are required to provide accessible facilities regardless of whether the guidelines have been finalized; the draft guidelines provide a good practice for accessibility in the absence of final guidelines.

Traffic Signal Modernization Cost

Without detailed condition information for the signals in the region, cost information was compiled in Table 2 to show a range of potential program costs, based on varying needs for low-cost improvements versus complete reconstruction. The cost estimates also show a few options for the breadth of an improvement program, ranging from modernizing all signals in the region (about 8000 signals) to only those on the National Highway System (about 3,500 signals). These costs were estimated based on recent projects.

Table 3: Potential annual program costs for a 15-year program – signals only

Improvement Mix		Annual cost over 15 years by number of signals improved (*$ million*)		
Controller, cabinet, and accessible pedestrian signals at $27,000 per signal	Full signal reconstruction at $475,000 per Signal	8000 signals improved (all signals in the region)	7000 signals improved (all IDOT, county, and CDOT signals)	3500 signals improved (all National Highway System signals improved)
85%	15%	$50	$44	$22
80%	20%	$62	$54	$27
75%	25%	$74	$65	$32
70%	30%	$86	$75	$38
65%	35%	$98	$86	$43
60%	40%	$110	$96	$48
55%	45%	$122	$107	$53
50%	50%	$134	$117	$59
45%	55%	$146	$128	$64
40%	60%	$158	$138	$69
35%	65%	$170	$148	$74
30%	70%	$182	$159	$79
25%	75%	$194	$169	$85
20%	80%	$206	$180	$90
15%	85%	$217	$190	$95
Signals per year		*533*	*467*	*233*

Souce: CMAP

Note the following caveats:

- These improvements would take place over time. A ramp-up phase would also be required while improvements are designed.
- The number of contractors and agency staff available to design, install, and configure the signals may be a constraint. Developing a larger cadre of engineers may require a longer ramp-up time.
- Most traffic signals (but not every signal) must be upgraded so the cost may be somewhat lower than shown above.
- Without asset condition information, it is unknown how many signals require complete reconstruction, but our inability to find that information may indicate that higher

numbers of signals will require complete reconstruction. Regardless, collecting signal asset condition information is a priority.

Traffic signal communications scope

Decisions about traffic signal communications strategies for individual projects and signals will be made in the future based on the technology available at the time and engineers' judgement. Development of an agency-specific signal communications plan is recommended for agencies with a significant number of signals, where communications have not been fully modernized. Based on typical publicly available signal communications plans, it is expected that communications in the near future will be based on a mixture of fiber-optic cable and 5G wireless communications, with dedicated short-range communications (DSRC) being phased in to facilitate vehicle-to-infrastructure communications. For the foreseeable future, fiber-optic cable will provide the trunk communications backbone.

When many existing signal interconnects were installed, copper cable was used. However, an analysis in California noted that copper is a legacy technology "with limited speed, range, and bandwidth."[7] Such cable should be replaced when communications are modernized. Communications should be modernized from serial to ethernet, where that hasn't already occurred.

Communications modernization will typically consist of installing new fiber optic cable and conduit to replace copper cable and to eliminate gaps along key corridors, including trunk cable (up to 144-strand single-mode cable) and distribution cable (up to 24-strand single-mode cable). Trunk cable is ideally arranged in rings to provide redundancy.

Wireless communications may be installed at isolated intersections, as appropriate. Communications from such locations can then be tied into to the nearest or most appropriate trunk fiber access point.

[7] City of Sacramento. *ITS (Intelligent Transportation Systems) Master Plan.* February, 2019. P. 15. Posted at https://www.smartregionsacramento.org/wp-content/uploads/2019/03/Smart-Region-Sacramento-ITS-Master-Plan_FINAL_02.2019.pdf. Accessed October, 2020.

Traffic signal communications cost

To estimate regional signal communications cost, average costs were drawn from signal improvement plans where communications costs were shown separately, as shown in Table 4.

Table 4. Signal communications costs from signal communications plans.

Plan	Cost per signal	Number of signals	Typical components
San Diego, California	$25,117	~1,500	Fiber repairs, fiber gaps, compatible with future industry standards, eliminate single-vendor dependency, increase system capacity. Includes downtown system, excluding TMC, staff, and ITS elements.
Chula Vista, California	$45,827	267	Upgrade to fiber optic cable and wireless, where appropriate (excludes ITS elements).
Des Moines, Iowa	$9,055	389	Fiber cable and conduit, pull boxes, miscellaneous communications hardware and equipment.

Sources:
City of San Diego. *Traffic Signal Communications Master Plan.* Prepared by Stack Traffic Consulting, Inc. December, 2014. Posted at https://www.sandiego.gov/tsw/projects/trafficsignalcomm. Accessed October, 2020.
City of Chula Vista. *Traffic Signal Communications Master Plan.* Prepared by STC Traffic, Inc. July, 2017. Posted at https://www.chulavistaca.gov/departments/public-works/master-plans/traffic-signals-communications-master-plan. Accessed October, 2020.
City of Des Moines. "Approving the ITS Master Plan as the Framework for the City of Des Moines Future Traffic Management and Communications System Architecture." November 19, 2018. Posted at https://councildocs.dsm.city/Resolutions/20181119/9.pdf. Accessed October, 2020.

Applying the weighted average cost of approximately $24,800 per signal to the Chicago region, the potential costs are shown in Table 5. Note that expected costs will need to be adjusted as program history is developed.

Table 5. Potential Chicago-Region Signal Communications Program Costs

Program Timeframe	8000 signals improved (all signals in the region)	7000 signals improved (all IDOT, county, and CDOT signals)	3500 signals improved (all National Highway System signals improved)
Full program	$198	$174	$87
Per year over 10 years	$19.8	$17.4	$8.7
Per year over 15 years	$13.2	$11.6	$5.8

Source: CMAP.

Note that expected costs will need to be adjusted as program history is developed. In particular, fiber deployment costs may be as high as $220,000 per mile for high-bandwidth single-mode cable in the region, though a more typical cost for lower-bandwidth cable is less than $100,000 nationally.

Automated traffic signal performance measures

Automated traffic signal performance measures (ATSPMs) collect information for engineers to determine the key elements of signal timing:

- Signal phases, or the intervals that are assigned to a traffic or pedestrian movement or a combination of movements. For vehicles, the phases will consist of green (right-of-way), amber (change), and red clearance intervals. Pedestrian phases include the walk interval, the clearance/countdown interval, and the don't-walk interval. Some phases can be skipped if volume is not detected.
- Splits, or the amount of time assigned to the individual signal phases within a cycle.
- Cycle length, or the time it takes to repeat all phases from beginning to end (and noting that, if phases are skipped for lack of volume, the time is assigned to other phases, rather than a shorter cycle). In a coordinated system, the cycle length for all coordinated signals is typically the same.

ATSPMs measures actual signal performance instead of relying on modeled performance. ATSPMs typically include, for example, the percent of vehicles arriving on a green signal, approach delay, approach volumes, turning vehicle counts, split failures (failure to clear during a phase), and each signal timing plan (there are often several over the course of a day). ATSPMs are not automatically a component for central signal systems, but are a key part of the regional recommendation.

Lake County Division of Transportation has entered into a contract for an ATSPM service and offered other agencies the opportunity to piggyback on that contract at a cost of $15,000 per year per 100 traffic signals.[8] This is $1.2 million annually to include all 8,000 regional signals. Such a shared-service approach could save regional agencies substantial funds compared to developing the system on their own, and allow regional agencies to focus on modernizing signal equipment and communications.

An interim alternative to collect signal data is available through vehicle probe data. Using probe data, INRIX offers a signal analytics package for approximately $30,000 per year per 100 signals, or approximately $2.4 million annually for the region's 8000 signals.[9] This interim solution may provide a bridge to provide performance data for signals without communications or the appropriate controller until updated technology is put in place.

[8] Discussions with Lake County Division of Transportation staff, 2019.

[9] Discussion with INRIX representative, October 2020.

Regional funding programs

Northeastern Illinois is not alone in addressing the pressing issue of how to modernize a signal regional signal system, bring it up to a state of good repair and prepare for the future. Some regions opted to establish a set-aside signal improvement program.

- Denver Regional Council of Governments (DRCOG) began a Traffic Signal System Improvement Program (TSSIP) in 1994. This program was a predecessor of today's Regional Transportation Operations and Technology Program. This program is a $5 million annual set-aside of federal funds to fund transportation technology and system improvements. Funding recipients include the Colorado Department of Transportation, the City of Denver, the local transit system (for transit signal priority), and suburban jurisdictions. https://drcog.org/planning-great-region/transportation-planning/transportation-improvement-program/transportation.
- The Georgia Department of Transportation initiated the Regional Transportation Operations Program (RTOP) in spring of 2010. RTOP is a multi-jurisdictional program focused on maintaining, managing, and operating traffic signals in the Atlanta area. http://www.dot.ga.gov/DriveSmart/SafetyOperation/Pages/RTOP.aspx.
- Southwestern Pennsylvania Commission (SPC), the metropolitan planning organization for Pittsburgh, operates a Regional Traffic Signal Program to re-time signals and upgrade equipment. This program is funded through the CMAQ program, Automated Red Light Enforcement (ARLE) penalties, and local communities. https://www.spcregion.org/programs-services/transportation/operations-safety/.
- Mid-America Regional Council (MARC), the metropolitan planning organization for the Kansas City, coordinates Operation Green Light (OGL) to improve traffic signals and signal coordination in both Missouri and Kansas. The project is funded with federal, state, and local funds. https://www.marc.org/Transportation/Programs/Operation-Green-Light/About-OGL.
- The Maricopa Association of Governments, the metropolitan planning organization for Phoenix, has completed 112 projects spanning 1,100 signalized intersections through its Traffic Signal Optimization Program (TSOP). This program is focused primarily on optimization. https://www.azmag.gov/Programs/Transportation/TSMO-ITS/Traffic-Signal-Optimization-Program.

Other locations do not have a dedicated funding program.

- The North Carolina Department of Transportation decided in 2017 to establish a statewide central signal system to operate the 10,000 signals throughout the state. "In 2017, with the vision of moving the state's closed loop systems towards high- resolution data, automated traffic signal performance measures, and connected/autonomous vehicle capability, the decision was made to begin transitioning away from isolated closed loop systems by establishing a statewide central signal system server to which the hundreds of closed loop systems across the state could communicate."[10] This project is funded using a variety of federal and local sources without a specific signal modernization program.

A number of funding sources are available to improve traffic signals.

- Northeastern Illinois currently receives around $112 million per year in CMAQ funding apportionment. CMAQ has often been used to fund traffic signal interconnects and traffic management centers. Combined with the local match, CMAQ has $143 million per year. The history of the CMAQ program is replete with projects that developed traffic management centers, traffic signal interconnects, intersection improvements, and a variety of ITS implementations. https://www.cmap.illinois.gov/mobility/strategic-investment/cmaq.

- The CMAP programmed STP Shared Fund receives approximately $40 million per year, or $50 million including match. This fund can also be used for traffic signal improvement projects if the project cost is at least $5 million. https://www.cmap.illinois.gov/committees/advisory/council-of-mayors/stp#STP_Shared_Fund_2017.

- The recently passed state capital bill, "Rebuild Illinois," brought $33.2 billion in additional transportation funding. https://idot.illinois.gov/about-idot/stay-connected/blog/rebuild-illinois.

- The Illinois Competitive Freight Program funds can be used for traffic flow improvements covering freight bottlenecks. The fund was $225 million over 5 years, or $45 million per year. http://www.idot.illinois.gov/transportation-system/transportation-management/planning/illinois-competitive-freight-program.

In fact, since traffic signal modernization will cover aspects of intelligent transportation systems, safety, ADA compliance, transit users, non-motorized users, safety, truck bottlenecks, rail grade crossing safety, and system resilience, most other fund sources can be used to fund the program. Highway resources available to northeastern Illinois that can be used for traffic signal modernization total $940 million annually. To improve system performance and signal asset condition, it is recommended that more funds be dedicated to traffic signal projects.

Traffic signal projects can compete favorably for any of these funds. The main issue facing the region in many cases is a **lack of leadership support** for aggressive efforts to develop traffic signal project applications and push them to the forefront as priorities. It will take a concerted, yet not unprecedented effort to bring focus and funding to signals as an important class of

[10] "NC-DOT Statewide Central Signal System NOCoE Case Study FINAL.Pdf," National Operations Center of Excellence, accessed January 10, 2020, https://transops.s3.amazonaws.com/uploaded_files/NC-DOT%20Statewide%20Central%20Signal%20System%20NOCoE%20Case%20Study%20FINAL.pdf.

investment. In the 1990's, "Operation Greenlight"[11] was championed by the Illinois Department of Transportation, the Illinois Tollway, CMAP's two predecessor agencies the Chicago Area Transportation Study and the Northeastern Illinois Planning commission, and the Regional Transportation Authority.[12] This program resulted in the designation of roadways in the Strategic Regional Arterial System (SRA), and significant investments in arterial traffic management so the SRA system could operate more efficiently, and support and supplement the expressways system.

The region should do three things:

1. Raise the visibility and priority of regional traffic signal modernization within the policy-making community. This will require agency champions and supporting outreach material.
2. Develop and support a greater number of competitive applications for signal modernization, communications, and central signal systems to accelerate system modernization.
3. Identify and dedicate a portion of regional highway funding to modernize the system.

[11] "Strategic Regional Arterial Design Concept Report, Operation Greenlight" (Illinois Department of Transportationi, February 1994), https://www.cmap.illinois.gov/documents/10180/16420/SRA_DCR_v1_11-5-2010.pdf/cfe9557b-a101-4a51-a9b0-df9a783b4e19.

[12] Illinois Department of Transportation. *Operation GreenLight.* Pamphlet. Posted at https://archive.org/details/operationgreenli00illi/page/n13/mode/2up. Accessed October, 2020.

State of good repair and asset management

To further support prioritized investment, operating agencies should commit to collecting signal and communications asset condition information that can be used in modern traffic signal management. CMAP can support this effort by supporting applications to fund asset condition data collection using UWP funds. One or more asset condition inventories should be developed, funded through the Unified Work Program (UWP)[13] process or the Statewide Planning and Research Funding (SPR) program[14]. This has been completed in other locations; see Iowa's Traffic Signal Inventory Project Final Report[15]. Procurement of signal asset management software and hardware and a sample test should be undertaken to measure the level of effort required to develop traffic signal condition inventories.

A region wide standard template should be developed for this activity, and agencies should commit to maintaining asset condition information in the future. Such templates already exist. Beyond pilot projects, collection of signal asset condition should be included as part of project development for any road improvement.

Why is asset condition important? Advances in transportation system management and operations have been developed and proven effective. The innovations can improve performance and quality of life but large-scale innovation can't be implemented successfully without understanding conditions in the field. Planning and budgeting for system improvement, and understanding the impacts of various investment scenarios can only be accomplished with sufficient depth of knowledge of system conditions. These pressures will increase when the region is faced with supporting new connected vehicle technologies and the opportunity to take advantage of the operational information they will provide.

Unknown but poor asset condition also imposes costs on agencies and the public. Traffic signal maintenance contractors are aware of system conditions, and have stated that they include additional contract costs to cover expected maintenance and repairs.[16] It is unknown if changes to equipment or procedures could reduce maintenance costs because agencies don't track the maintenance activities in a systematic way. If a signal frequently malfunctions, it imposes a cost in delay on the public and on resources for other equipment needs.

---

[13] Chicago Metropolitan Agency for Planning, "CMAP UWP Program," accessed December 24, 2019, https://www.cmap.illinois.gov/committees/other-groups/unified-work-program/materials#FY_2020_FY_2021_Program_Schedule.

[14] Illinois Department of Transportation, "Statewide Planning and Research Funds (SPR)," page, General-refresh, accessed December 24, 2019, http://idot.illinois.gov/transportation-system/transportation-management/planning/index.

[15] Gary B Thomas, "Traffic Signal Inventory Project" (Center for Transportation Research and Education, Iowa State University, June 2001), http://publications.iowa.gov/21324/1/IADOT_CTRE_00_67_Traffic_Signal_Inventory_Project_2001.pdf.

[16] Interviews, 2019.

Municipal Signal Maintenance

Where municipalities lack resources to maintain their traffic signals, maintenance partnerships between municipalities and counties should be established. Some municipalities with resources may also desire similar agreements. "Agencies that manage small numbers of traffic signals are very unlikely to have staff with a proficient level of technical expertise to effectively manage and operate traffic signals." [17]These agreements should cover routine and on-call maintenance, as well as signal operations and signal retiming.

Like larger agencies, many municipalities contract with signal engineering firms to maintain their signal equipment. In many cases, this addresses the mismatch between the municipalities' resources and the resources required to maintain modern traffic control equipment. However, one signal engineering firm reported that, for municipalities with very limited resources, the contracts are only able to fund reactive, complaint-based maintenance and operations practices, sometimes without regular scheduled maintenance checks.[18]

Outreach to encourage smaller municipalities to review and improve signal conditions, enter into maintenance agreements, and join a county or regional central signal system should be pursued. Efforts to develop awareness, knowledge and skills related to traffic signals should also be undertaken.

As outlined below, municipalities should review signal warrants to determine if signals should be removed. As some communities' population have declined, the traffic volumes that once warranted signals have declined too. Removing unwarranted signals may reduce long-term municipal costs and reduce motorists' delay.

Table 6: Estimated of number of signals owned and maintained by municipalities other than the City of Chicago, by county

County	Signals
Cook	400
DuPage	260
Kane	154
Lake	64
McHenry	28
Will	131
Total	1,037

Source: CMAP analysis of HERE Technologies' map data, 2019.

[17] Koonce, Lee, and Urbanik, "Regional Traffic Signal Operations Programs: An Overview."

[18] Interviews, 2019.

Removing signals that are no longer warranted

Signals are installed based on signal warrants. However, traffic volumes change over time, so a signal that met a warrant in 1980 may not meet any warrants today. To reduce agency expenditures and motorist delay, such signals should be removed. As agencies face funding shortages, the agencies should consider removal of unnecessary signals. This will enable agencies to focus available funds on warranted signals, facilitating better management and maintenance for those assets.

While there is often a constituency for installing traffic signals, there is often no such constituency for removing signals, and the process may result in opposition. An effort in Kansas City, Missouri to remove aging unwarranted signals as an alternative to modernization was moderately successful, resulting in 17 unwarranted signals removed of 37 identified (46%) in a removal process in 2012-2013.[19] In Binghamton, New York, 35 of the city's 82 signals were judged to merit a warrant review. Of the signals studied, 26 were recommended for removal, just three (12%) have been removed to date.[20] But those are signals that no longer need to be modernized, are no longer maintained, and no longer cause delay. As noted above, reconstruction of aging traffic signals can cost $475,000 each. And replacing unwarranted traffic signals with four-way stop signs might reduce the number of crashes at intersections.[21]

As with the process for installing new traffic signals, the Manual of Uniform Traffic Control Devices (MUTCD) lays out guidance for removing traffic signals if they are no longer justified:

A. Determine the appropriate traffic control to be used after removal of the signal.
B. Remove any sight-distance restrictions as necessary.
C. Inform the public of the removal study.
D. Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.
E. Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed.[22]

---

[19] Holloway, Bill. "Kansas City Faces Public Backlash over Traffic Signal Removal Plans." State Smart Transportation Initiative. https://ssti.us/2012/11/13/kansas-city-faces-public-backlash-over-traffic-signal-removal-plans/. November 13, 2012. An additional 43 of Kansas City's remaining 622 signals are under review for signal warrants. https://data.kcmo.org/Traffic/Traffic-Counts-at-Signals/s7kw-x59n. The success rate was determined by reviewing a list of traffic signals to be removed at https://www.kcur.org/community/2012-10-22/plan-to-remove-traffic-lights-on-hold-for-now using Google StreetView imagery from approximately 2011 and 2018-2019. One of the named locations could not be verified – a signal could not be found in 2011 imagery.

[20] Binghamton Metropolitan Transportation Study. *Unwarranted Traffic Signal Study.* Prepared for City of Binghamton. June, 2016. Pp. 3-4. Posted at http://www.bmtsonline.com/sites/default/files/Reports%20and%20Documents/Binghamton_Signals%28v2%29%202016%2006-02.pdf. Accessed October, 2020. Status verified through Google Streetview, images 2018-2019.

[21] Federal Highway Administration. *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-light Running.* 2003. Posted at https://safety.fhwa.dot.gov/intersection/conventional/signalized/rlr/rlr_toolbox/chap3.cfm. Accessed October, 2020.

[22] Federal Highway Administration. *Manual of Uniform Traffic Control Devices.* 2009 Edition with Revisions 1 and 2 Incorporated. Section 4B.02. Posted at https://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf. Accessed October, 2020.

Signal Systems Capabilities

The National Operation Center of Excellence and the Institute of Transportation Engineers have prepared a series of self-assessments with levels of potential capabilities for agencies with traffic signals.[23] These capability levels might inform the programming of capital and planning funds in the Chicago region. The capabilities identified in the self-assessments may be useful in determining whether capital projects are ready for funding for a particular agency, and if not, how to increase the capabilities with planning funds. Improving management and maintenance capabilities will assure that capital funds spent on signal improvements are high-priority and lasting investments.

Table 7 presents capability levels for systems, technology, and infrastructure. While there are not particular technologies or infrastructure elements specified, the capabilities focus on the ability of an agency to determine the appropriate technologies and infrastructure elements appropriate for that agency. Measurement, monitoring, and evaluation are key strategies identifying agencies with high capabilities.

Table 8 presents capability levels for maintenance and management. Good planning, with well-defined goals and objectives, is a key element for high capability agencies. Other key elements include well-defined processes, measurement of outcomes, and asset inventories and management.

While several agencies operate at an A or B level for these capability levels, many agencies may still be operating only at the C or even the D levels. Opportunities thus exist not only for the improvement of physical signals, but also the processes to manage and maintain them.

[23] National Operations Center of Excellence and Institute of Transportation Engineers. *Traffic Signal Benchmarking and State of the Practice Report.* December, 2019. Posted at https://transops.s3.amazonaws.com/uploaded_files/TSBSOPR%20-%20Final%20Draft%20%28format%20fix%20needed%29.pdf. Accessed October, 2020.

Table 7: Levels of Signal Systems, Technology, and Infrastructure Capabilities

Level	Systems and Technology Capability	Infrastructure Capability
L 4 "A"	In addition to Level 3: Systems and technology needs are continuously evaluated to validate the attainment of operations and maintenance objectives and to identify deficiencies and opportunities for improvement by investing in systems and technology. - Performance measures inform budget and resource allocation decisions. Asset management	In addition to Level 3: - Infrastructure measures are regularly evaluated to ensure consistency with required condition and functionality. Gaps in functionality and opportunities for enhancement are monitored to identify needed investments.
L 3 "B"	In addition to Level 2: - Processes are established to verify that systems provide the required functionality. - Measures are established to validate that systems and technology provide the required functionality to execute needed operations and maintenance strategies and attain objectives. - Traffic signal equipment is replaced/updated through regular upgrades that consider life cycle and functionality gaps.	In addition to Level 2: - Processes and measures are established to track the condition of infrastructure components to ensure the consistency of functionality with specifications. - Measures are established to ensure that infrastructure provides and maintains the required functionality (visibility, recognition, and understanding) to meet objectives and compliance with national standards.
L 2 "C"	- Requirements to support procurement of system (e.g., local control central control, detection, communication) are established via systematic processes (systems engineering, architecture standards, etc.) that link operations and maintenance objectives and needs to requirements. - The appropriate function and performance of systems and technology is established and is based on the definition of operations and maintenance objectives and strategies. - System components are replaced based on life cycle and or when needed improvements in functionality are identified.	- Infrastructure specifications and requirements for functionality are based on established operations and maintenance needs which support component selection. - The capability to confirm that the current condition and function of signalized infrastructure components (e.g., poles, mast arms, span wire, wiring, signal heads) is consistent with well-established operations and maintenance requirements. - Infrastructure location and placement is recorded on As-Built plans that are readily accessible to support ongoing design, maintenance, and operations activities
L 1 "D"	- Requirements to support procurement of systems (e.g., local control central control, detection, communication) are not well-defined, ad hoc selection of systems and technology is typically based on the preferences of key individuals. - The appropriate function and performance of systems and technology is not well defined and the capability to evaluate performance is limited and typically dependent on complaints. Visual observations and citizen complaints are used to determine the effectiveness of signal operation and maintenance. - System components are typically replaced when there is equipment failure.	- Infrastructure specifications and requirements for functionality are not well-defined; ad hoc selection of components is made based on preferences of key individuals. - The capability to confirm that the current condition and function of signalized intersection infrastructure components (e.g., poles, mast arms, span wire, wiring, signal heads) consistent with operations and maintenance requirements is not well defined. - Infrastructure location and placement must be identified each time design, operations, and maintenance activities are initiated due to the lack of adequate recorded keeping.

Source: National Operations Center of Excellence and Institute of Transportation Engineers. Traffic Signal Benchmarking and State of the Practice Report. December 2019. Pp. 18, 21. Posted at https://transops.s3.amazonaws.com/uploaded_files/TSBSOPR%20-%20Final%20Draft%20%28format%20fix%20needed%29.pdf.

Table 8. Levels of Maintenance and Management Capabilities

Level	Maintenance Process Capability	Management Process Capability
L 4 "A"	In addition to Level 3: - Maintenance objectives, strategies, and performance measures are fully-integrated across the program. - The relationship between activities, processes, systems, and performance is acknowledged by efforts to predict, detect, and proactively make improvements. - Processes are continuously improved by validating the effectiveness of day-to-day activities, systems, and technology and workforce capabilities with performance measures.	In addition to Level 3: - Program businesses processes are continuously improved by validating the effectiveness of the day-to day-activities, systems and technology, and workforce capabilities with measures. - Asset management, funding processes, training, implementation of technology and innovation, and investments in innovation and technology are informed by evaluation measures. - Priorities and investments are referenced in the Agency strategic plan.
L 3 "B"	In addition to Level 2: - Measures (output and or outcome) are defined for maintenance-related activities. - Measures (output and or outcome) are established to validate the attainment of maintenance objectives and the effectiveness of strategies. - Reporting of maintenance output and outcomes is a core business practice.	In addition to Level 2: - A set of measures (output and/outcome) are defined for management-related activities as well as the overall program. - The capability and processes to validate and routinely report on the attainment of program objectives and strategies is developed or under development. - Asset management inventory is available.
L 2 "C"	- Established maintenance strategies, activities, processes are practiced to guide preventative, routine/scheduled, and emergency maintenance. - Guidelines, checklists, or other documentation is available or under development to support traffic signal maintenance to ensure the reliability of infrastructure, systems, and technology. - Efforts to make improvements to maintenance processes are limited, tend to be reactive, and have limited accountability	- The potential loss of continuity resulting from the attrition of key staff is mitigated by documenting program goals and objectives in the form of a Traffic Signal Management Plan (TSMP). - The TSMP references National standards and guidelines to support agency practices. The TSMP considers and documents the need for collaboration among traffic signal-related activities. - Workforce competencies, asset inventories, procurement processes (e.g., systems engineering) are documented. An asset management system is available to track life cycle of equipment.
L 1 "D"	- Maintenance activities are not well-defined, ad hoc, and are driven by individuals who are equipped with or developing the skills and expertise to implement maintenance strategies. - Little or no documentation exists to guide maintenance processes. Updates to existing guidelines are rare and are not tracked. - Processes to evaluate infrastructure condition are ad hoc and not well-defined. The systems, technology, and infrastructure components may be dated (potentially obsolete), with gaps in functionality and typically replaced upon failure.	- The clear articulation of the goals and objectives of the traffic signal program relies on one or more program champions as documentation to support the day-to-day activities in the areas of design, operations, and maintenance have not been fully developed. - The loss of key staff due to attrition or retirement presents a risk to continuity of administration activities. - Little or no documentation exists to provide direction, vision, and goals to guide traffic signal program processes. - The relationship between workforce, systems and technology, asset management, and agency goals is reliant on key individuals. Updates to existing guidelines are rare and are not tracked

Source: National Operations Center of Excellence and Institute of Transportation Engineers. Traffic Signal Benchmarking and State of the Practice Report. December 2019. Pp. 26, 27. Posted at https://transops.s3.amazonaws.com/uploaded_files/TSBSOPR%20-%20Final%20Draft%20%28format%20fix%20needed%29.pdf.

Roles and responsibilities

Regions where traffic signal programs have been developed found it is valuable to take advantage of existing structures and relationships. Within northeastern Illinois, the county signal engineers have been meeting quarterly. The Regional Transportation Operations Coalition also serves as a forum to discuss operations from a regional perspective, including traffic signal operations, and involves additional stakeholders and perspectives.

Chicago Metropolitan Agency for Planning

As the Metropolitan Planning Organization for northeastern Illinois, CMAP has responsibility for coordinating federal funding, programming projects for a limited set of funding programs, programming funds for planning studies, and recommending improvements to help the region and state meet established performance goals. CMAP recognizes the role that traffic signal modernization can play in meeting performance goals and will provide support for activities that advance the region's progress in this area.

Regional Transportation Operations Coalition (RTOC)

The Regional Transportation Operations Coalition is housed in the Chicago Metropolitan Agency for Planning (CMAP), the Metropolitan Planning Agency (MPO) for northeastern Illinois. The coalition is supported by CMAP staff, who provide planning and analysis support on operations topics. RTOC is the conduit for introducing operations issues into the regional transportation planning process and provides valuable expertise and insights into operations topics. The coalition is an appropriate venue to discuss planning, strategies, policies, and programming issues unique to operations challenges and including a variety of stakeholders. RTOC may have a role in identifying and starting a discussion of necessary operations agreements for communications sharing and advanced traffic signal performance measures.

County signal engineers

The county signal engineers meet on a quarterly basis to discuss new procedures or equipment being tested, debate new operational ideas, and report back on discussions with contractors, consultants, and vendors. They also discuss agreements, permitting, safety, pavement markers and marking, signing, and traffic signals. IDOT participates in these meetings, but the City of Chicago does not. The City of Chicago has jurisdiction over a large share of the region's traffic signals. This group should be the origin of endorsed guidance on signal system development, and it will be important to include CDOT in developing it. Additional areas where the signal engineers can be instrumental in establishing the groundwork for efficient program implementation include the development of standards and changes to procurement practices. CMAP and RTOC can provide funding, staffing, and review to support these efforts.

Develop guidance traffic signal projects

Signal modernization means different things to different people, especially municipalities and consultants with much less expertise in the subject matters of ATSPM, ATMS, and communication requirements. Guidance would help to ensure that the region can achieve its targets with the smallest number of technical requirements.

Identify and adopt procurement improvements

The signal engineers and their respective procurement staff can facilitate a discussion of bulk or cooperative procurement of equipment and services to reduce costs. Lake County individually negotiated an Automated Traffic Signal Performance Measures contract that includes the option of other agencies adding their signals to the system. This lowered the entry cost for other agencies and also saved time and procurement resources for other agencies who choose to participate. There may be other opportunities for similar savings.

Develop and adopt standard designs

Signal design engineering consumes up to 20% of traffic signal modernization cost, which is in addition to the 10% construction engineering cost. It might be possible to reduce the design engineering costs by developing a number of standard designs for key system elements that can be reused in different locations.

Data use standards

Installing controllers with data logging capabilities and communications to easily transmit the data will result in a valuable asset useful to agencies and outside parties. The data will be used by agencies to monitor and operate traffic signals. Outside agencies such as universities may use it for research, and private companies can develop useful products from it.

North Avenue (IL 64) Smart Corridor demonstration

This 27.5 mile, 70 traffic signal project is included in the regional Transportation Improvement Program under the title "Illinois Route 64 SMART Corridor (Smith/Kautz Road to Illinois Route 50 (Cicero Avenue))" and arose from the Cook-DuPage Smart Corridor Study that was completed in 2015. The project cost is $17 million, with construction taking place in 2023 and completion expected in 2024. There are 70 traffic signals included in the project. This cost averages $243,000 per signal, including communications and modernization and other costs discussed below. Note that three other corridors were selected in the Cook-DuPage study – Harlem Avenue, Cermak/22nd /Butterfield Road, and Roosevelt Road.

Along with travel time monitoring and dynamic message signs, the project will complete the fiber communication network by filling gaps between the existing traffic signal interconnects, and install transit signal priority at 37 traffic signals. The project will convert all detection to video detection, and replace outdated controllers with ATSPM-capable controllers. Except for implementing a central signal system, an effort that is progressing through another project, and implementing Automated Traffic Signal Performance Measures (ATSPM) this project essentially implements the recommendations of the signal modernization program. If IDOT has not established a central signal system by the time the project has been implemented, the corridor could temporarily be operated from the Lake County TMC (an IDOT workstation here already exists) and piggyback on the Lake County ATSPM contract which is offering performance monitoring services for $15,000 per year per 100 traffic signals.

The project description notes that "*Review of existing conditions included signal head type, size, and placement; signal posts and mast arms; street name signs; signal timing; battery backup; pedestrian push button and/or countdowns; and traffic sensors for traffic signal detection.*"[24] Controllers and detection are not listed among the existing condition inventory because these items will be reviewed during Phase II engineering. This effort would be easier to complete with an accurate existing condition inventory.

The Cook-DuPage study recommended assembling groups of stakeholders to identify corridor goals and ensure the corridor improvements are designed to meet corridor goals. Since this corridor is long, it traverses a variety of development types, traffic conditions, road characteristics, and signal designs. It is an opportunity to identify difficulties associated large signal improvement projects, undertake a small signal asset management data collection effort, and develop a plan for before and after data collection to measure the benefit of these investments. Later stakeholder activities include developing goals, procedures, agreements and other topics needed to operate a smart corridor.

[24] "Illinois Route 64 (North Avenue) Kautz Road to Illinois Route 50 Project Description" (Illinois Department of Transportation Office of Highways Project Implementation, January 27, 2020).

Conclusions

Northeastern Illinois must improve traffic signal performance to help meet the regional road performance goals for the safety and mobility of people and goods. While traffic signal retiming programs are useful, they provide neither long lasting improvements nor the ability to monitor traffic signal performance. System operators should modernize signals and connect them to central signal systems. This will require significant investment in signal technology and communications. To facilitate planning and budgeting for modern signal system management, data to support signal asset management should be collected. A specific funding program to adequately fund a signal modernization program is not proposed, but the region is ripe for a multi-agency modernization pilot that will inform the development of a full modernization program. This initial effort will be supported by:

- Promoting the importance of signal investments;
- Improving the capabilities of agencies with traffic signals;
- Supporting agency development of signal asset inventory and asset management capabilities; and
- Development of more signal improvement projects and funding applications.