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Abstract

Smart city planning has become a popular concept in a time of increasing urbanization and its accompanying challenges, particularly in the face of climate change. Critiques say it is too generic to prove more useful beyond utilization as a buzzword in political discourse. Smart planning requires a cross-disciplinary and adaptable effort that combines and optimizes the range of quantitative and qualitative methodologies available to identify opportunities and actionable solutions while acknowledging the challenges and shortcomings of a given approach. In this paper, this theory of smart planning is applied to

the case of Philadelphia, where a multi-perspective lens – specifically, from the viewpoints of mobility and quality of life – is used to develop an integrated and adaptive evaluation of the needs of the city along with practical solutions for implementation. We show that integrating interdisciplinary resources and perspectives can uncover alternative solutions which enrich planning development.

Keywords (separated by '-')	Mobility - Philadelphia - Quality of life - Smart cities - Urban planning

A Multi-lens Approach to Smart City Planning: Philadelphia

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Abstract. Smart city planning has become a popular concept in a time of increasing urbanization and its accompanying challenges, particularly in the face of climate change. Critiques say it is too generic to prove more useful beyond utilization as a buzzword in political discourse. Smart planning requires a cross-disciplinary and adaptable effort that combines and optimizes the range of quantitative and qualitative methodologies available to identify opportunities and actionable solutions while acknowledging the challenges and shortcomings of a given approach. In this paper, this theory of smart planning is applied to the case of Philadelphia, where a multi-perspective lens – specifically, from the viewpoints of mobility and quality of life – is used to develop an integrated and adaptive evaluation of the needs of the city along with practical solutions for implementation. We show that integrating interdisciplinary resources and perspectives can uncover alternative solutions which enrich planning development.

Keywords: Mobility · Philadelphia · Quality of life · Smart cities · Urban planning

1 Introduction

The idea of Smart Cities has rapidly grown since the start of the 21st century, first appearing in the early 2000s and being utilized in many papers and debates especially since 2013 [1]. The definition of what constitutes a smart city is still unresolved given that different stakeholders such as Giffinger [2], Caragliu [3], and Angelidou [4], have divergent ideas regarding what makes a city "smart." However, there are general characteristics which hold consistent, these being: 1) the role of technology, 2) the planning for sustainability, and 3) the role of governance in managing these for a policy that is beneficial to people [1–4]. The Centre of Regional Science at the Vienna University of Technology (CRS) identified six main areas which have become widely accepted as background for the framework upon which a city can be assessed for smartness: smart economy, mobility, environment, people, living, and governance [2]. One popular definition based on these axes says a city is smart "when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." [3].

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This paper seeks to assess the opportunities and challenges for contributing to a "ideal plan" for a city and to develop proposals tackling these opportunities in an innovative manner using a multi-perspective, integrated, and adaptive approach. The City of Philadelphia is evaluated as a case study using this methodology to assess the needs of the city and to develop solutions that could be proposed for practical implementation. The methodology used may at first seem self-evident but is important to revise with an open mind that seeks opportunities for adaptations and syntheses for an ideal solution. Thus, the main contributions of this work are to show the value obtained by 1) synthesizing and finding relationships between seemingly disparate variables, data sources, and disciplines, 2) using a flexible and adaptive approach to optimize solution alternatives, and 3) applying this methodology to offer new perspectives on some urban planning challenges faced by Philadelphia.

The article is organized as follows: in the following section, the methodology adopted for approaching the planning project is discussed. Section 3 through Sect. 5 present the case study of Philadelphia through the phases described in Sect. 2. Section 6 discusses weaknesses of the methodology, and Sect. 7 presents the conclusions with some remarks and recommendations for future works.

2 Methodology and Materials

2.1 Methodology

The methodology adapted for a time-constrained evaluation of a city can be divided into three phases. First is selection of a research focus for the case study, exploring the motivation and background information for determining a location and the smart city pillars for comprehensive study. Given the smart city characteristics identified by the CRS [2], it is useful to select more than one to evaluate individually and also in relation to each other. Once these pillars are chosen, an extensive review is performed of the city's history and current situation with respect to the selected pillars of study, including recent statistics and planning documents developed by the city administration. This establishes a baseline from which challenges can be identified for further investigation. Case study constraints should also be defined in this phase.

Next, the identified challenges are evaluated to develop broad solutions for an "ideal city" from the lens of the selected perspectives. The proposals should be assessed both quantitatively and qualitatively for their impacts.

Following that is a refinement process to reevaluate the proposed solutions and process them into strategies and actions for implementation. Alternative scenarios are studied, and a "best approach" selected using varying methodologies of evaluation.

2.2 Materials

There are a plethora of tools and materials available for developing solutions for an "ideal city," to be selected depending on the area of interest and researcher's expertise. For this case study, the resources used include academic literature, open geospatial and survey-based data, articles and institutional reports, and planning documents.

3 Case Study Introduction: Philadelphia

3.1 Motivation and Research Focus

Given the long-term nature of infrastructure, planning a city by default requires consideration for sustainability from social, economic, and – increasingly – environmental perspectives. Following a preliminary review of the city's background, two issues of interest are selected for development using a multi-perspective approach.

The first is based on the phenomenon of the decrease in the city's population following publication of its first comprehensive city plan in 1960, from a peak of 2.1 million inhabitants in 1950 to 1.5 in 2010 [5]. Decline in population and neglected properties have become prominent characteristics of "unsavory" neighborhoods, giving rise to the question of whether these areas are thus due to the inherent qualities of their inhabitants or due to a systemic issue exacerbated by the built environment. Given that Philadelphia is still considered one of the most unsafe cities in the United States [6], it is of interest to explore how smart city solutions can improve safety and hence quality of life in the city. This assumes a correlation between safety and quality of life, which also bears further investigation.

The second issue centers upon transportation in Philadelphia. In 2020, Philadelphia was the second-most congested city in the United States, and the fifth most congested city in the world [7]. Although the city recently produced an extensive transit improvement plan and has been subject to discussions regarding new mobility solutions, there is a question of whether transportation issues can be cured just by improving transit, or whether there are more nuanced issues to examine in solution proposals.

The following two-pronged approach is adopted: examining how to plan a city smartly through the perspectives of quality of life and mobility. These two pillars may seem disparate and utilize different methodologies for analysis but are linked if only in the purest sense by the city resident for whose benefit the solutions are devised.

3.2 Case Study Constraints

Constraints must be identified at the beginning of the work which should be borne in mind throughout solution development, evaluation, and proposal:

- Data: availability, relevance, and quality of data may be limited.
- Scope: given a city's magnitude, the study scope should be limited to devise an applicable solution; thus, it is useful to focus on a single district or neighborhood.

3.3 Review of Extant Information

To develop a solution proposal, it is first necessary to understand the existing situation. This diagnosis can be performed by investigating the city history, contemporary facts and figures, reference plans, and literature review of the areas of interest. Integrating this information helps guide the development of a preliminary proposal.

The history of the selected location's urban development provides context leading to present-day characteristics. Recent plans present the planning efforts of the city while

helping contemporize research efforts to actual developments in progress. This avoids redundancy in proposals developed through the study. Studying the academic information concerning the areas of interest related to the city helps the researcher better understand the complexities of the situation and contextualizes the interaction of the selected issues with social implications along with scientific investigations.

Historical Review. The City of Philadelphia was chartered in 1701 and became a key location for culture, science, and education. Until 1800, Philadelphia was the largest city in the United States and the second-largest English-speaking city worldwide [8].

By the early 20th century, Philadelphia was a railroad hub experiencing great transit growth in addition to the manufacturing, industrial, and financial growth from the century prior [9]. However, political corruption, disease, and violence caused waste and stagnation in infrastructure expenditures. This was exacerbated by the Great Depression, which hit the city hard, followed by suburbanization, as residences and businesses moved out from the city center to the Greater Philadelphia region [9].

In 1960, the first comprehensive plan for the city was developed by the Philadelphia City Planning Commission, which laid out a 20-year plan for the physical development of the city. At the time, the city plan had a population estimate of around 2.5 million residents by 1980, since between 1890 and 1950, the population had doubled in size from one million to two million inhabitants. However, instead of continuing the trend, Philadelphia's population would instead decline to 1.5 million by 2010 [5].

Entering the 21st century, Philadelphia's population has experienced some growth (+0.6%) between 2000 and 2010, according to the 2010 census [5]. However, as of 2013, the city still had the highest unemployment rate in the region, also 1.9% higher than the national rate of 6.5% [10]. Even though the population is no longer declining, Philadelphia has yet to return to the economic prowess it was known for in its past.

City Plans. The principal city plans examined are the comprehensive development plan [5] and transportation plan [11]. Other documents contributing information regarding Philadelphia's visions and goals include the city's plans for smart city planning [12], sustainability [13], road safety [14], and transit [15].

Academic Literature Review. The study undertaken ranges from exploring the design philosophies involved behind the 1960 Comprehensive Plan [16] to assessing the impact of urban revitalization plans through programs such as historic preservation and anchor institutions [17, 18]. Other literature also critiques the sustainability and smart planning efforts previously undertaken by the city, discussing strengths and drawbacks to Philadelphia's previous proposals for becoming "smart" [10, 19].

When measuring quality of life in a city, the determinant factors are difficult to identify, and usually only validated through subjective surveys and estimated correlations between select indicators and the mental/physical satisfaction of citizens. While some authors such as Cohen argue that incidents of crime do not have as strong of an impact upon quality of life as other factors [20], others find that exposure to high rates of crime can adversely impact short- and long-term health, which are associated with quality of life [21]. From an alternative lens, studies of crime and resulting costs to society find that programs designed to prevent crime reduce costs incurred by stakeholders on individual and systemic scales, impacting overall quality of life [22].

Publications on mobility in Philadelphia provide historical and social contexts for the present-day transportation system and current conditions. They emphasize the importance of the role that mobility plays in society with social, economic, and environmental impacts on both Philadelphia's residents and its physical setting. These papers range from explaining relationships between urban spatial form and mobility with the role of social issues such as racial segregation and discrimination in historic policies [23, 24] to recommendations for context-sensitive transport design [25] and strategies for reducing greenhouse gas emissions from transport [26].

3.4 Challenges and Areas for Development

Challenges. From the background research, several challenges can be identified. Predominantly, Philadelphia's physical infrastructure has been deteriorating in hand with its declining economy since the previous century. Its neighborhoods are also home to high rates of crime: 139% more violent crimes and 41% more property crimes compared to the national averages [27]. High crime rates also deter investors, both commercial and residential, creating a feedback loop resulting in locations left to degrade into conditions that may facilitate the occurrence of crime.

Deteriorating infrastructure is also a challenge for Philadelphia's transportation system. Lack of space and funding for new transportation infrastructure has resulted in reduced reliability of transit options and a declining public transport ridership [15]. The impact upon reliability is both a reason for and a result of growing congestion on the city's roadways with the corresponding increase in the number of single-occupancy vehicles. This negatively impacts economy, environment, and health.

Opportunities. Addressing the challenges of each pillar separately allows brainstorming of multiple opportunities. For example, to tackle the challenge of high crime rates, the authors select an urban planning lens, as design is not often considered as relevant to crime prevention yet is a potent tool for creating safer environments that deter crime occurrence [28]. Rather than examining individual motivation, environmental factors are assessed for correlations with crime occurrences including issues such as access for intervention, likelihood of passerby, and the likes.

From the mobility perspective, the authors choose to focus on congestion, which has social, environmental, and economic implications making it an ideal study in sustainability. Socially, relieving congestion has a safety impact and would also improve accessibility of transit for carless travelers. Reducing congestion decreases greenhouse gas emissions from vehicles that spend less time idling in traffic and through the increased use of transit. Economically, congestion management could add a revenue source for the city, and partnerships may boost economic growth.

4 Analysis and Initial Proposals

4.1 Quality of Life

Analysis. The analysis is primarily based on the census block groups defined by the U.S. Census Bureau. The data used is sourced from ESRI Living Atlas and from Philadelphia's

open data portal, OpenDataPhilly. Population and economic data have been obtained from the U.S. Census Bureau and ESRI Living Atlas.

First, Incidents and Shootings from 2020 have been mapped in ArcGIS Pro [29] and Optimized Hot Spot Analysis performed over the data sets, using a fishnet grid data aggregation method over the census blocks. Figure 1 shows two main areas identified through this analysis, as indicated by the red zones.

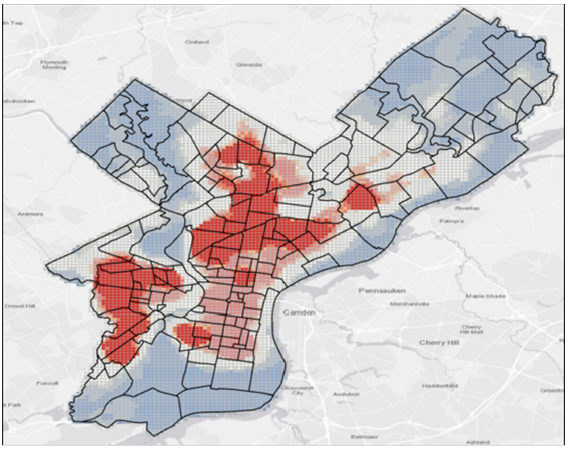

Fig. 1. Hotspot analysis of 2020 incidents. Data source: opendataphilly.org/dataset. Shapefiles downloaded April 14, 2021

Incidents are classified into Violent/Non-Violent and Opportunistic/Non-Opportunistic sets to determine whether patterns exist in motivations and/or nature of the crime. Hotspot analyses are performed over these and mapped against factors such as land use and demographic indicators. Positive correlations exist between crime and factors like vacant spaces, low household income, and high population density.

Google Earth Pro Street View [30] is used to examine neighborhoods of high crime rates; we observe that these areas are characterized by large, empty lots. These unused spaces are in disarray and may thus attract undesirable characters and their misdeeds.

Solutions. Defining a solution to address the problem of high crime rates in Philadelphia is complex due to the observed feedback cycle: neighborhoods with higher rates of crime are correlated to high poverty, low education, and low employment, but it is unclear which causes which.

Two possible solution approaches are considered: addressing crime motivations and addressing crime enablers. Looking at crime motivations evaluates which incidents are crimes of opportunity compared to personal grievances and helps understand which crimes might be addressable before the deed, and which are arbitrarily motivated by the human factor. Reducing crime enablers requires searching for specific scenarios or environments that are more conducive to crime occurrence, and how to suppress them. The practical implications of both approaches may be manifested in two ways: through environmental design, and through on-the-ground actions.

When evaluating the built environment, Crime Prevention Through Environmental Design (CPTED) is considered, which targets "designing safety and security into the environment of a specific area" [31]. This methodology first emerged in the 1960s following Jane Jacobs' theorization of concepts such as "eyes on the streets," the idea that urban design should locate people on public streets, thereby increasing the number of public witnesses which could deter potential offenders from committing crimes [32]. These implications are valuable not only for new developments but also for revitalization of an existing area. Studies investigating the relationship between safety and neighborhood vibrancy show that making more use of spaces in a neighborhood could significantly reduce the probability that a crime occurs in that location [33, 34].

To implement this concept in solution, one approach lies in enabling community ownership through a communal lens promoting actions such as 1) increasing community initiatives, 2) fostering formation of local-level leadership, 3) enabling community ownership via participatory actions like townhalls, surveys, etc., 4) developing "block properties" to be collectively used and maintained (such as gardens, playgrounds, and gathering areas), and 5) organizing communal activities like a cleanup day or "block party" cookouts. These actions are meant to foster sense of community and camaraderie and encourage communal upkeep of public and private properties.

A second approach uses an operational lens focusing on technical solutions, through services such as monitoring platforms or surveillance technologies which analyze locations of crime occurrences to optimize resource deployment to prevent or mitigate crime. Some actions promoted through this include 1) coordination and collaboration with neighboring municipal police divisions, 2) optimization of response routes, 3) predictive analysis using historic incidents to optimize patrols, 4) streetlight maintenance and surveillance camera installation in crime-prone areas, and 5) installation of smart cameras to detect weapons, incidents, flagged license plates, etc.

4.2 Mobility

Analysis. The analysis draws upon on traffic and congestion resources such as Texas A&M Transportation Institute, Google Maps, and the ESRI Living Atlas Portal. Neighborhood boundaries defined using PhillyOpenData's Philadelphia Neighborhood Boundary shapefile have been mapped with ESRI's World Traffic Service layer to identify areas of high congestion. The benefits of a congestion management solution are then analyzed using data from Texas A&M Transportation Institute.

First, congestion patterns can be identified by examining traffic patterns and average daily traffic within the city. The intent is to identify where and when congestion is most experienced to select an area best suited for implementing a pilot program with the proposed solution. This area is in and around the Center City neighborhood, a central location for many firms and a key commuter destination.

Solutions. Multiple strategies are studied for alleviating congestion: congestion pricing, lowering speed limits, restricting certain zones and times to public transit access, adding park & ride stations near key intersections and entry points to the city, and implementing electric shuttles between transit access locations and points of interest.

Since the part of the city experiencing the highest amount of congestion is the downtown, central area, downtown congestion pricing (DCP) is first explored for development. DCP is a strategy for reducing congestion by charging a payment for vehicles entering a city's downtown area.

A full in-depth analysis of the costs and benefits of implementing such a program is beyond the scope of this project; however, it is beneficial to identify the cost variables needed to be considered in an extensive feasibility analysis, as well as to develop high-level quantifications of the possible benefits.

The main costs include study and design, physical and systems infrastructure capital and integration, commercial costs, and operations and maintenance. The primary benefit of a DCP program is congestion reduction. The pricing mechanism should be designed to encourage drivers to take alternative modes of transportation or to enter the downtown part of the city during less crowded times of the day, thereby smoothing out traffic peaks and reducing the overall traffic delay resulting from congestion. The knock-on impact is a shift to modes of transport that have lower greenhouse gas emissions compared to a single occupancy vehicle.

Because crashes are more likely occur with higher speed variability [35], reducing congestion will also reduce stop-and-go motion with high variations of speed, thus effecting a decrease in car crashes. This not only increases safety, but also increases the total time that roads are clear, since accidents cause congestion when cars and emergency responders are blocking one or more lanes.

Reducing congestion should also improve trip times for travelers on all roadway transport modes. This produces cost savings in time and fuel, since time is money, in addition to the monetary cost per gallon of fuel. Based on studies in other cities where congestion pricing has been implemented, we estimate a 10% reduction in trips and 30% decrease in travel delays [36, 37]. Cost savings according to the value of time and from conservation of fuel wasted when idling in traffic are an estimated $1.1 billion annually. The reduction in travel delay will also have an environment impact of approximately 0.6 million-tons of annual CO_2-equivalent reduction in greenhouse gas emissions. These values are calculated using the assumptions in Table 1. In addition to these benefits, the program could also potentially procure revenues for investment in other initiatives like cycling, walking, and public transport.

Table 1. Congestion pricing benefits assumptions and sources

Indicator	Quantity	Source
Philadelphia annual VMT	11,132,500,000	Streetlight Data (2021)
Average fuel economy of passenger vehicle, miles/gallon	22	U.S. Environmental Protection Agency (EPA) (2018)
Average CO_2 emission rate for passenger vehicles, g CO_2/mile	404	EPA (2018)

(*continued*)

Table 1. (*continued*)

Indicator	Quantity	Source
Average tailpipe CO_2 emitted, g CO_2/gallon	8,887	EPA (2018)
Average price of gasoline, $/gallon	2.57	Texas A&M Transportation Institute (TTI) (2019)
Annual total delay, hours	194,655,000	TTI (2019)
Value of time, $/hour	18.12	TTI (2019)
Idling fuel use, gallons/hour	0.39	Calculated from U.S. Department of Energy (2015)

5 Revisions and Recommendations for Action

Quality of Life. The advantages and disadvantages of the two alternative scenarios previously proposed are evaluated in Table 2 below. "The Vibrant Block" refers to the communal approach; "The Policed State" refers to the technological method.

Table 2. Pros and cons of "The Vibrant Block" vs "The Policed State"

	The Policed State	The Vibrant Block
Pros	- More sensors allow quicker detection and deployment of resources to prevent or mitigate a situation - Data aids prediction of incident location and time of occurrence	- Fosters ownership behavior - Fosters relationships between community members, reducing likelihood of anonymous or unattended incidents - Supports economic development in underutilized spaces
Cons	- Unclear if increase in police force guarantees lower crime rates - Difficult to implement surveillance and responsive monitoring solutions on local scale - Subjective human factor complicates incident prediction	- Soft approach makes it difficult to quantify immediate impact - Difficult to assess scale of implementation - Requires community buy-in

"The Vibrant Block" is selected upon which to develop an action plan and strategy due to an interest in addressing design elements particularly following observation of the correlation between land use (or disuse) and crime occurrence shown in Fig. 2.

Actions and Strategies. The proposed action plan adapts the more recently developed Second Generation Crime Prevention Through Environmental Design (2nd Gen CPTED), which uses urban design to influence a potential offender's decision to commit a crime in a given space [32]. This approach centers on four main pillars: social cohesion, community culture, connectivity, and threshold capacity.

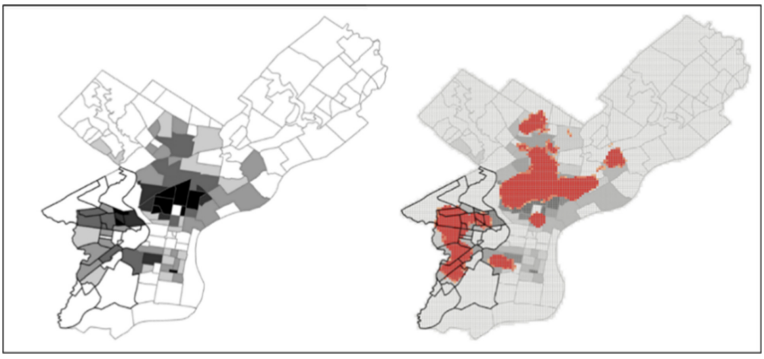

Fig. 2. Vacant lots per square mile (left), vacant lots per square mile overlaid with 2020 shootings hotspot analysis (right). Data source: OpenDataPhilly, US Census. Shapefiles downloaded April 14, 2021. Census data accessed May 14, 2021.

Social cohesion is the belief that communities form bonds by addressing problems together: proposed action elements associated with this pillar include 1) developing a local leadership committee, 2) organizing townhalls, listservs, etc., and 3) forming neighborhood watch groups. *Community culture* is the concept of creating a sense of ownership through interactions between residents as well as the built space. This can be fostered through 1) organization of neighborhood events like cleanup days or barbecues, and 2) cultivating shared spaces such as community gardens or art installations. *Connectivity* is important in and between neighborhoods due to the "permeability" of connected spaces, in which enacting measures in one space sometimes results in the criminal activities simply moving one street over, not actually mitigating the overall perpetration of crimes [38]. To address this, 1) neighborhood cluster leadership committees should be formed, and 2) inter-neighborhood activities will help improve network bonds. Lastly, *threshold capacity* is the concept of maximizing use of open spaces to reduce the physio-temporal opportunities for a crime to be committed. Some practical applications include 1) cleaning and transforming abandoned lots and buildings into communal spaces, and 2) diversifying uses for common public spaces. For example, vacant lots can be reimagined into a multi-functional space used for community-building, economy-boosting, health-improving initiatives.

A community-centric approach with design element considerations for the built environment creates an environment that is not only designed for, but also by, the community. To ensure this, community surveys would help determine which initiatives to prioritize. One major aspect of cultivating a sense of ownership and responsibility over a space is to motivate upkeep and order of the neighborhood. Areas with greater physical disorder tend to embolden criminals while (and perhaps because) residents are less protective of the common space and are hence less willing or able to intervene and prevent crime. An act as simple as "greening" a vacant lot can result in reduction of gun assaults and petty crimes, while also decreasing resident stress and improving health [34]. Proposed uses include spaces for picnic tables and playgrounds, an open space for multi-modal use, such as community activities, and spaces for mobile vendors like food trucks on various days throughout the week.

Mobility. Although downtown congestion pricing was initially the focus of the proposed solutions for resolving the issue of congestion in Philadelphia, other solutions should also be evaluated. Those programs already implemented or planned by the city are left out of the diagnosis to avoid redundancy, although it is helpful to keep them in mind for possible syntheses. The alternatives considered previously are assessed in comparison with the initial congestion pricing proposal and summarized in Fig. 3.

1. *Changing downtown speed limits:* Implement lower speed and/or variable speed limits near intersections downtown. Contrary to intuitive expectation that lowering speed limits results in slower trips (and more congestion), studies show that congestion causes slow speeds but slow speeds do not necessarily cause congestion, and in some cases actually improve traffic flow [39].
2. *Transit-only geo-temporal zones:* Define lanes along key transit routes dedicated exclusively for bus/transit use during peak travel periods. Implementing dedicated bus lanes during peak hours should improve travel times for buses and reliability of public transit options [40] while motivating drivers to shift to public transit.
3. *Expansion of Park & Rides:* Expand park-&-ride lots to key locations in suburbs and in the city with express routes to downtown. There is a dearth of parking lots providing good connections to the transit network. Designing lots as commercial centers may also help foster economic growth in areas near these access points.
4. *Micro-transit services:* Establish on-demand flexible or fixed route electric shuttle service between key transit stops and destinations of interest. Micro-transit services can help reduce traffic by 15%–30% [41] and can be implemented as a standalone solution or integrated with existing transit fleets running during off-schedule hours.

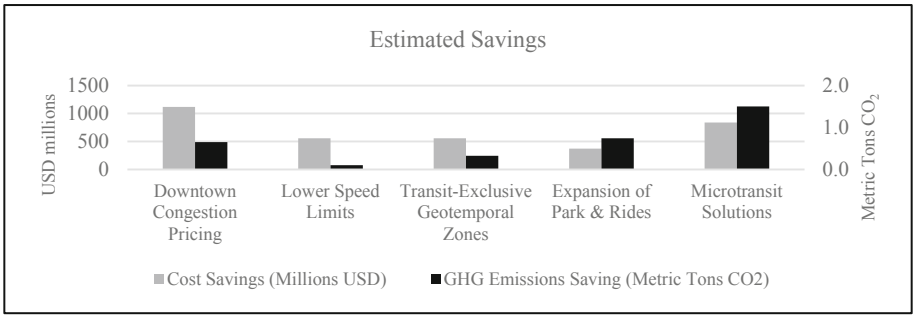

Fig. 3. Estimated benefits of time/fuel costs savings and GHG emissions.

To select the optimal solution, B-Box Software [42] is used to perform an analytic hierarchy process which evaluates the five alternatives discussed above, ranking them against and with respect to six different criteria. The criteria are defined and ranked using Saaty's scale [43] to assign intensities of importance and develop pairwise comparisons between alternatives with respect to the criteria, followed by establishing priorities of

the criteria with respect to the objective as shown in Fig. 4 and Table 3. Based on the given inputs, micro-transit emerges as the alternative of choice.

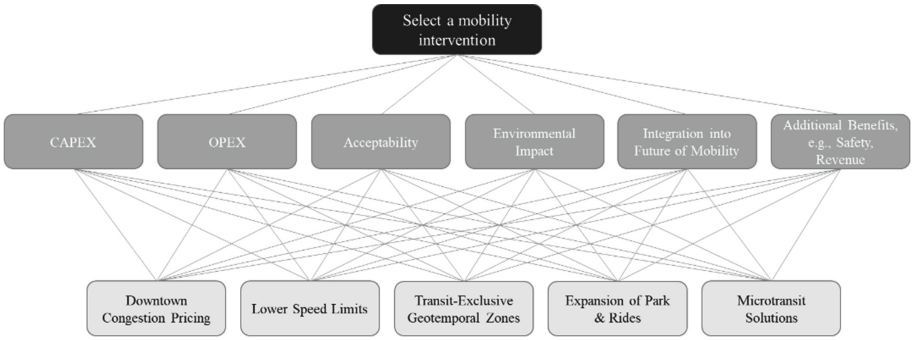

Fig. 4. Analytic Hierarchy Process for selecting a mobility intervention.

Table 3. AHP computation of final priorities and conclusion

	CAP-EX	OP-EX	Acceptability	Environmental impact	Future of mobility	Additional benefits	Total
Downtown congestion pricing	0.078	0.064	0.038	0.198	0.377	0.314	**0.150**
Lower speed limits	0.260	0.294	0.147	0.048	0.037	0.342	**0.183**
Transit-exclusive zones	0.481	0.409	0.075	0.325	0.104	0.047	**0.231**
Electric microtransit	0.128	0.157	0.370	0.325	0.393	0.086	**0.252**
Weight(s)	0.136	0.109	0.273	0.273	0.031	0.179	

Actions and Strategies. The proposed action plan is divided into three phases: planning, implementation, and follow-up. In the first phase, travel routes are assessed to determine which corridors would most benefit from micro-transit solutions. From these, one or two which run through the downtown area will be selected for an initial pilot. This phase will also consider on-demand options for non-fixed route services, i.e., if shuttles can deviate from usual routes to deliver passengers to alternative stops. Next, several options are assessed for implementing the solution: 1) form a public-private partnership with a micro-transit provider; 2) select an existing transit fleet to repurpose; 3) purchase new (ideally electric) vehicles for on-demand services. In addition, the platform for accessing the service must be developed and ideally integrated with existing services like that of the local transit operator. To follow-up, a marketing campaign will

increase familiarity with the new service. Ridership and usage over the pilot period will be monitored and evaluated for continuity and scaling.

6 Weaknesses

The following are the most salient limitations identified in the case study.

First, **the city is a dynamic entity that changes continuously.** Even with limitations in accessibility, data collection continues to improve; however, it is critical to maintain organized, reliable, and updated information to ensure accuracy and relevancy of analyses. Philadelphia is a clear case demonstrating that a city is always changing and that it is crucial to remain up to date on information that serves as the foundation for planning. Philadelphia did not follow the growth trajectory expected in its 1960 plan; as a result, trends from recent years are not representative of the long term.

Second, **studies are restricted in time and expertise**. Researching, analyzing, developing, and evaluating an "ideal solution" for a city is a daunting endeavor. Even with restriction to just two of the six smart city pillars in this case study, it was difficult to narrow the scope to meet the time constraints of the project. Lack of expertise in the field also costs more time and effort spent collecting background information as well as limiting access to certain sector-specific resources.

Lastly, **robust quantitative data is necessary to support proposals**. The analyses of the demonstrated case study were highly simplified. Applying advanced statistical analyses and simulations would provide validation for the impact of proposed solutions. Proposals could be further strengthened with firsthand evidence like community surveys, which could be analyzed to assess scenarios and priorities of stakeholders.

7 Conclusions and Future Work

A key problem with traditional city planning is that most decisions are made in silos without accounting for the nuanced interactions between supposedly disparate variables. This work offers an integrated methodology to address this challenge, emphasizing the benefits of using a multi-perspective approach. The open-ended approach offers an innovative perspective that places seemingly disparate issues in the same room, enabling a more comprehensive evaluation of the city's needs.

It is seen through the evolution of hypotheses and solutions ultimately selected that the optimal solution is not always the first. For example, the initial expectation for addressing quality of life was to find a technological solution to mitigate crime, but additional research led to the conclusion that a human-centric approach is paramount. In the mobility case, while the study initially began with one value-adding solution, evaluating other criteria led to a different optimal solution. This demonstrates the importance of remaining open to new inputs which may influence initial hypotheses.

Future research lines include further exploration of the mathematical correlations between the different socio-economic and environmental factors and occurrences of crime, along with sensitivity analyses. Statistical analyses verifying the qualitative observations made in initial studies would further serve to support solution proposals.

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Chapter 5

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