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Designing an integrated smart parking application

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Abstract

The past decade has witnessed a renewed interest in city living. Associated with this trend are parking problems in city centers and central business districts. Using the City of Pittsburgh as a case study, our study identifies a critical parking issue and how best it could be ameliorated. The study reveals that a demand-side intervention; providing real-time and predictive information to parking users, provides the most robust option in addressing the lack of parking availability in downtown Pittsburgh. Towards this end, we design a schema for an integrated smart parking application project and discuss how its functionalities could be enhanced as well as how it could be replicated in other cities. The development of the schema also includes a robust needs assessment and a user centric design process. The use of an open source platform, modular structure and ease of retrofitting can enable other cities to lower the cost of implementing and managing similar smart parking solutions.

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Keywords: Integrated smart parking; Needs Assessment; Environmental scan; User centered design; Schema

1. Introduction and background context

We document the process employed for a needs assessment of the parking situation within the City of Pittsburgh, and the design of an intervention to remedy the observed deficit in performance. The methodology utilizes two key approaches; a stakeholders' analysis and an environmental scan where the phrase "environmental scan" is used as a component of a strategy development process. The environmental scan was conducted not only in a static sense but by also projecting into the near future assuming the status quo continues.

The information gained from these approaches was subsequently used to identify the feasible options in a menu of product designs to best address the shortcomings identified. This approach situates the information obtained from the stakeholders in a comprehensive context by identifying structural constraints that limit systems' performance, synergistic opportunities within the system that could be explored, and key levers that could be utilized during the

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product design and implementation phases. Issues addressed include an examination of the forms by which the identified shortcomings in systems performance could be addressed and questioning the initial set of assumptions made by the product development team.

We demonstrate the approach using as a case study the parking situation in the City of Pittsburgh. Pittsburgh, a city of 310,000 residents, is a mid-sized American city in southwestern Pennsylvania. Ownership and management of City parking facilities is carried out by both the public and the private sectors with a significant portion of these facilities located in the downtown area. However, other neighbourhoods within the City of Pittsburgh such as The Strip District, Oakland, Shadyside, East Liberty, Lawrenceville, Bloomfield and the South Side also have a substantial parking capacity. This is due to appreciable commercial presence and/or the location of major institutions in these neighbourhoods. This is the case for Bloomfield with the presence of West Penn Allegheny Health Systems and Oakland, given the location of the University of Pittsburgh Medical Centre (UPMC), the University of Pittsburgh and Carnegie Mellon University.

The challenges of finding a parking space is however most acute in the city's downtown area. Nicknamed the Golden Triangle, Pittsburgh's downtown is a geographical area of approximately 0.5 square miles area with a workforce strength of approximately 130,000, representing 32% of the City of Pittsburgh's working population (Pittsurgh Downtown Partnership, 2012). It is bounded by Grant Street and both the Allegheny and Monongahela Rivers with the rivers acting as natural boundaries that limit the area within the triangle. Apart from the geographical limitations, policy measures put in place during the 1990s that were motivated in part by the Pittsburgh Downtown Plan (Strada, 2009) have reduced the supply of available parking spaces over the last two decades. This is largely a result of the modified zoning ordinances that relaxed the minimum parking requirements for prospective properties. In addition, current and proposed developments that include the repurposing of existing facilities and the movement of corporate entities are anticipated to further reduce the total available number of parking spaces (University of Pittsburgh, 2010).

These developments, and the need to avoid a situation where parking becomes a binding constraint to the economic vitality and growth of the downtown area prompted key stakeholders to seek solutions to these parking problems. Addressing this challenge demands a robust approach that can establish the nature of the problem, design and implement a program intervention to remedy the situation and provide an assessment of the degree to which the problem has been ameliorated. The needs assessment speaks to the first of these requirements. Our approach to the needs assessment involves a gap analysis where the difference between the desired state and the present state determines the need or the perceived shortcoming in systems performance.

The paper is divided into five sections. Section Two documents the study approach. Using a combination of data elements, document review and stakeholders' interviews, Section Three paints a rich picture of the parking and transportation ecosystem within the City of Pittsburgh. The proposed strategy is discussed in Section Tour while the product design is detailed in Section Five. Section Six concludes.

2. Study approach

In order to have a robust framework, we employ a socio-technical system approach to the design of the integrated smart parking application project. A socio-technical system approach is an engineering system made up of both a physical domain where the technical system resides and an institutional sphere that defines the context within which the physical domain is implemented (Baxter & Sommerville, 2011). In addition, we have also emphasized a user centric design; a design process in which user requirements are considered from the conceptualization stage and included throughout the product development cycle (Preece, Rogers, & Sharp, 2002). Stakeholders and end-users' input are obtained and reflected in the design process through a series of interactive methods. This process creates a platform on which stakeholders could reflect on the key issues, table their concerns and discuss their expectations of the project with the product development team. These expectations are examined for feasibility and if possible, are reflected in subsequent designs of the socio-technical system.

The International Standards Organization (ISO) Human Centered Design for Interactive Systems (International Standards Organisation, 2010) specifies the principles of a user centered design approach that include among others the understanding of the users' needs and the environment in which the design will be implemented. Cognizant of this requirement, we have placed the users squarely at the core of both the design process and project implementation. A key advantage of the user-centric design is that a more thorough understanding of the non-technical factors affecting the use of the technology to be deployed emerges by involving stakeholders and users. This ensures that the product is effective – in terms of addressing the deficit it is intended to correct, and efficient – in terms of usability issues. In addition to fostering a sense of ownership, making stakeholders and end users an integral part of the process allows for better management of their expectations. Figure 1 provides a diagrammatic explanation of the process.

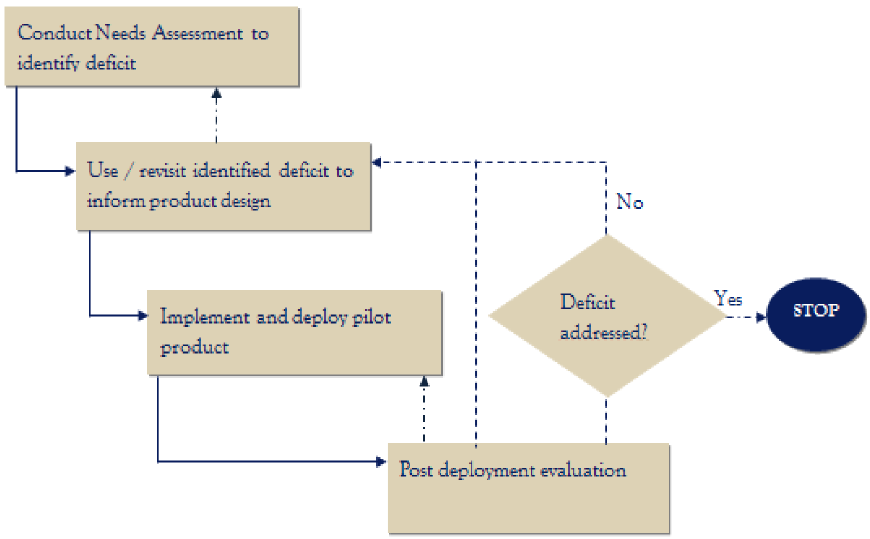


Fig. 1. Overview of the methodological framework

Figure 1 presents an overview of the methodological framework. It is made up of four stages of a broadly conceived product development life cycle that includes identifying and specifying the nature and magnitude of the deficit in system performance; the (re) design of the system to be implemented; the implementation of the design, and post deployment evaluation (Fabusuyi & Hampshire, 2013). Stages 1 (Needs Assessment) and 2 (product design) are the focus of the present research effort and entail the identification of key stakeholders and obtaining input from them with regards the parking situation, including limitations within the City of Pittsburgh. This information is subsequently used to specify the nature and magnitude of the existing deficits. In stage 2, the profile of the deficit constructed is passed to the product development team whose objective is to reflect this insight in the product's design. Typically, this process is a two-way street in that various iterations of the design, for example, paper prototypes or a simulated, non-operational software prototypes, are shared with the stakeholders and the back and forth process ceases only when stakeholders feel sufficiently comfortable with the design. On the part of the design team, this process fosters a deeper understanding of the intended use of the application.

Stages 1 and 2 are achieved by conducting a series of interviews with stakeholders to obtain their input as regards the present state of the parking situation and their expectations of the integrated parking application project. The feasibility of these expectations is examined by carrying out an environmental scan that consists of both a supply and demand side analysis. On the supply side, we conduct an inventory of parking facilities and examine parking-related initiatives that are currently either active, in the planning stage or presently being mainstreamed. On the demand side, we employ workforce commuting patterns to ascertain the nature of parking demand in the present and in the future using multiple datasets.

3. Data collection and analysis

Our data analysis is conducted using a mixed-methods approach that integrates both qualitative and quantitative data. The blend of these data types guarantees a platform robust enough to capture the complexity of the system being studied. The ill-structured component of the system is addressed using an interactive, qualitative type data while the more structured component that is more amenable to analytical methods is carried out using quantitative data. Summary results including data collection methods are provided in the following subsections.

3.1. Stakeholder analysis using qualitative data

We conducted semi-structured, one-on-one interviews with a select number of stakeholders with significant interest in the city's parking. Stakeholders were identified based on their roles and legitimacy, the resources they control or the responsibilities they have and the relationship they have within the parking community or greater transportation ecosystem using the Venn diagram in Figure 2. The diagram was adapted from a similar approach from a study commissioned by the German Agency for Technical Cooperation (GTZ) (Zimmermann & Maennling, 2007). We extended invitations to organizations that have relevance in at least two of the areas identified in the Venn diagram. In all, ten organizations were invited to participate. Eight confirmed their interest; however due to scheduling difficulties interviews were only conducted for seven of these organizations. Questions addressed during the interviews include the perceptions and concerns with regards the city parking situation; perceptions of the role of technology in finding parking spaces; legacies to be taken into consideration; the use of zoning ordinances; initiatives in the pipeline within the Pittsburgh transportation ecosystem and their expectations for the project.

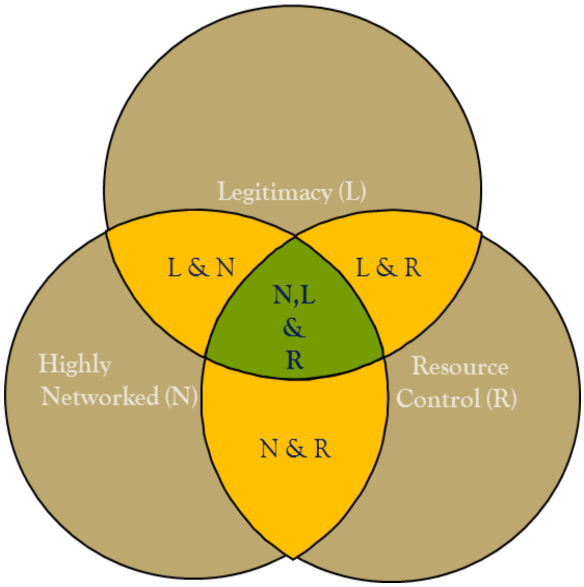


Fig 2. Venn diagram of stakeholders' influence

From the semi-structured interviews conducted we were able to obtain key insights as to the state of parking within Pittsburgh. We found that the problem is less an absolute shortage of parking spaces but more of a limited parking availability in close proximity to individuals' destinations. Secondly, in talking to the stakeholders, we heard numerous complaints about little turnover in parking spaces – a situation attributed to employees parking in prime parking spots. In addition, the need to emphasize off-street parking became clear, particulary in the downtown area given that only 3% of all available parking is on-street. Finally, we saw the need to focus on commuters given the consistency with which the viewpoint kept resurfacing throughout the semi-structured interview sessions.

3.2. Environmental scan

Given these insights, we complemented the interview sessions with a broader environmental scan that provided more information on the factors that influence the parking market. The approach to the environmental scan was a holistic one that included both supply and demand factors. The supply side issues addressed parking or transportation-related initiatives that are active, in the planning stage or presently being mainstreamed. Demand side analysis focused on commuting patterns to ascertain the nature of parking demand. We carried out the demand side analysis by triangulating data using multiple data sources including the US Census PUMS data on commuting pattern (United States Census Bureau, 2015), the Local Employment and Household Dynamics (LEHD) and the Quarterly Workforce Indicators (QWI) (United States Census Bureau Center for Economic Studies, 2015).

3.2.1. Supply side issues

As previously mentioned, within the City of Pittsburgh, the management of parking facilities is carried out by both the public and the private sectors. The biggest players within this space are the Pittsburgh Parking Authority (PPA), which is publicly owned and ALCO Parking, which is a private sector parking entity. Parking assets are categorized as off-street, metered parking lots that employ both single and multi-space meter technologies and on-street metered spaces. The off-street category includes both garages and non-metered surface parking lots. Table 1 provides estimates of the parking inventory.

Table 1. Inventory of Parking Assets

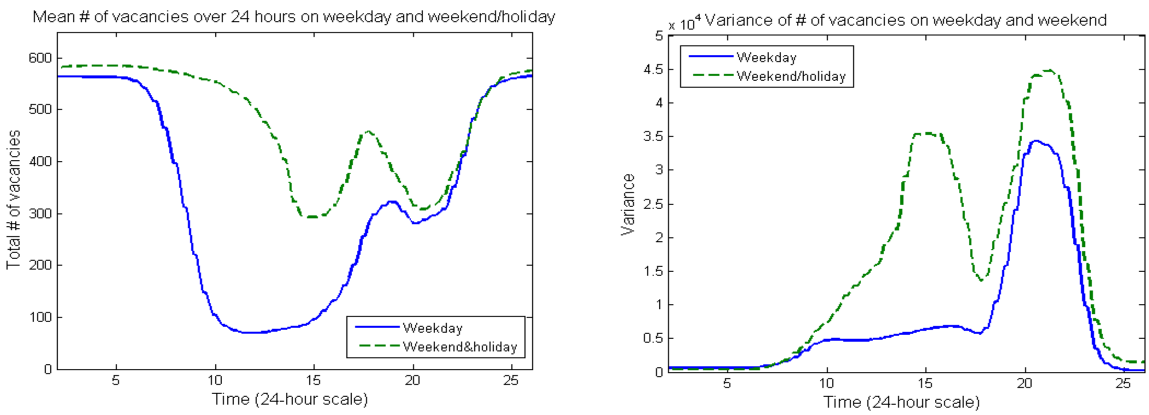
Parking Facilities	Downtown Area		Other Neighborhoods	
	Magnitude	%	Magnitude	%
Off-Street				
Garages	21,495	78%	12,013	47%
Lots	5,321	19%	7,457	29%
On-Street				
Single & Multi-metered	674	3%	6,263	24%
Total	27,490	100	25,733	100

From Table 1, the total number of parking spots is 53,223. In conducting the inventory, we have excluded parking facilities dedicated primarily for retail purposes or those with restricted access – for example, garages and lots meant solely for permit holders. For those with public access, an appreciable churn in the supply exists given the spate of recent developments in the City. A report commissioned by the Urban Redevelopment Association (URA) estimates that 646 parking spaces from surface lots will be eliminated in East Liberty (East Liberty Development Inc., 2013). In the same vein, the downtown area is expected to witness a reduction in parking supply from new construction and the repurposing of existing parking facilities. As only 3% of the parking spaces in the downtown area are on-street, any meaningful strategy needs to focus on off-street parking facilities.

3.2.2. Demand side issues

Our approach to the demand side analysis centres primarily on the commuting patterns of the workforce population. Figures from the US Census Longitudinal Employer-Household Dynamics (LEHD) (United States Census Bureau Center for Economic Studies, 2015) shows that of the approximately 280,000 individuals who worked in the city in 2015, 210,000 commuted into the city. Apart from this segment, there are 55,000 city residents who work outside the city. This translates to a daytime population of 463,000 on any workday. This net gain of 155,000 is the result of workers commuting to the city and is equivalent to a more than 50% increase in the city's overall population.

Figure 3, obtained from a representative parking garage over a 600-day period, illustrates parking demand using the average available parking spaces for weekdays and weekend-holidays and their corresponding variances (Hampshire, Fabusuyi, Hill, & Sasanuma, 2011). The huge drop in the number of available spaces observed between 10 am and 3 pm on weekdays is work-related given that the number of spaces is relatively stable with low variance. In contrast, we consider the drops around 3 pm and close to 8 pm on weekends to be event-driven because the number of parking spaces fluctuates greatly (i.e. high variance) depending on event occurrences. This realization further underscores the need to focus on commuters.



Figs 3(a) and (b): Mean and variance of the number of vacancies on weekdays, weekends and holidays.

To estimate parking needs, we need information on the means of transportation and vehicle occupancy for commuters, both city and non-city residents. Using the US Census Public Use Micro-data Sample dataset (United States Census Bureau, 2015), we generated population estimates of commuters' transportation modes and their associated margins of error at the 90% confidence interval level. We calculate the estimates based on the 2015 US Census Public Use Micro-data Sample (PUMS) population records. In calculating the estimates, we employed two types of weights: person weight and replicate weights. The person weight is required for the point estimates and both person weight and the replicate weights are needed to calculate the standard errors.

We employed the Fay's variant of the Balanced Repeated Replication (BRR) method in calculating the standard errors (Fay, 1995). Fay's approach, called the Modified Half Sample (MHS) improves on the BRR by addressing the problem of perturbed weights and decreased sample size using an adjustment factor called the Fay coefficient that was set to 0.5 for the PUMS data. We implement the procedure that generated the point estimates and the associated margins of error using Stata econometric software with the point estimates and margins of error figures presented in Table 2. Of the total number of employees who live in Pittsburgh, 86,700 commute to work either by car, truck or van, a figure equivalent to 60% of all city resident workers. A much higher proportionate figure (85%) was obtained for Allegheny County, excluding the City of Pittsburgh. The analysis was restricted to Allegheny County given that approximately 90% of commuters reside less than 25 miles from their place of work.

Table 2. 2015 Means of Transportation to Work relative to place of abode ('000)

	City of Pittsburgh		Allegheny County (Excluding the City of Pittsburgh)	
Means of Transportation	Population Estimates	90% Confidence Interval	Population Estimates	90% Confidence Interval
Car, Truck or Van	86.7	86.7 ± 2.46	397	397 ± 4.09
Drive Solo	75.0	75.0 ± 2.21	359	359 ± 4.07
2 person Carpool	10.2	10.2 ± 1.06	32.6	32.6 ± 1.71
3 or more	1.60	1.60 ± 0.33	5.16	5.16 ± 0.71
Public transit system	26.1	26.1 ± 1.37	27.1	27.1 ± 1.42
Walked/ worked at home	31.1	31.1 ± 2.18	39.0	39.0 ± 2.45

Using the figures from Table 2, we estimate that the demand for parking spaces by workers in the City of Pittsburgh on any working day is 208,000. We obtain this figure by applying the proportionate breakdown of the forms of transportation and vehicle occupancy to the relevant cohort – workers who reside in Pittsburgh and those who reside outside Pittsburgh. The equivalent number of vehicles was obtained by dividing the number of vehicles by the occupancy number while taking a conservative view by assuming that maximum occupancy for any vehicle is three.

In a dynamic sense, compared to 2015 parking demand levels, our analysis revealed a projected estimate of 20,000 increased demand for parking spaces across the city over the next six years. Given the trend in the city's workforce composition, this increase will come primarily from commuters who are not resident in the city. A 5% reduction in the absolute number of individuals who drive unaccompanied would translate to a reduction in parking demand of more than 4,800 spaces. We would however like to mention that these reductions are optimistic. The mayor's office has made it a priority to encourage car-pooling and higher public transit ridership. However, an earlier report on a multicity analysis (Fabusuyi & Hampshire, 2013) shows that commuters are reluctant to car-pool but they are more amenable to using the public transit system. And here lies the conundrum – the only option that could be effective in achieving this witnessed a series of reductions in services in the past five years.

From the supply and demand for parking estimates, there is a deficit in the supply for parking spaces relative to the demand. We caution however against drawing any conclusions from this given that a true picture of the mismatch is more nuanced compared to what the demand and supply figures reveal. Commuters perceive that there are not enough parking spaces especially in Oakland and the downtown area. However, there seems to be a consensus among the key stakeholders interviewed that while shortages may exist during peak periods, the severity is not as pronounced as the commuting public would have one believe. This is also the position being canvassed by IBM's Smart Cities Challenge Report (IBM, 2013). We also reiterate that the parking supply figure does not include facilities owned by retailers or those meant primarily for retail purposes. Also excluded from the estimated number of parking spaces are non-metered on-street parking spaces and off-street facilities that are only accessible to permit holders or have limited accessibility.

4. Proposed strategy

Findings from the previous section make it obvious that a strategy that is solely supply-driven is not feasible particularly given the input from the stakeholders, the City's fiscal capacity, the present parking market and the projected demand for parking spaces. Given this, we have embraced a demand-side-oriented strategy. Our approach has been to embrace a menu of initiatives that will impact commuters' demand for parking spaces and their commuting behaviors. We have used this to provide recommendations that are divided into two sets – product-specific and policy-related. In framing the strategy, we have taken a broad look at the overall transportation system and have addressed instances where non-parking issues impact on parking availability. In addition, we have taken into consideration synergies that could be exploited across the mobility ecosystem. A summary of the salient findings categorized into two sections is provided below.

4.1. Exploring synergistic opportunities and leveraging existing legacies

The city presently has a parking app, ParkPGH that provides real time parking information primarily in the downtown area (Fabusuyi, Hampshire, & Hill, 2013), (Fabusuyi T. , Hampshire, Hill, & Sasanuma, 2014). In conversations with key stakeholders, we were reminded how effective the parking app has been in addressing some of the parking challenges within the city's central business district (CBD). This was further reinforced from the document review done for the environmental scan section. The IBM Smarter Cities Challenge report, for example, mentioned the value added by the ParkPGH app and provided suggestions on how its functionality could be enhanced. We have taken a cue from these sources and recommended that added functionalities be added to ParkPGH and that this should form the core of the system wide intervention being planned. Current developments within the city also make this more of a reality. An example is the electronic parking meters with the associated pay stations that was recently scaled up citywide. This should make transitioning into a fully-fledged integrated parking application project more feasible.

The design of ParkPGH lends itself to easily reflect these new attributes. The original design is modular in nature. This feature makes provision for product enhancements and ensures that retrofitting could be implemented with relative ease. In addition, the product development team of ParkPGH spent considerable time addressing operational issues across the different platforms used by the garage owners that featured in the application. Some of these issues emanate from the challenge in trying to integrate data across garage operators that use different software and hardware that are often incompatible. The development team was able to achieve a sufficient degree of standardization that guarantees the interoperability of processes and procedures – an attribute that will prove invaluable as added functionalities are added to the application.

More importantly, the insight obtained from the deliberations with stakeholders and the environmental scan revealed that the most effective way by which significant reduction in demand for parking spaces could be achieved is through the provision of predictive parking information. Of all the components of the integrated parking application, the promise of the predictive algorithm has the greatest potential to influence commuters' travel and parking demand patterns. Integrating parking information with traffic flow patterns has true potential if the parking information provided is not only real time but also predictive. It can encourage commuters to change the way they travel or how they schedule their trips. Apart from providing information on the demand side, garage operators could use the predictive information to better manage their facilities. For example, a predicted higher than normal demand for parking spots could allow a garage operator to artificially increase the facility's capacity by making provision for valet parking.

Finally, some of the insight obtained from the environmental scan and the discussions we had with stakeholders revolved around how best to explore synergistic opportunities to improve the effectiveness of the integrated smart parking application. A feasible option is relaying the information provided through ParkPGH on parking availability to the public using variable message signs (VMS). This strategy could be implemented at very low cost but with high impact. Given that more than more than 210,000 non-city residents commute to Pittsburgh on any work day, we could target this population using the major transportation arteries. For example, close to 60,000 commuters use Interstate 376 to get to work while Route 28 and Interstate 279 account for approximately 70,000 of the commuting population on any work day. This provides some insight on potential routes to use in displaying parking availability information.

4.2. Policy related insights

Arguably the most recurrent theme raised by the stakeholders we interviewed centred on individuals that park in high-density areas for extended period. Typically, these are leaseholders; employees who take up prime parking spots and residents with access to desirable parking locations. This is most noticeable in the downtown and Oakland areas. The low vehicle turnover that this behaviour generates has often being blamed as a key disincentive by customers who need parking space for an hour or two. This situation, if not addressed, may imperil economic activities in these business districts. Apart from the negative impact, the persistent perception of not enough parking spaces is also fuelled precisely by this parking behaviour. In our assessment, a carefully designed pricing regime could ameliorate this situation – specifically, one that incentivizes people who park for extended periods of time to use available fringe parking facilities and by so doing, free up choice parking spots in the high-density area for patrons in need of parking for a limited period.

In addition, some existing practices could be modified by sensitizing the public on how socially inefficient they are. For example, as part of being good corporate citizens, institutions and corporations could choose to decouple parking privileges from the contracts they have with upper echelon employees and instead monetize these parking privileges (Shoup & Breinholt, 1997). This frees up employees from using a specific parking facility, a development that removes some of the rigidities in the parking market. Getting rid of a lease contract similar to an "all you can eat" buffet moderates demand for parking spaces.

A key challenge towards promoting effectiveness is addressing the parking problem with the broader transportation ecosystem. A policy that is local to the Port Authority of Allegheny County, the agency with oversight on transit within Allegheny County, has effects on parking, as does an edict that calls for a fixed proportion of parking spaces for real estate developments. In most cases, these policy measures are also executed in silos, leading to sub-optimal outcomes. It is also relevant to point out that some of these ordinances exist in *de jure* sense but in a *de facto* sense, they are not being implemented.

As we recognize that some policy issues that may be relevant to the implementation of the schema go well beyond what could be decided at City Hall, a multi-jurisdictional deliberation may be required. For example, the objective of reduced demand for parking spaces may be achieved through a policy pronouncement that nudges commuters to higher vehicle occupancy with a focus on commuters who do not reside in the city since such a policy will be most effective for this cohort. A case in point is utilizing high occupancy vehicle (HOV) dedicated lanes and tolling of roads while waving the fee for vehicles with 3 or more occupants. This could be complemented by encouraging *slugging*, a commuting practice where impromptu carpooling are formed to gain access to HOV lanes and/or avoid toll cost (Spielberg & Shapiro, 2000).

5. Product design

5.1. Schema

We obtained the schema overleaf through an iterative process between the product development team and key stakeholders. This two-way street interaction is invaluable in that it facilitates the mutual adjustment that matches what is feasible, from the perspective of the product development team, with what is desirable, from the stakeholders' viewpoint and thus, moderates their expectations. The schema is made up of four modules: data gathering module; analytics and decision rules; integration and interface module; and a multichannel information module. Data gathered is processed and converted to usable information using the rules specified in the analytics and decision rules module. The integration and interface module standardizes the information generated and the information is subsequently relayed to the public via the information channels.

A key component of the schema is the parking prediction model. The predictive parking algorithm as presently conceived has two separate components – a long-term predictive module and a short term one. The time element has nothing to do with the length of time the parking is required but rather the time horizon before the parking decision is made. Thus, a 3-day look-ahead would be deemed long term while a short term could be a 2-hour horizon. The model is beneficial for individuals on the demand side and for the organizations that supply parking services. It also provides the most opportunity of exploiting synergies across the interconnected components of the mobility system. For example, integrating parking information with traffic flow patterns has potential if the parking information provided is not only real time but also predictive as this can encourage commuters to change the way they travel or how they schedule their trips.

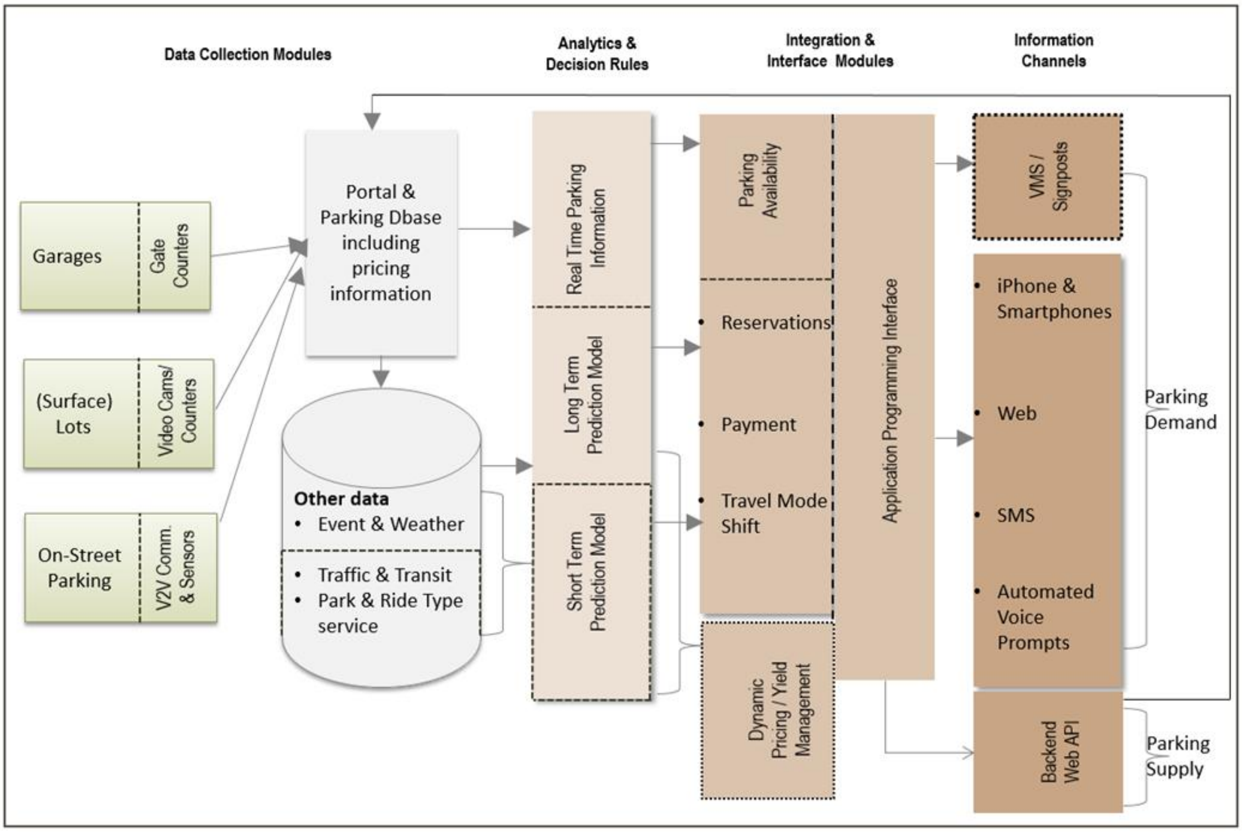


Fig 4. Integrated smart parking application schema

5.2. Extensions and generalizations

As noted above, the yet to be implemented short term predictive module could be used to influence travel behavior or mode shift. Compared to the long term predictive module where the parameter values are the average impact of each explanatory variable (Fabusuyi T. , Hampshire, Hill, & Sasanuma, 2014), the parameter of the explanatory variable of interest will have to be revised given that the significance of recent events may be different compared to historical averages. In doing this, we considered a regression model in vector form with error term e with properties $E(\boldsymbol{e}) = 0$ and $E(\boldsymbol{ee'}) = \boldsymbol{\Delta\sigma^2}$ where Δ represents the Kronecker delta. The parameter estimates are also assumed to be normally distributed around a mean value for each parameter. These simplifications allow us to represent the covariance matrix associated with the error term as a diagonal matrix – i.e. independence is assumed across the error terms and enables us to apply the least squares estimator to obtain best, linear, unbiased estimates. In the subsequent period, parameter estimates are generated by assuming an $AR(1)$ process with a random error term that captures shocks between parameter estimates across the time period. Sequential updates of the parameter estimates are subsequently derived recursively with the estimated available inventory of parking spaces and demand used to set parking rates. The reader will no doubt observe that the stationarity assumption dampens the effect of the shock over time.

The data used for the demand side of the environment scan are available throughout the continental US, guaranteeing that comparative studies could be carried out in other cities with existing studies showing similarities in commuting patterns across cities. For example, an earlier study of commuting patterns across 15 US cities of comparable size to Pittsburgh using the US Census data revealed that Pittsburgh is not an outlier (Fabusuyi & Hampshire, 2017). The multi-city analysis, using the county as the geographical area where most workers are resident, revealed that for the cohort that drives to work, close to 90% drive unaccompanied for all the cities featured in our analysis. When individuals who drive solo are compared relative to the total commuting population, only Newark, NJ and Oakland, CA have percentage figures less than 70%, a testament to the effectiveness of the public transit system in Essex County and the Bay area. The high solo commuting figures underscore the need to put in place a program that has the potential to influence the travel demand choices individuals exercise. In addition, the lessons learned from the integrated parking application, its highly modular nature, the ease of retrofitting, and its open source platform will allow other cities and metropolis to significantly shorten their learning curves and lower the costs of implementing and managing similar smart parking solutions.

6. Conclusions

This paper summarizes the approach and findings of the needs assessment and environmental scan of the parking situation within the City of Pittsburgh. The study's primary objective is to reflect stakeholders' input in the design of an integrated smart parking application project, an initiative that employs both centralized and decentralized systems in providing parking information within the City of Pittsburgh. By conducting interviews with key stakeholders and carrying out detailed data analyses, we were able to determine what issues and concerns exist around parking within the City of Pittsburgh. Not only does the paper document these issues, it also highlights the key drivers of the demand for parking and provides insights that inform the design and conceptualization of the integrated smart parking application project.

We employ a user-centric approach that emphasizes the centrality of stakeholders and end users in the design process. The framework provides a platform on which stakeholders can reflect and contribute to the design process through a series of interactive activities and discuss their expectations of the project with the product development team. The platform also facilitates the examination of the political, institutional and cultural context within which the system will be implemented. This robust approach fosters community buy-in, informs successful design and implementation strategies, builds credibility and ensures that the application addresses the deficits identified by the stakeholders.

We draw on a multitude of data sources in painting a rich picture of the parking and transportation ecosystem within the City of Pittsburgh. These include primary data from the semi-structured interviews, secondary data from local publications, U.S. Census data on workforce and commuting patterns and document review of the relevant literature. An appreciable degree of the data analysis is directed at commuters. The rationale for this is two–fold: the need to focus on daytime parking when most of the peak demands in parking were observed, and the city's workforce size relative to its resident population. Pittsburgh's daytime population increases to more than 460,000 as compared to its residential population of 305,000. This net gain of 155,000 is a result of workers commuting to the city and represents more than a 50% increase in the city's overall population. A salient finding from the analysis is the recognition that a supply-driven strategy is not feasible, thus our approach has been to embrace a menu of initiatives that will influence both commuters' demand for parking spaces and their commuting behaviour.

The insights obtained from the study are classified broadly into two sections – one is product specific and the other is policy related. On the policy side, we examine a host of issues and provide suggestions on how they could be addressed. Some of these issues are price related while some address the factors that condition the parking market. A specific example is how to incentivize commuters to exercise parking choices that are socially optimal. On the product side, an insightful realization is the potential impact the predictive module could have in shifting the driving populace towards utilizing a multi-modal transportation system. This could influence how individuals demand parking spaces and more importantly, how they modify their travel demand pattern. However, the benefits of the predictive module go beyond moderating the demand for parking spaces given that garage operators could use the predictive information to better manage their facilities. For example, a predicted higher than normal demand for parking spots could allow a garage operator to artificially increase the facility's capacity by making provisions for valet parking. Further downstream, the information provided by the predictive module could be used to dynamically price parking spaces.

Taking a cue from the interviews we had with stakeholders and the review of existing documents that highlighted the benefits of ParkPGH, we have made the existing smart parking app the core of an integrated smart parking application project. Added functionalities can be reflected by building on ParkPGH's open source platform and by exploring synergies between the app and other existing initiatives. This is demonstrated by showing how to target the more than 210,000 non-city residents that commute to Pittsburgh on any work day by using Variable Message Signage (VMS) placed at major transportation arteries and relaying information sourced from ParkPGH.

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