Aurora Parking & Mobility Enterprise

July 2015 • Final

Technology Master Plan

Includes a discussion of parking technologies needed to support the implementation of the Parking and Mobility program. This section includes a discussion of off-street, on-street, enforcement, and data management technologies.

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Expect More. Experience Better.

Technology Master Plan

Contents

The introduction of parking management strategies within the Aurora community is going to require corresponding parking management technology. Each system component has its own technology needs to ensure efficient and effective implementation and management of the component. The graphic below illustrates the program's primary technology components and the needs associated with each. Each of these components requires coordination between the Parking and Mobility Manager and the Information Technology department. The combination of technologies shown in this graphic represents an ideal state, one which the City of Aurora will work over time to achieve. Even with this master plan, it may be difficult to achieve this ideal state with the variety of technologies and communication platforms. The ultimate goal should be for the City to achieve a platform that is easy to understand and use for both the parking patron and the staff of the Parking and Mobility Program.

Off-Street

Revenue control for off-street management is typically handled through a combination of gate access for ingress/egress, ticket or validation capabilities, and a payment platform. That payment platform could include cashiers, pay-on-foot kiosks with exit validation, or pay-in-lane technology with cash and/or credit card acceptance at the exit. Many facilities also allow for a pay-by-phone validation now as well, which allows motorists to conduct transactions through their phones (either call, text, or app based) rather than interacting with parking access revenue control systems (PARCS). Facilities with permit or regular user access can be configured to accept proximity cards or radio-frequency identification (RFID) reader acceptance. Also, many facilities can be configured to accept the same payment platform as local road or highway tolling. The Canopy off-airport parking facility at the Denver International Airport is an example of this configuration, using similar communication technologies and platforms to transmit payment validation through an RFID transponder. In the case of the E-470 toll detection, the City would need to coordinate with administration at E-470 to access reading of the existing 6c sticker in use on the toll road. In the Canopy Airport parking example, E-470 charges the operator $0.10 per first transaction for each registered user that accesses the system.

Many new facilities are also using license plate recognition (LPR) technology for entry and exit validation, with payment validation being made through either pay-on-foot or online payment systems using the license plate as the validation credential. However, the reading capabilities of those LPR cameras is greatly enhanced by the presence of a gate system to slow vehicles upon ingress and egress. Otherwise, a gateless system with mobile mounted LPR enforcement will be needed to ensure that all vehicles are accounted for within the facility.

There are a number of types of off-street revenue control technologies the City should consider, including the types found in the table below.

		General Cost
Cashiered Exit (no PARCS)		
A staffed booth or exit plaza allows for interaction with parking staff, and options for cash or credit payment upon exit. Electronic cash register systems represent a manual system with a cash register capable of producing limited accounting and management reports.	Pros » Higher customer service » Provides some systematic data on transaction types and amounts Cons » Higher ongoing costs (staffing related) » Higher potential for fraud » Requires aggressive auditing	$$

		General Cost
Automated Exit with Payment		
The Parking Access and Revenue Control System (PARCS) utilizes an online real-time computerized environment connected to a central computer system to process tickets, payments, and validations for users. The use of PARCS increases the capability to monitor devices within the system, maintain space availability, and maximize the collection of parking revenue due. The objective of the implementation of the fully-automated parking system is not only to increase but also maximize service provided to the patron and revenue to the airport. Also, it is designed to control and account for all parking vehicle revenue, collected or not, with less than 0.1% error. PARCS with automated exits can come in many varieties, including ticket readers, exit stations, automatic vehicle identification (AVI), RFID, and LPR verification.	Pros » Highest level of revenue control and ability to prevent potential abuses » Lower ongoing costs » Faster processing speeds » Easy to use Cons » Higher capital costs » Requires ongoing accounting, auditing, and exception ticket controls » Ongoing maintenance and management of PARCS equipment » Replacement costs » Lowered customer service	$$$
Pay-on-Foot Station with Automated Exit		
This system is similar to the fully automated system, with the exception that payment is moved from the exit lane to a centralized location within the parking facility. This pay-on-foot payment platform is usually handled with one or more kiosks that accept the patron's ticket and allow for cash or credit/debit payments. The benefit is that the exit process can be handled quicker if the payment processing is completed prior to arriving at the exit plaza. Appropriate grace periods need to be built into the ticket processing time to allow patrons to make it from the payment kiosk to their vehicle to the exit plaza. Typically this grace period is five to 15 minutes.	Pros » Less queuing at exit machines » Less time spent at the exit station » Less equipment needed at the exit plaza (just ticket reader) » Lower cost than exit PARCS » Fully automated Cons » Higher capital costs than cashiered » Requires ongoing accounting, auditing, and exception ticket controls » Ongoing maintenance and management of PARCS equipment » Replacement costs » Lowered customer service	$$$

		General Cost
License Plate-Based Payment with Gates		
The next advancement in automated parking systems is the use of license plate cameras as the verification and validation system. In this configuration, the entry and exit credentials associated with each vehicle are directly tied to its license plate. Pole-mounted LPR cameras are situated to capture license plate images at both the front and back of the vehicle upon both entry and exit. The payment for this type of system can be done virtually through license plate-based permits, tolling systems, or pay-on-foot stations with the license plate number used as the validation.	Pros » Ticketless entry/exit » Favors repeat users who can purchase a virtual permit » Allows for quicker entry/exit Cons » Higher costs » Current technology still requires vehicles to slow or stop upon entry » Transient users will need a payment option, like pay-on-foot	$$$
License Plate-Based Payment without Gates		
Similar to the configuration above, this platform utilizes license plate credentials to verify payments and tie the transaction back to the motorist. However, in this configuration there are no gates to control ingress and egress movements. The license plate reading would be conducted using mobile mounted LPR units which would patrol the facility and document license plate information. Payment is handled at a pay-on-foot kiosk within the facility and tied to the license plate number for the vehicle (which is manually entered by the patron). The system can also utilize permitting that is tied to the license plate to verify proper facility credentials.	Pros » Ticketless entry/exit » Favors repeat users who can purchase a virtual permit » Allows for quicker entry/exit » Less capital investment for City Cons » Requires consistent and prominent signage to identify payment requirement » Requires heavier patrolling of facility for enforcement	$$
RFID Based Payment with TollTag		
Some communities and parking management operations are beginning to use Tolling information as a payment credential in parking facilities. Under this configuration, the toll pass that a motorist uses for highway tolling can also be used for entry and exit into parking facilities. The toll pass would be read by an RFID transponder that would be mounted above or adjacent to the entry/exit lanes, allowing the motorist to pass through the gate access using their toll account as payment credentials.	Pros » Ticketless entry/exit » Favors repeat users who can pay for tolling and parking from one account » Allows for quicker entry/exit Cons » Higher costs » Transient users will need a payment option, like pay-on-foot	$$$

There are a number of access configurations that could work within City parking facilities, including manned booths, automated gates with pay-on-foot stations, automated gates with pay-in-lane configurations, and gateless configurations. However, two configurations appear to be the most likely scenarios for these facilities, given the current direction the parking industry is headed and the needs of the two facilities. These options include:

1. License Plate-Based Payment without Gates (Iliff)
2. Automated Exit with Pay-on-Foot Station (Hotel/Conference Center)

These two options are discussed further in the following sections.

LICENSE PLATE-BASED PAYMENT WITHOUT GATES

In this configuration, no access control equipment is provided at the entrance to the parking facility. In a single entry/exit lane configuration like the ones proposed for Iliff, the introduction of parking control equipment at the gate can limit the space available for vehicle entry, exit, and queuing. Additionally, a gateless entry and exit will not restrict the flow of traffic into and out of the facility, which could be particularly heavy during rush hour commute times.

The equipment included in this configurations is limited, but would require:

- **Pay-on-Foot Station –** This would provide the primary payment method for the transient patron, allowing for the user to pay for the parking transaction. The pay-on-foot station should be configured to accept a license plate based payment credential, where the patron enters their license plate at the machine as the primary identifier for the transaction. That license plate number would then be made available to enforcement technologies to help enforcement staff validate the vehicles presence throughout the day.

- **Mobile Mounted License Plate Recognition Equipment –** this would include a vehicle with mobile mounted LPR to collect and validate licensed plate based payment information within the parking facility. The vehicle would circulate the parking facility on a regular basis to monitor vehicle presence and determine if the vehicle had paid through either pay-on-foot or permit based transactions. The data collected from the LPR unit could be tied back to the back-end processing system which would search the payment database of the vehicle to determine if a payment had been made or if a citation needs to be issued for an unpaid vehicle.

- **RFID Transponder for virtual permit entry –** This would allow for permit holders to enter and exit the facility without pulling a ticket. Permits would be either hang tags or stickers affixed to the vehicle that provide entry and exit credentials for the motorist. This entry configuration could also include the use of the toll tags for entry and exit credentials. The use of toll tag credentials would require close coordination with IT staff at E-470, ensuring that the bar code and transponder credentials are correctly matched to read the toll tags that are in place. In this scenario, E-470 patrons would enter the facility and a mounted AVI reader would recognize and read the toll tag. The data would then be passed from the parking office to the toll road systems valid tag list, where the cost of parking would be deducted from the toll account.

Pay-by-phone could also be used as an alternative, and the platform is rapidly gaining acceptance as a primary method for parking payments. Many cities throughout Europe and the Middle East have moved to a pure pay-by-phone parking environment in the past five years, reducing their capital expenditure and increasing access for customers. Within the past year, several communities in the U.S. have begun to experiment with this type of system, implementing pilot areas to measure acceptance and potential for revenue offsets.

The initial reluctance to institute a pay-by-phone-only system was the perception that the system would not be equitable. More directly, how would those citizens without cell phones pay for their parking? As cell phones become a more integrated part of society, that fear is dwindling. According to research by the Pew Research Center1, 88% of Americans own a cell phone. Even more important, 46% of Americans own a smartphone and use their cellular devices for more than phone calls, a trend that is escalating quickly (with another estimated 10% bump by the end of next year).

With these statistics and the continued evolution of the cell phone, is it any surprise that pay-by-phone payment methodologies are popping up in communities everywhere? Pay-by-phone is not a new concept, but its acceptance is at an all-time high. And for the first time since its introduction in the U.S., we are starting to see communities consider all pay-by-cell systems. Think about some of the benefits:

- The user pays an overwhelming majority of capital and maintenance costs – the only equipment needed is the user's cell phone
- The user only pays for the time that they park – the transaction is engaged at the beginning and can be disengaged when completed
- The user can receive notifications before they go over time, allowing for remote addition of time or advanced notification prior to violation
- Integration of smartphone applications allows for wayfinding, payment, management, enforcement, and communications all through the user's smartphone
- Most systems have robust back-end management systems that can provide advanced management of the parking system
- Transaction and gateway costs (sometimes as high as $0.16 per transaction with traditional meters) are negated or passed on to the consumer

AUTOMATED EXIT WITH PAY-ON-FOOT STATION

In this configuration, gates are posted at both the entry and exit aisles, where an entry ticket spitter and an exit ticket reader would be located. With dual entry configurations, such as those seen in the Hotel and Conference Center garage, there would need to be an island for each entry gate.

The equipment included in this configurations is limited, but would require would include:

- **Ticket Spitter and Entry Gate –** This would control access to the entrance points of the garage and would include a ticket issuer, typically with a push button for entry access. The entrance configuration would need a AVI/RFID transponder for hotel room cards to allow access for overnight patrons of the garage without ticket issuance. The entrance could also be outfitted with a proximity card reader or RFID/AVI reader that could control monthly permit access. The monthly permit option could be appealing to regular user. The RFID reader would most likely be mounted overhead and would read a signal from the vehicles permit, whether hang-tag mounted or sticker based on the windshield of the vehicle. You can also place a proximity card reader on the ticket machine and give patrons RFID cards to wave as they enter the facility.
- **Pay-on-Foot Station –** this would provide the primary payment method for the transient patron, allowing for the user to pay for the parking transaction. The pay-on-foot station should be configured to accept a license plate based payment credential, where the patron enters their license plate at the machine as the primary identifier for the transaction. That license plate number would then be made available to enforcement technologies to help enforcement staff validate the vehicles presence throughout the day.
- **Ticket Exit Verifier and Exit Gate –** This would control egress movements and a ticket reader to validate the exit credentials of the motorist. A credit card pay-in-lane station could also be provided to allow motorists to pay upon exit, assuming they had not previously paid at a pay-on-foot station. The exit configuration could also be outfitted with a proximity card reader or RFID reader for the monthly commuter permit, accelerating the motorist's exit process. An RFID/AVI transponder should also be added to read room key validations for hotel guests. If the City determines that the user would be better served by pay-in-lane gate-controlled access, the width of the access points would need to be addressed for the island configurations, but the length of islands may be appropriate for gate access technology.

The design considerations for this type of entry configuration generally require:

- Nine to 11 feet of aisle width for each entry and exit lane
- At least three feet for the width of each island, which would be wide enough to house the gate arm technology
- The island length needs to be at least 20 feet for queuing and housing payment and access equipment
- Appropriate turning radii as vehicles enter the entry/exit plaza, as well as move from the plaza into the parking facility
- Additional queuing capacity will be needed based on the expected traffic and arrival patterns for the garage, as well as the type of gate access control selected. The table provided below includes queuing and response times for LPR based systems.
- Vehicular loop detection can be cut in during the time of equipment installation and is not a primary concern in the design phase

Table 4-4. PARC Service Rates

	Veh/hr	Sec/veh
Prepaid Frequent Parker Entry or Exit		
Insertion Card	435	8.3
Proximity Card	600	6.0
Automatic Veh ID	800	4.5
Pay Per Use Patron Vehicular Entry		
Push Button Ticket	400	9.0
Auto Spit Ticket	450	8.0
Pay on Entry-flat fee, gated, ticketed	200	18.0
Pay on Entry flat-fee, non gated/ticketed	300	12.0
Pay Per Use Patron Vehicular Exits		
Cash to cashier-Variable Rate	135	26.7
Credit card-online check (telephone line) and sign	95	38.0
Credit card online check but no sign	110	32.7
Credit card-batched or high speed line and no sign	175	20.7
Validated for free parking	300	12.0
Flat Rate Transaction (gated)	180	20.0
LPI if front plate	100	36.0
LPI if rear plate only	80	45.0
LPR	120	30.0
Insertion Ticket for POF Validation	360	10.0
POF Central Pay to Cashier		
Cash to POF cashier – Variable Rate	175	20.7
Credit card-online check (telephone line) and sign	115	32.7
Credit card-online check but no sign	135	26.7
Credit card-batched or high speed line and no sign	245	14.7
Validated for free parking	600	6.0
POF Central Pay to Machine		
Cash to APS-Variable Rate	75	48.0
Credit card – online check (telephone line) and sign	NA	NA
Credit card – online check but no sign	66	54.5
Credit card – batched or high speed line and no sign	100	36.0
Validated for free parking	240	15.0

SPACE DETECTION AND AVAILABILITY

In addition to the revenue and access control equipment, the City should consider the addition of space detection systems to provide real-time availability to garage users. There are several types of communication methods for in-garage space detection, including lights above spaces indicating open (green) or full (red) spaces. There are also floor-by-floor space counting systems that provide a space count at the entrance to each floor. These types of systems could prove especially helpful with peak demands from commuters. When tied to a smartphone application or web-based detection system, the space detection system can help motorists find available spaces and make smarter decisions about where to park. More discussion on this type of system is provided in the wayfinding section of this document.

RECOMMENDATIONS AND PROGRESSION OF THE CITY PARCS

More than likely, the PARCS that is implemented on day one will evolve over time to a more robust and seamless system as technology improves and the need for enhanced management is realized. In general, the City should design the system for the future system needs and use incremental advancements to improve the system. Generally, this is the anticipated phasing of such a system:

1. At the Iliff Garage, the City should use gateless access, pay-on-foot stations, and mobile mounted LPR enforcement to validate payment for vehicles. Payment could include transient, permit, or E-470 toll (once the interaction with that technology is facilitated with tolling administration).
2. At the Hotel/Conference Center Garage implement an automated payment system that uses ticket spitters, pay-on-foot stations, RFID readers for permitted and credential entry, and ticket readers at the exit stations to accept validated tickets. The RFID readers should be configured to accept E-470 toll tag payment, to simplify payment options for area motorists (once the interaction with that technology is facilitated with tolling administration).
3. Evaluate new technologies as the Parking and Mobility Program evolves and the parking technology industry continues to advance. Future configurations could include:
   a. Introduce an LPR system, in conjunction with virtual permitting, pay-on-foot, and a toll-based entry configuration. The initial LPR will need to have gate control to allow for proper recognition of plates by the LPR system.
   b. As the speed and accuracy of LPR increases, the City can remove entry gates and have a more streamlined free-flow entry exit with LPR validation.

On-Street

Revenue control equipment for on-street management typically includes parking meters, either of the single- or multi-space variety. Advances in the past 10 years have moved the parking meter from a coin-operated, battery-powered solution to a credit/debit card-readable, solar-powered solution. Further advancing that field, the introduction of pay-by-phone and smartphone application platforms is allowing the motorist to pay in a variety of ways. Many communities are now reversing their plans of implementing hundreds or thousands of parking meters, and instead using a mixture of mobile payment platforms with a limited number of meters accepting cash and coin. This concept, known as "asset light," is reducing capital expenditures and ongoing maintenance costs, while still providing the same level of customer service as a meter-heavy system. Many programs also implement parking space sensors for data collection and vehicle detection (either for management or enforcement needs). However, sensors can be very costly and should be evaluated for a wide variety of needs, rather than for a single purpose.

There are a number of types of on-street meter technologies the City should consider, including the types found in the table on the following page.

Asset Light Concepts

The District of Columbia has been pioneering the concept of "Asset Light" which aims to manage parking without the full-scale implementation of parking meters, as most communities have been following in recent years. Under this concept, the District is promoting the use of pay-by-phone by minimizing the actual number of meters or kiosks and making the phone-based payment option the easiest for patrons. In their pilot areas, District parking management removed meters from most blocks, leaving them spaced every three to four blocks. Patrons who wanted to use a meter could walk to the meter and pay, but signs and marketing encourage patrons to pay through mobile-based payments, which has the benefit of reducing capital and operating costs for the management entity.

			General Cost
Single Space Meters			
	Today's single space meters are capable of accepting coin, credit, debit, and smart card payments. Most variations have solar-powered panels to extend battery life. Each space will need to have a meter head, whether on its own pole or mounted on a dual-head pole.	Pros » Simple to install » Easy to use/comprehend » Data stream for all metered spaces Cons » Meter required for every space » Higher up-front cost » Higher ongoing maintenance needs » More collection for coin » Reactive enforcement	$
Pay and Display			
	Pay and display uses a multi-space parking kiosk as the point of transaction for the user, with a printed receipt serving as the in-car validation. The user must walk back to the car and display the receipt on the dash or window. Typically, kiosks are placed one to a block, serving between 10 and 20 spaces, depending upon configuration.	Pros » Provides receipt » Simple operation » Less clutter » Time is "portable" » More parking in the same space » Proactive maintenance and enforcement Cons » Requires "walk-back" » Requires visual enforcement » Cannot add time remotely	$$
Pay-by-Space			
	Pay-by-space uses a multi-space parking kiosk as the point of transaction for the user, with the space number serving as the transaction credential. The user inputs the space number at the kiosks and is not required to display a receipt. Typically, kiosks are placed one to a block, serving between 10 and 20 spaces, depending upon configuration.	Pros » Can provide receipt » Proactive maintenance and enforcement » Payment anywhere in the system Cons » Harder to operate (Forgotten space # or mistyped space #) » Space signs create clutter » Numbering systems can get complex	$$

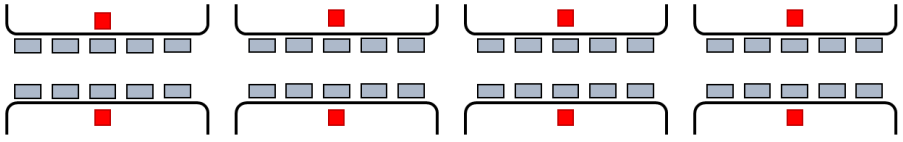
			General Cost
Pay-by-License-Plate			
	Pay-by-license-plate uses a multi-space parking kiosk as the point of transaction, with the user's license plate serving as the transaction credential. The user inputs their license plate number at the kiosk and is not required to display a receipt. Typically, kiosks are placed one to a block, serving between 10 and 20 spaces, depending upon configuration.	Pros » No need for numbered spaces » Portability (within zone) » Creates a more streamlined enforcement environment » Pay at any location within a zone Cons » Hard to remember your license plate » Requires license plate recognition software for effectiveness » Some margin for error in reading plates » Not effective where snow or dirt build-up can block license plates	$$
Pay-by-Phone			
	Pay-by-phone platforms, including call, text, and application-based payments, are becoming more prevalent in the industry. In many cases they are provided as another alternative to payment at the meter, with minimal to moderate usage. In other cases, they are used with aging technology to provide credit/debit payment choices. In these cases, the use is much higher. The user typically has to create an account and tie the transaction to a license plate number.	Pros » Easy payment method » Warning texts for time expiration » No need to go to the centralized meter » Receipts and transactions stored online » Proactive enforcement Cons » Not everyone has a cell phone » Requires numbered spaces or zones » Requires account setup, with credit card	$
Prepayment Options			
 E470	Many communities provide opportunities for pre-payment, either through smart cards or in-car metering devices. The user goes online or to the physical parking office and preloads payment onto the device, which then allows them to park in on-street spaces with the prepaid device. These are fairly common for repeat users, but do not provide a benefit to casual users.	Pros » Easy payment method » Improved security of transactions » Reduced vandalism » Up-front payment for parking » Pay-as-you-go parking » Allows for branding and marketing Cons » Lost card is lost money » Requires advance purchase » Requires large user base for economic feasibility » High implementation cost » Limited success after credit/debit payments	$$

The City is in a unique position where they can dictate how technology is implemented on-street, rather than trying to adjust or update outdated technology that has been in place for a number of years. Additionally, the motoring public in Aurora has not been trained on any specific type of payment technology, leaving a blank slate for the City to educate the users on a system that is efficient but also economically feasible. The City should follow the lead of the District of Columbia and focus on an asset light approach to providing technology. Recent studies of that program have shown that an emphasis on the use of pay-by-phone applications over an intensive parking meter platform can provide capital and operating cost reductions of approximately 30 to 60 percent over credit card and coin payments. The reduction in parking meters tends to drive motorists to utilize the pay-by-phone platform. In DC, the practice of removing meters has led a shift of pay-by-cell usage from approximately 5 percent to over 50 percent in a span of four years. Most communities who implement both pay-by-phone and metered parking only see a peak usage of 10 to 15 percent.

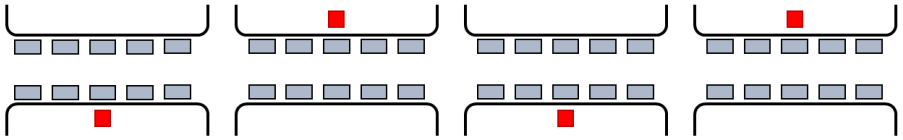
The asset light approach would likely include the following components:

1. Introduction of a pay-by-phone platform, including smartphone and web-based payment ability. This payment platform should be available throughout the community, including both on-street and off-street parking assets. The consistency amongst the program will help with quicker integration into the program.
2. For on-street parking, the City should invest in multi-space kiosks to be placed every two to three blocks, alternating sides of the street where appropriate. In locations where all pedestrian traffic will likely funnel to the same location (like a light rail station), the City could even concentrate payment kiosks close to the transit station, allowing patrons to move toward their destination.
3. Payment kiosks should be pay-by-license plate, removing the need for a walk-back (pay-and-display) or space numbering for all spaces. In combination with the pay-by-phone system and LPR based enforcement, this system should provide the City with the most efficient approach to payment and management.

This asset light approach will provide costs savings initially and into the future, considering the lessened need for expensive metering technology and ongoing collections and maintenance costs. The graphics below depict the configuration and the potential cost savings.



Traditional Configuration:
8 kiosks at $10,000 per kiosk
Total capital cost: $80,000



Asset Lite Configuration:
4 kiosks at $10,000 per kiosk
Total capital cost: $40,000

PARKING SPACE DETECTION (SENSORS) AND MONITORING

The use of parking space detection devices is a rather new technology that provides enhanced management and operations capabilities. These devices allow the parking operator, through wireless communications, to know when a vehicle is parked in an on□street space. smartphonesmartphone

While these sensors provide a very advanced metric for data, they are often inaccurate and costly, which has prevented their widespread adoption throughout the industry. The City should consider other on-street data collection metrics until such time that pavement sensors are less costly or more accurate. In the interim, the City could consider these types of data collection metrics, which help with program benchmarking (as described in the Business Plan):

- **Manual Data Collection –** outsourced staff can be used to count parking space utilization and other parking behavioral characteristics like duration and turnover. This data can be used to help define and test policy related to parking management, pricing, and enforcement.
- **License Plate Recognition Data Collection –** the LPR equipment used for parking enforcement can also be used to collect parking utilization and duration information, usually with less staffing needs and quicker turnaround.
- **Transaction Reports –** on-street and off-street revenue control equipment will provide back end reporting capabilities, including transaction, revenue, and operational reports. These metrics can be used to track changes to the system over time and provide valuable insights into how policy changes are impacting parking behavior.
- **Public Feedback –** ongoing public outreach will provide a good channel to learn about the perception and performance of the program through the lens of the patron. As part of the marketing and education component of the program, the Parking and Mobility Manager should collect and use this data to help inform ongoing policy decisions and changes.

ENFORCEMENT

Enforcement practices are typically managed with a handheld device capable of connecting license plate information to a central database, digitally storing ticket information and accelerating the ticket processing process. These handheld computers have replaced the manual ticket writing process in most programs across the country. In recent years, the use of specialized handheld computers has been replaced by the use of smartphones, which can provide the same functionality at a fraction of the cost. The primary need is a wireless connection that can link data from the smartphone or handheld device back to the central database, as well as ticket printing capabilities so the parking ambassadors (PAs) can issue citations.

Some advanced programs are also using LPR equipment, typically vehicle-mounted, to speed up the observation process, allowing less staff power to cover a larger coverage area. The LPR data is linked to the centralized database and can be used in the same manner as a handheld, only much more automated. In many campus settings, the LPR is used to replace physical permitting, with a virtual permit tied to the license plate and the LPR reader used to verify that the vehicle has accessed the appropriate facility. In addition to these technologies, the sensors mentioned in the on-street description above can be used for targeted enforcement, allowing management to identify violations from a back-end system and point enforcement staff towards the vehicles in violation. This practice should only be considered in areas of

extreme violation, as the practice of heavy handed enforcement is not consistent with the community-focused and customer-friendly components of Aurora's Parking and Mobility Program.

	General Cost
Manual Ticket Writing	
The days of manual ticket writing are quickly fading away, but there are still some departments that use the manual hand-written ticket that is later keyed manually into a back-end system. This system is simple in the field but requires a great deal of management and oversight on the back end to ensure that all tickets are coded appropriately.	$
Handheld Ticket Device	
The next evolution in the ticket writing device was an electronic handheld device that could remotely tie back into the back-end management system, allowing for a review of license plate information and previous infractions. This device also allowed for more seamless ticket writing and could print digital tickets with a secondary device that communicates with the handheld. Many communities use these handhelds in conjunction with police handheld devices that are used for citation issuance.	$$
Smartphone-Based Enforcement	
In more recent years, parking departments have turned to smartphone applications which can perform the same functionality of the handheld device, at a fraction of the cost. Many programs are now using smartphones or tablets as their primary in-the-field device, with the ability to connect to the back-end system as well as print tickets.	$$
License Plate Recognition (LPR) Enforcement	
The use of LPR vehicles to collect license plate information and write parking citations reduced the overall staff power needed to enforce parking assets and can provide a more streamlined enforcement operation. The vehicles can be used for scofflaw enforcement, as well as collection of license plate information to review overtime regulations. Additionally, many communities are beginning to use the LPR for data collection purposes, which provides a secondary benefit for investment in the system.	$$$

Given the advancements in the industry, the City should implement the simplest solution available, which is likely the use of smartphones as the primary handheld enforcement device. This approach will likely prove more cost-effective and can be tied into a back-end management system along with revenue information and payment credentials from both meters and PARCS equipment. The City should also invest in LPR enforcement vehicles because it will streamline the enforcement process and pair nicely with off-street LPR-based payment and on-street license plate credentialing at kiosks.

WAYFINDING

The previously described technology components were directly related to the management of spaces and assets within the community parking system. This element, wayfinding and communications, is meant to be a customer-focused asset, providing information about the system to the end user to help them make a more informed decision about where to park and how to get there. The wayfinding and communications element can be as simple as the introduction of static parking information on a system website, or as complex as the introduction of parking guidance systems that provide electronic navigation to available spaces. The typical components of a system like this are the system website, smartphone applications that provide static system

information or real-time availability, social media components that provide program and policy updates, or the dynamic signage that can provide space information. The primary technology needed to fuel this type of system is space and availability data. For static information, the program will only need periodic updates of inventory and use information. For real-time space availability, the system will need data counting systems, including sensors or vehicle detection loops.

Wayfinding technology for parking is used to direct drivers to available parking areas. The purpose of using wayfinding is to reduce vehicle miles traveled and congestion by limiting the amount of time it takes for drivers to find available parking. Wayfinding can be static or dynamic. Static wayfinding signs are positioned to direct drivers to parking areas, but do not provide further information, such as availability. Dynamic wayfinding signage uses electric messages to provide real-time parking availability as well as the location of parking. In areas with special events, the dynamic wayfinding signs are flexible and can accommodate changes in parking rates and times on event days.

Off-street parking can utilize both static and dynamic wayfinding systems. Theses signage systems prove beneficial to off-street parking locations because they are confined to single locations with large parking capacities. Additionally, it is easier to use parking space detection sensors in off-street garages and lots to monitor availability in real-time. These sensors can relay the availability information to the dynamic wayfinding system to show real-time availability for that garage or lot.

Using wayfinding technology for on-street parking is more challenging. On-street parking spaces are spread out, making it difficult to direct drivers to specific locations. The signage required to direct motorists to available parking would number in the hundreds or thousands and would create a cluttered look in the community. At this point, there are no known communities that have used dynamic wayfinding signage to provide navigation to on-street parking. The closest possible alternative is the use of Global Positioning System (GPS) or smartphone applications to direct drivers on an individual basis. However, the use of on-street parking space detection sensors has yet to be thoroughly tested or proven to be effective and cost efficient.

The City should strive to implement some type of wayfinding system, even if it is just a mixture of static signage and online information. At the minimum, the City should initiate a website (e.g. ParkAurora.gov or Aurora.gov/Parking) and provide information about how to use the system, location of public parking facilities, rate and payment information, and program information. As the website evolves, the website could introduce functions for citation payment and management, permit payment and management, advanced reservations, and real-time parking availability.

In terms of wayfinding for motorists, the City should work with vendors or software developers toward the development of a smartphone application that provides static and real-time parking information to motorists. As PARCS, meter, and space detection data is accumulated, the City should make that data available for open-source application development. This open-source approach provides a cost-effective market for the development of multiple applications and the potential for advanced applications that link transportation, transit, and parking data.

BACK-END MANAGEMENT SYSTEM

All of the above systems will need to be tied to a back-end management system. This back-end management system will provide real-time reporting about the functionality of the system, including operations, maintenance issues, revenue tracking, and citation management. In an ideal situation, all of these systems would tie into one back-end management system for easy parking system observation and evaluation. However, in today's industry, there are not many solutions that integrate seamlessly into one back-end management system. There are providers who have nearly all of the components highlighted above, but none of the components is considered "best in class." Those providers who have best in class systems for each of the respective components above, typically have their own back-end management system that does not integrate well with other components. There are data aggregators who will pull data from each system and provide you a back-end management system that includes all components, but they can be more costly than implementing multiple systems, and there may be some loss of functionality with each system's translation into the centrally aggregated system. Additionally, the implemented platform would ideally integrate with the City's other data and program management systems.

The City of Aurora and its new Parking and Mobility Manager, in coordination with the Information Technology department, will need to make decisions about the applicability of a completely automated and integrated system as the program evolves. The introduction of technologies sporadically could complicate the introduction of a fully-integrated system. However, the City should consider the use of a centralized data aggregator to manage all streams of data, which should help the City make more informed decisions as it relates to the evolution of the program and the implementation of parking management strategies. This data aggregator should provide a project manager who is embedded in the City offices and functions as a City staff member in close coordination with the Parking and Mobility Manager.

In general, there are two approaches to the development of a back-end management system for use by the Parking and Mobility Program. The first approach would use a platform that integrates specific equipment into a back-end system that works as one platform. This approach would use one vendor who could provide on-street, off-street, enforcement, and counting equipment that is part of the package along with the integrated back-end. This approach would provide a highly developed back-end platform, but might not provide the highest and best pieces of individual equipment for use in the various parking facilities within the system.

The second approach focuses on purchasing best in class parking equipment, independent of whether it can be integrated into one back-end platform. Then after purchasing the equipment, the City would hire a data management firm to build a back-end management platform that aggregated data from each individual system into a usable back-end platform. This approach would use a vendor who does not own any particular type of equipment, but rather uses the reporting outputs from each of the individual back-end systems to create a usable platform for the City's Parking and Mobility Manager. In this scenario, customized reports and dashboards could be created to serve the needs of the City as it manages the community's parking assets.

Both of these approaches are feasible from an initial implementation standpoint, and the management, operation, and development of the back-end system could be outsourced as part of the outsourced vendor management contracts. The primary decision the City will need to make is whether it would prefer a best in

class back-end platform with corresponding technologies, or best in class parking equipment with a customized back-end platform. The table below includes some factors to consider as the City makes this decision.

Factor	Best In Class Back-End System	Best in Class Parking Equipment
Cost	May have lower licensing costs and do not require costly interfaces. Are usually less expensive and, provides easier access to shared data. The potential exists for both containing costs and earning additional revenue through better decision-making.	Specialized features create a competitive advantage that may serve to cut costs or increase revenue. Cost justification may be needed to show advanced features compensate for higher up-front and ongoing costs.
Leverage	When adding new modules, you have less clout in negotiating price and terms.	The prospect of replacing customized systems is daunting versus replacing off-the-shelf systems.
Human Resources	Shortage of IT people who can integrate and maintain disparate systems is an advantage. They become specialized subject matter experts, fully versed on the nuances of how software and hardware interact.	IT staff must be trained to use and support multiple systems with potentially different hardware platforms, operating systems, databases, and programming languages.
Support	Easier to coordinate with one vendor rather than multiple companies.	Hardware vendor blaming software vendor and vice versa is magnified.
Data Sharing	Systems may have been pieced together through acquisitions and may not be easy to interface.	Easier and faster to access shared data and should be able to interface with other identified systems.
Functionality	Integration appears seamless.	Richer functionality. More likely to provide regular enhancements. Web-enabled and technologically advanced systems take longer to re-write a suite of applications because there could be multiple developers, software languages, and platforms on which different technologies are built.