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# Signal-Free Corridor Development and Their Impact on Pedestrians: Insights from Expert and Public Surveys

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**Abstract:** Increasing vehicular demand has compelled decision makers to turn urban roads into signal-free corridors (SFCs) in Lahore. These corridors aim at prioritizing car flow over other modes and consist of various car-centric projects (CCPs), such as continuous flow intersections, grade separation, and continuous through movement. These projects often ignore pedestrian requirements and, thus reduce pedestrian safety. Considering the ongoing development projects in Lahore, this study aimed at evaluating the concept of SFCs. A total of 6 existing SFCs were identified in Lahore, which lacked basic pedestrian infrastructure. An expert survey was then conducted to understand the purpose of creating these SFCs, their effects on pedestrians, and the way forward. The thematic analysis regarding the purpose of creating these SFCs and their effect on pedestrians indicated the prioritization of private cars and pedestrian safety issues as the two underlying themes. A questionnaire survey was conducted to evaluate the perceptions of pedestrians on these two themes, i.e., pedestrian safety and car priority. Principle component analysis extracted two components labeled as pedestrian safety and car priority. Component scores were computed, and the three CCPs were then compared using non-parametrical tests in terms of both these components. According to the results, continuous flow intersections were declared to be significantly safer than continuous through movement and grade separation, whereas continuous flow intersection was found to be prioritizing cars over pedestrians significantly more than continuous through movement and grade separation. Finally, policy implications were presented for practitioners.

**Keywords:** signal-free corridors; car-centric projects; pedestrians; continuous flow intersections; expert survey



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## 1. Introduction

The growing number of automobiles during the twentieth century led to government policies aimed at redesigning cities for a seamless flow of private cars [1]. As a result, car-centric and car-prioritized transportation planning has long been a policy for many cities and countries worldwide [2,3]. This approach involves expanding the transportation network, such as the construction of new roads, flyovers, underpasses, and widening existing roads to allow cars to constantly flow through cities [4]. The car-centric policy resulted in an unprecedented growth in the number of cars and diverted the attention of the

relevant authorities away from active modes [5]. Furthermore, such policies may aggravate traffic congestion instead of reducing it [6] and cause financial losses. For instance, the economic cost of traffic congestion reached about 4% of Egypt's GDP [7]. A study conducted by Mao et al. [8] indicated that the congestion cost reached about 4.22% of the GDP in Beijing in 2010. Profillidis et al. [9] estimated the total annual congestion cost for the 25 countries of the European Union, Norway, and Switzerland at approximately 1.6% of the GDP for the year 2011. Besides congestion, car-centric transport planning has resulted in several other negative consequences, including but not limited to increased greenhouse gas emissions, air pollution, driver stress, road accidents, and injuries and deaths, etc. [9]. In addition, car-centric policies make walking less attractive due to reduced comfort and safety for pedestrians [10] and could negatively impact pedestrian accessibility [3]. Meanwhile, it is extremely difficult to ensure the safety and efficiency of both vehicles and pedestrians on the road [11].

It was soon realized that sustainable transport was the key to minimizing the negative externalities caused by car-centric policies [12]. Sustainable transport can be defined as "satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs" [13]. A sustainable transport system requires that the movement of people and goods is provided in an environmentally, socially, and economically viable way [14]. Active modes of travel, e.g., walking and bicycling, meet these specifications and are considered to be sustainable modes of transportation. A traditional recommendation to achieve sustainable transport is to promote active mobility [15,16]. The advantages of active travel are manifold, such as reduction in financial losses due to reduced congestion, reduction in greenhouse gas emissions and pollution, reduction in road fatalities, improved health, improved equity, social cohesion, and perceptions of security and livability [17,18]. Thus, several countries, such as the Netherlands, developed policies to shift toward active mobility [2]. Several studies have shown that promoting pedestrian-friendly cities requires careful consideration of aspects such as urban design and infrastructure [19]. However, the developing countries in the Asian continent remain far behind in promoting active mobility [20].

Like many developing countries, Pakistan has witnessed a boom in motorized transport in recent years. The authorities have adopted various car-oriented policies to cater to this increasing travel demand, which has negatively impacted the safety of pedestrians. Zia et al. [21] reported that, in the capital city alone, pedestrians were involved in 56% of fatal traffic accidents, contributing to 53.3% of the total fatalities over a three-year period from 2008 to 2010. The development projects in Lahore indicate a clear unwritten car-centric policy of the concerned authorities. The flow of private vehicles is being gradually encouraged and promoted throughout the city at the expense of reduced accessibility and mobility of other road users, particularly pedestrians. The recent car-centric projects (CCPs) include the construction of new roads, the widening of existing roads, flyovers, and underpasses, the introduction of frequent U-turns, continuous flow intersections, and the redesigning of existing roundabouts and intersections, etc. The purpose of CCPs is to create signal-free corridors (SFCs) that provide unobstructed through movement to private vehicles [22]. Such corridors encourage high vehicle speeds and maneuverability, restrict the right-of-way for active travel, and, therefore, compromise the mobility and accessibility of bicyclists and pedestrians [10].

The previous studies explored the impacts of isolated CCPs, such as the impact of the construction of a flyover, an underpass, the widening of a road, etc. [23–25]. However, the literature on the impact of SFCs created due to constructing various CCPs on pedestrians is scarce [26,27]. Therefore, this research study is intended to fill this gap in the body of the literature. This study aimed to evaluate the concept of SFCs via expert and pedestrian surveys. To achieve this overall objective, first, this study defines SFCs and identifies SFCs in Lahore. It also discusses how CCPs are constructed to create SFCs. Then, the themes about the purpose of SFCs and their effect on pedestrians are identified via an expert survey.

The themes identified via the expert survey are then evaluated using a pedestrian survey. Finally, policy implications are derived.

### *1.1. National Transport Policy of Pakistan*

For a significant amount of time since its creation in 1947, Pakistan did not have a formal integrated national transport policy [28]. The indicators, however, pointed toward a car-centered transport planning approach. Recently, the national transport policy of Pakistan was approved in 2018 [29]. The transport sector was divided into several sub-sectors, including road and urban transport. The policy directions related to road transport state the following:

> *"(i) The priority for passenger transport by road will be to enhance the usage of non-motorized transport and public transport. An increased focus will be made to the provision of public transport services and integration to other modes. Private transport will be considered complimentary to non-motorized transport and public transport, and will provide reliable access to low density and remote areas".*
>
> *"(iv) Urban roads will be designed to support efficient and effective urban transport, with priority given to non-motorized transport and public transport".*

Furthermore, the policy directions related to urban transport state the following:

> *"The aspiration or attraction of the use of private motor vehicles in urban areas will be dissuaded".*

In addition, policy directions were outlined to promote the use of active modes.

> *"Walking and cycling networks and facilities will be developed and implemented as an integral part of the urban streetscape and will be fully integrated with other modes to minimize use of private motorized transport where possible".*

Other policies, such as monitoring of air quality, following the national air quality thresholds, and limiting parking spaces to discourage private car use are also mentioned.

The policy seems to prioritize non-motorized transport, with its impacts yet to be seen. The ongoing projects, however, still indicate an unwritten car-centric transport policy.

### *1.2. Study Area*

In the recent past, the population of Lahore, which is the second-largest city in Pakistan, has increased drastically [30]. According to the recent census, the estimated population of Lahore is more than 13 million people [31]. This abrupt increase in the population of Lahore can be attributed to the attractive educational, commercial, healthcare facilities, and employment opportunities relative to the surrounding cities. Apart from this, Lahore has a large economy and is a place of growing urban middle class [32]. This increased population has led to an increase in the demand for traveling. According to an estimation, the average increase in vehicle ownership is 17% annually [33]. The growth in vehicle ownership has given rise to traffic congestion [32]. Since the current public transport system is not capable enough to sustain this ever-growing demand, the pressure to improve the flow of cars has encouraged the construction of heavy road infrastructure with little consideration for pedestrians. In the previous few years, the government has been trying hard to extend the road network in an attempt to mitigate traffic congestion. This is apparent from the creation of SFCs throughout the city, encouraging the car-oriented development in Lahore. All these reasons make Lahore a suitable candidate for this study.

### *1.3. Methodology*

First, SFCs were defined by referring to existing literature. After defining SFCs, detailed desk and field studies were conducted to identify the existing and potential SFCs in Lahore. For this purpose, the relevant institutions and authorities were also consulted.

For the expert survey, transport planners and engineers belonging to various academic and professional institutions were contacted. A short questionnaire was prepared consisting

of only three pertinent questions. A thematic analysis was conducted to identify the common themes behind the responses for each question.

Based on the themes identified via the thematic analysis of the expert survey data, a questionnaire was prepared for the pedestrian survey to evaluate their perceptions about those themes. For the pedestrian survey, three representative locations with CCPs along three different SFCs were chosen in Lahore. It was deemed more suitable to ask the pedestrians about CCPs instead of directly asking them about SFCs. Initially, a descriptive analysis of the data was conducted. Principal component analysis (PCA) was performed to group together highly correlated variables into principal components. PCA is a widely used method for reducing data dimensionality, which enhances data interpretability while retaining the maximum possible information. Because the questionnaire included multiple items to measure the underlying constructs, PCA was conducted to reduce data dimensionality and retain these underlying components. Two principal components emerged in this study, hereafter referred to as factors. Factor scores were then computed for both factors. Non-parametric statistical tests, e.g., Kruskal–Wallis and Mann–Whitney-U tests, were performed on the factor scores to compare the CCPs in terms of the underlying factors. The Kruskal–Wallis test is the non-parametric counterpart of one-way ANOVA. It can be used to ascertain whether statistically significant differences exist among two or more groups of an independent variable in relation to a continuous or ordinal dependent variable. In this study, the grouping variable was the type of CCP, and the dependent variable was the factor scores for the underlying factors. The purpose of performing this test was to determine whether the perceptions of the respondents were statistically different about three different CCPs. The Mann–Whitney U test was employed as a post hoc statistical test to compare differences between two independent groups (i.e., two CCPs) when the dependent variable is either ordinal or continuous (i.e., factor scores). All the analysis was carried out using SPSS v. 20. The flowchart depicting the methodology adopted in this research study is shown in Figure 1.

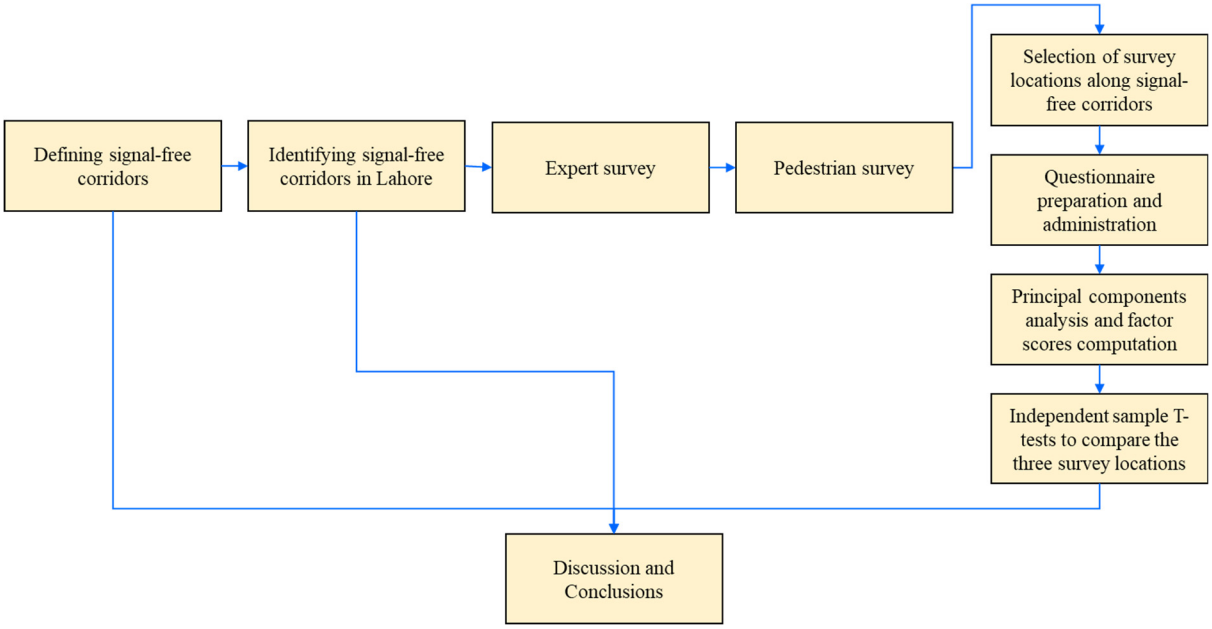



**Figure 1.** Methodology adopted for this research study.

The rest of the manuscript is organized as follows. SFCs are defined, and existing SFCs in Lahore are identified in Sections 2 and 3, respectively. Expert and pedestrian surveys are presented in Sections 4 and 5, respectively.

## 2. Defining Signal-Free Corridors

No proper definition of SFCs exists in the literature. A few studies, e.g., Kumar et al. [26], used this term, which were explored to come up with a clear description of SFCs. In this study, an SFC is defined as

> *"an arterial providing unobstructed through movement to private vehicles through the city while compromising on the access and mobility of active modes".*

Such corridors can be created by removing any obstructions to vehicular traffic, such as the removal of crosswalks, conversion of signalized intersections to continuous-flow intersections, the construction of flyovers and underpasses, etc. These development projects aim at prioritizing the car movement and are thus labeled as car-centric projects (CCPs) in this study.

### *2.1. CCPs to Create SFCs*

There are various CCPs that were completed in Lahore to create SFCs. Keeping in view the pattern of the current development projects in Lahore, these CCPs can be grouped into three broad categories: (1) converting roundabouts to continuous through movement, (2) converting at-grade intersections to grade separation, and (3) converting signalized intersections to continuous flow intersections, etc. The creation of an SFC may involve an isolated CCP, a series of CCPs, or a combination of these. The common theme behind these projects is to ensure a continuous unobstructed flow of private vehicles while compromising accessibility and mobility of active modes, particularly pedestrians. Brief descriptions of the three CCPs are given below.

#### 2.1.1. Converting Roundabouts to Continuous through Movement

Under this project, the functionality of the existing roundabout is taken away, crossing traffic is blocked, and through movement along the SFCs is allowed (Figure 2). Since there is no conflicting traffic, the through traffic can move unimpeded, resulting in higher speeds, which makes it difficult for pedestrians to find suitable gaps and cross the road.

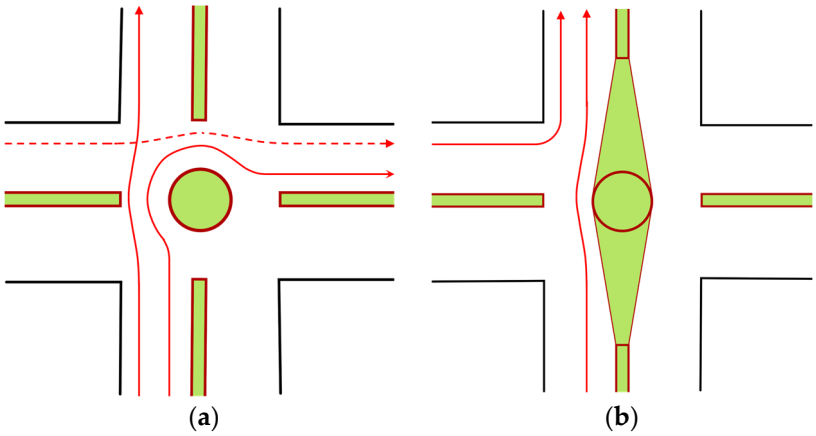



**Figure 2.** A schematic diagram showing conversion of roundabouts to continuous through movement: (**a**) before conversion; and (**b**) after conversion.

#### 2.1.2. Converting at-Grade Intersections to Grade Separation

Under this project, grade-separated projects are implemented to allow vehicles along the SFCs to bypass the conflicting traffic (Figure 3). Under certain conditions, such projects may help achieve various objectives, such as a reduction in congestion, travel time, and total emissions [34]. However, they give rise to complex geometries and scenarios for pedestrians.

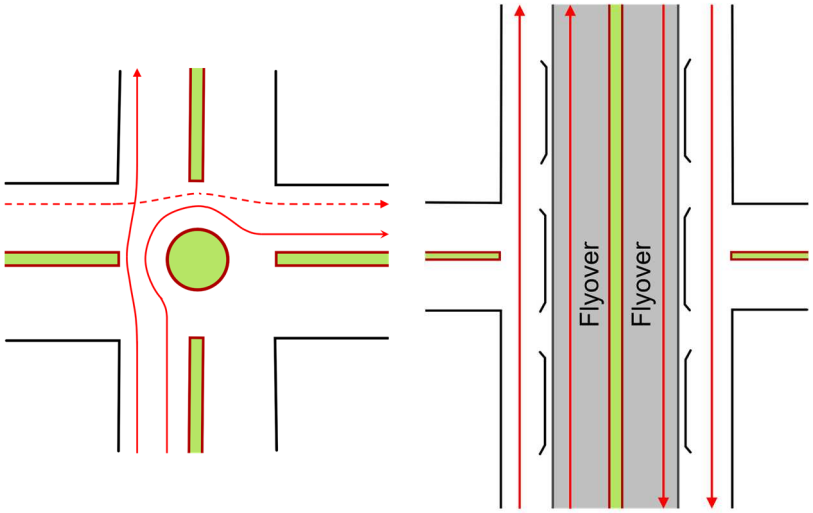



**Figure 3.** A schematic diagram showing conversion of at-grade intersections to grade separation: (**a**) before conversion; and (**b**) after conversion.

#### 2.1.3. Converting Signalized Intersections to Continuous Flow Intersections

Under this project, traffic signals are typically removed from existing signalized intersections, the crossing conflicts are removed by merging the crossing traffic with the traffic of SFCs, and U-turns are provided at a certain distance from the intersection to allow for the crossing traffic to complete their crossing (Figure 4). This increases the travel time for the crossing traffic. Road width needs to be increased where U-turns are provided. The increased number of lanes, complex traffic flow patterns, and continuously flowing traffic make it difficult for pedestrians to cross the road and increase the chances of crashes.

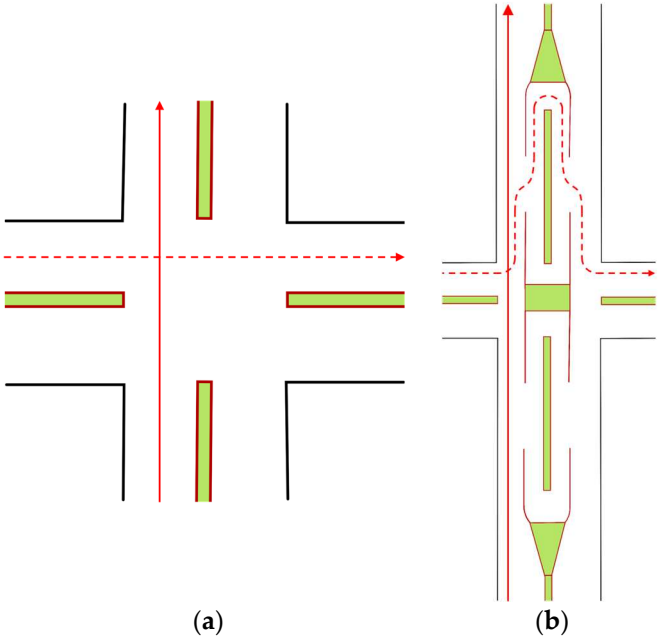



**Figure 4.** A schematic diagram showing conversion of signalized intersections to continuous flow intersections: (**a**) before conversion; and (**b**) after conversion.

## 3. Identifying Signal-Free Corridors in Lahore

Various SFCs were created in Lahore, and several others are in the pipeline. Figure 5 shows the currently existing SFCs in Lahore. A total of six SFCs were identified in the city.

The longest SFC at the moment is Canal Road, which is 22 km long, followed by Ferozepur Road (17.5 km). As explained earlier, these SFCs are created by initiating various CCPs. Three different CCPs, along with three different SFCs, were chosen as case studies whose description is given in Table 1. Figures 6–8 show the before and after designs of the CCPs at the three representative locations (source: Google Earth). Furthermore, Table 1 shows the comparison of these designs in terms of their pedestrian-friendliness. Figure 9 shows Jail Road SFC created as a result of constructing various CCPs, which primarily comprised continuous intersections. There is clearly a lack of pedestrian crossing facilities. The pedestrian overhead bridges are located fairly away from the intersections. The crossing width is quite long in all the CCPs.

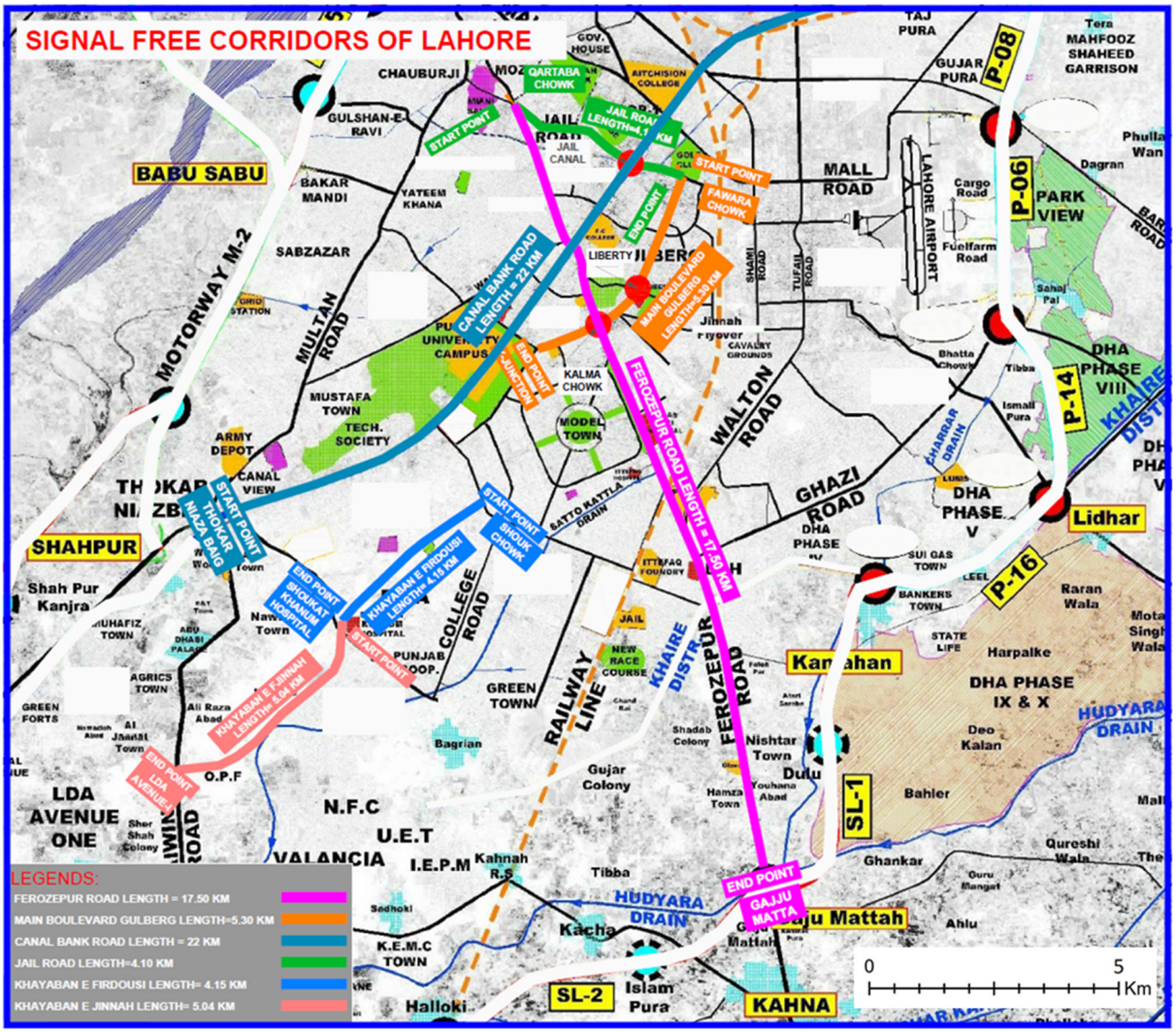



**Figure 5.** Existing signal-free corridors in Lahore.

**Table 1.** Details of the three representative locations with different CCPs.

| Location | Liberty Roundabout (CCP-1) | Kalma Chowk (CCP-2) | Jail-Canal Intersection (CCP-3) |
|---|---|---|---|
| CCPs | Converting roundabouts to continuous through movement | Converting at-grade intersections to grade separation | Converting signalized intersections to continuous flow intersections |
| SFC | Main Boulevard Gulberg | Ferozepur Road | Jail Road |
| Crosswalk existence | ✘ | ○ | ✘ |
| Overhead pedestrian bridge | ✘ | ✘ | ✘ |
| Sidewalk | ✘ | ✘ | ✘ |
| Pedestrian underpass | ✘ | ✘ | ✘ |
| Pedestrian signal | ✘ | ✘ | ✘ |
| Maximum number of lanes | 15 | 14 | 9 |
| Distance to the nearest overhead pedestrian bridge (meters) | 570 | 370 | 280 |
| Maximum crossing width, including median (meters) | 135 | 82 | 55 |
| Minimum crossing width (meters) | 45 | 55 | 40 |

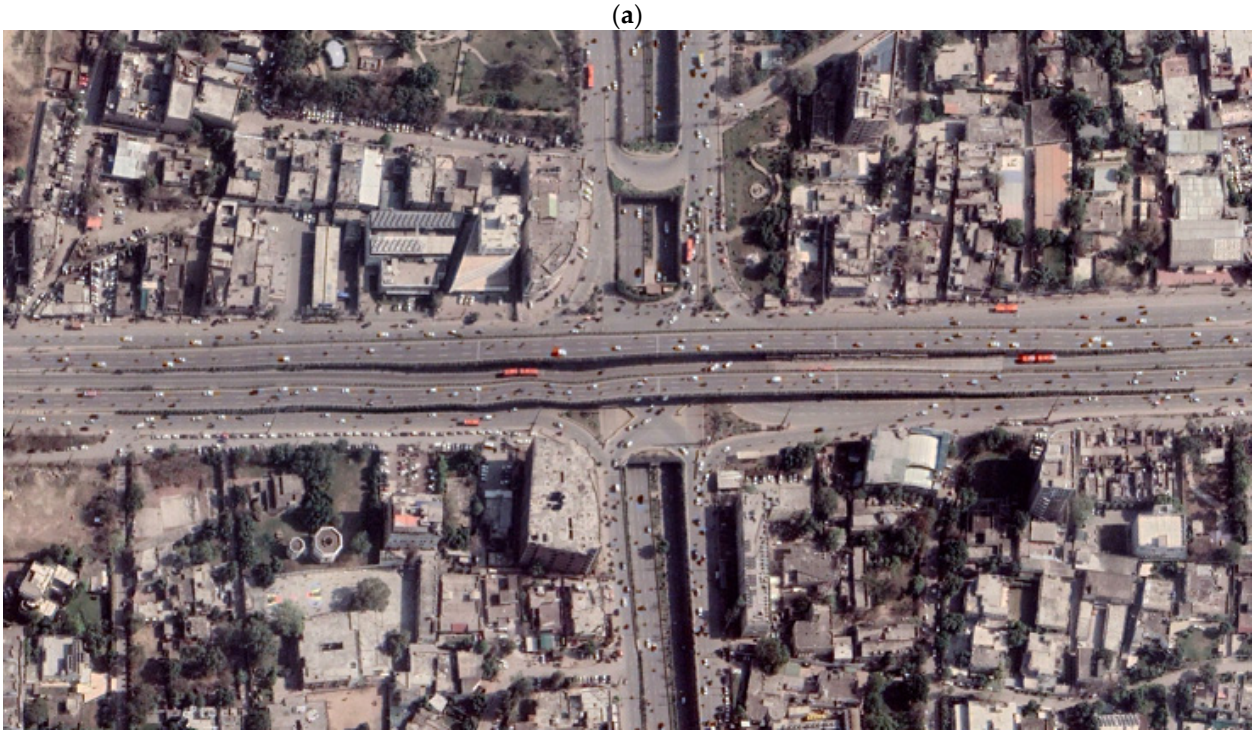
✘ No, ○ Partial.

(**a**)

(**b**)

**Figure 6.** Liberty Roundabout conversion along Main Boulevard Gulberg SFC (CCP-1): (**a**) before conversion in 2014; and (**b**) after conversion in 2022.

(**a**)



(**b**)

**Figure 7.** Kalma Chowk conversion along Ferozepur Road SFC (CCP-2): (**a**) before conversion in 2011; and (**b**) after conversion in 2020.

(**a**)

(**b**)

**Figure 8.** Jail-Canal Intersection conversion along Jail Road SFC (CCP-3): (**a**) before conversion in 2014; and (**b**) after conversion in 2022.


**Figure 9.** Jail Road SFC created as a result of constructing various CCPs (mainly continuous flow intersections).

## 4. Expert Survey

The purpose of conducting an expert survey was to gain a critical understanding of the purpose and effects of creating SFCs and extracting the underlying themes. Expert surveys are useful to understand difficult issues, particularly where limited empirical evidence is available. Expert surveys are widely used in the field of transportation planning and engineering [35,36].

### *4.1. Questionnaire Preparation and Administration*

The questions are kept short, concise, and in limited quantity for the sake of brevity. The participants were informed about the use of the data and that the responses will be kept anonymous. Keeping in view the objectives of this study, three questions were asked of each expert: (1) How do signal-free corridors affect pedestrians? (2) What is the aim of creating signal-free corridors? (3) Given that signal-free corridors have already been developed, what is the way forward for pedestrian access and mobility?

The participants were mainly transportation engineers, planners, and academics working in various governmental and non-governmental organizations with relevant expertise. The participants were contacted via social media and personal contacts using a non-probability convenience sampling approach. Further, some targeted participants also recommended their colleagues who could participate in the survey based on their expertise. A total of 10 interviews were conducted. Considering that the sample may be classified as elite, the sample size is adequate and can provide valuable insights [37]. Each interview took about 5 to 8 min. The interviews were conducted via social messaging apps during the month of May in 2022.

The sample was male dominated, as there was only one female participant. Most of the respondents were currently working in Lahore, while the others had experience working for several years in Lahore. The characteristics of the participants are shown in Table 2.

**Table 2.** Details of the participants contacted for the expert survey.

| Respondents | Gender | Organization |
|---|---|---|
| R1 | Female | Department of Transportation Engineering and Management, University of Engineering and Technology Lahore |
| R2 | Male | Department of Transportation Engineering and Management, University of Engineering and Technology Lahore |
| R3 | Male | Traffic Engineering and Transport Planning Agency (TEPA), Lahore Development Authority (LDA) |
| R4 | Male | Traffic Engineering and Transport Planning Agency (TEPA), Lahore Development Authority (LDA) |
| R5 | Male | Punjab Safe Cities Authority |
| R6 | Male | Regional Transport Authority |
| R7 | Male | Transport Department, Government of the Punjab |
| R8 | Male | University of Management and Technology, Lahore |
| R9 | Male | The NFC Institute of Engineering and Fertilizer Research, Faisalabad, Punjab |
| R10 | Male | Lahore Parking Company |

### *4.2. Thematic Analysis*

The data was analyzed using thematic analysis, which is a qualitative technique identifying, analyzing, and reporting themes in the data. The thematic analysis was conducted using a six-step approach as described in Braun and Clarke [38]: Step 1: Familiarizing with data; Step 2: Generating initial coding; Step 3: Searching for themes; Step 4: Reviewing of themes; Step 5: Defining and naming of themes; and Step 6: Reporting the findings. Three core themes emerged after performing the coding process on the responses obtained for the three questions. The themes derived from the responses obtained for the first and second questions were pedestrian safety and car priority, respectively. Interestingly, the themes derived from the responses to the third question differed and were labeled as a policy shift. An overview of the themes is presented below.

#### 4.2.1. Pedestrian Safety

Responding to the first question, the experts mainly highlighted the adverse effects of SFCs on pedestrian safety.

> *"R: Smooth but fast traffic stream can be fatal for pedestrians when they cross roads, especially when no safety measure is adopted".*
>
> *"R: Signal free corridors adversely affect pedestrian safety. Signal free corridor cause continuous and high-speed traffic stream and make it extremely difficult for pedestrians to cross the road. Moreover, severity of accidents tends to be more fatal as compared to signalized corridors".*
>
> *"R: Signal free corridors adversely affect pedestrian safety while crossing the road".*
>
> *"R: In signal free corridors, usually it is risky for pedestrians to cross the roads because of absence of proper infrastructure for crossing".*
>
> *"R: I believe signal-free corridors hinder pedestrian accessibility on the roads of Lahore. In the absence of crossing opportunities, pedestrians attempt to cross the road through heavy and speedy traffic resulting in reduced pedestrian safety".*

#### 4.2.2. Car Priority

Responding to the second question, the experts primarily mentioned the priority given to cars while creating SFCs.

*"R: The aim of developing signal-free corridors was to improve traffic flow in the city and facilitate vehicles to avoid long queues at intersections".*

*"R: The aim of creating signal-free corridors is to reduce travel times, delays, and improve level of service for vehicles".*

*"R: The aim of creating signal-free corridors is to provide better mobility of vehicles and lesser delays at intersections".*

*"R: Signal-free corridors are created to avoid long queues of cars at intersections".*

#### 4.2.3. Grade Separation

In response to the third question, some experts suggested grade-separated solutions for pedestrians along SFCs.

*"R: A grade separated pedestrian crossing infrastructure be provided for the safety of pedestrians".*

*"R: The pedestrian safety in such cases can be assured with the provision of foot bridges and underground crossing for pedestrian. The foot bridges need to be equipped with elevators".*

*"R: For pedestrian access and mobility, proper pedestrian bridges need to be constructed at busiest sections of road especially in front of hospitals and educational centers".*

*"R: One way is to provide overhead or underground pedestrian bridge".*

#### 4.2.4. Policy Shift

Some experts, while responding to the third question, criticized the current policy of developing SFCs. They hinted at adopting a policy shift where pedestrians are properly taken care of while designing roads.

*"R: Pedestrian inconvenience makes the overhead bridges/underpasses provided along signal free corridors a ridiculous alternative to safe crossings at road level. These are under-utilized for the trouble it puts pedestrians in, particularly the elder people, families with infant, people carrying luggage and people with disability. Safe and secure at-grade crossing facility is the only way forward for pedestrians to carry out their activities without any nuisance".*

*"R: Provide pedestrian crossing facilities at regular intervals especially in front of hospitals, schools,* etc. *considering handicaps also".*

*"R: Restoration of signal-controlled corridors".*

*"R: The only way forward is to improve the accessibility of pedestrians on the roads and make them feel safe (friendly roads for pedestrians). This is only possible if cohesive transport planning is carried out and concrete policy directions from the experts are incorporated into road design".*

## 5. Pedestrian Survey

SFCs improve vehicle flow while impeding pedestrian mobility. Therefore, it is important to understand the perceptions of pedestrians about SFCs. For this purpose, a pedestrian survey was conducted at three different CCPs along three different SFCs. The details of the pedestrian survey are given below.

### *5.1. Questionnaire Development and Administration*

A questionnaire was prepared to keep in view the themes identified during the thematic analysis conducted on the data obtained via the expert survey. The first part included questions related to the socioeconomic and demographic characteristics of the respondents. The second part included various items aimed at measuring pedestrian safety and car priority. The two themes, i.e., grade separation and policy shift, identified via the responses to the third question, were omitted from the pedestrian survey since those

were related to the policy implementation and were not in the public domain. The first section of Part 2 of the questionnaire aimed at determining the perceptions of pedestrians about the safety aspects of these CCPs creating SFCs. The second section of Part 2 of the questionnaire aimed at determining the perceptions of pedestrians about whether or not these CCPs are aimed at prioritizing car movement. Both sections of Part 2 consisted of various 5-point Likert scale items.

A team of surveyors was hired to conduct the survey at the desired locations. The team was properly briefed before the commencement of the survey. A number of 250 responses were obtained from each location, resulting in a total of 750 complete useable responses. All the responses were kept anonymous. The survey was conducted from 9 May 2022 to 21 May 2022 at the three CCPs shown in Table 1 and Figure 10.

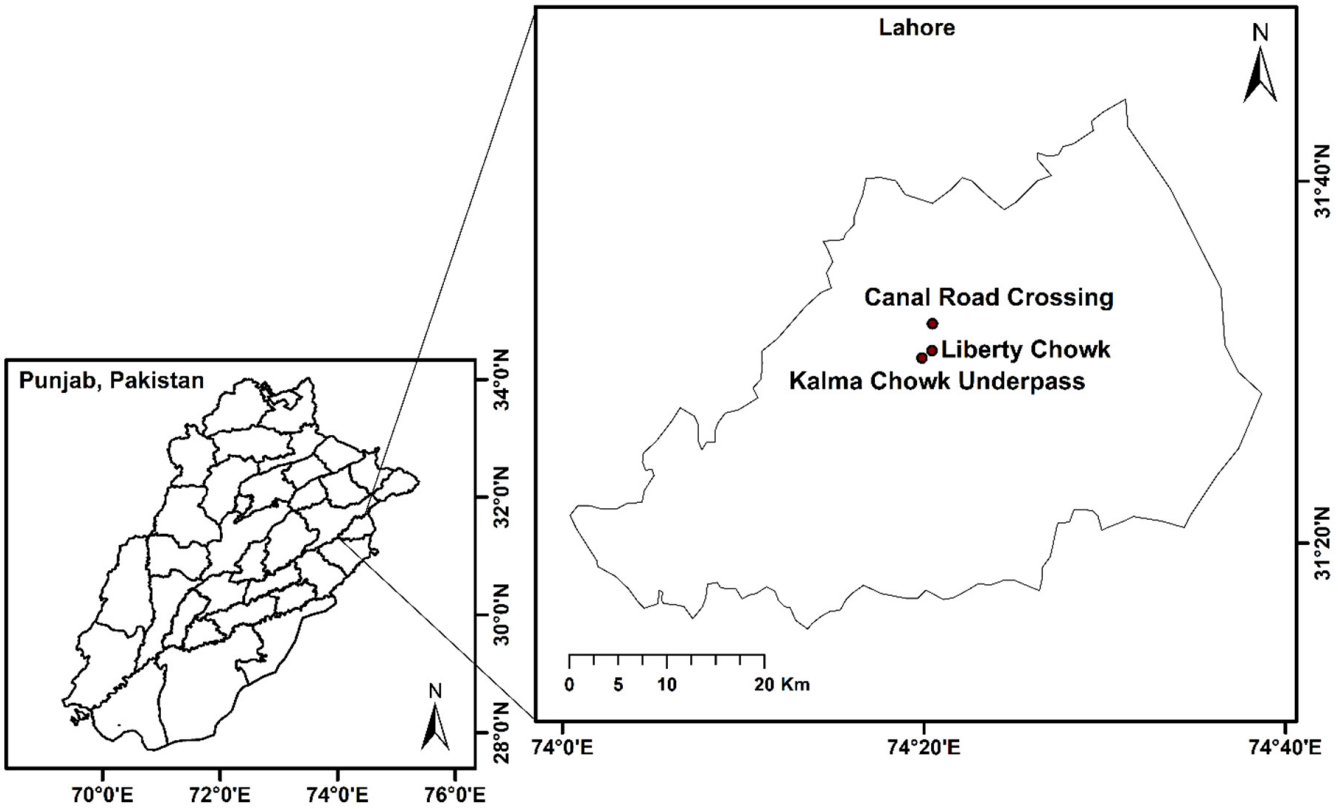



**Figure 10.** Locations of the CCPs where pedestrian survey was conducted.

### *5.2. Descriptive Statistics*

The sample was male dominated since the working population of women is comparatively small in Lahore and thus, a lower road crossing population. The answer to crossing frequency indicated that several pedestrians would cross at these CCPs if proper pedestrian infrastructure were provided. In terms of age, the sample was skewed toward the younger population. Further details of the sample are given in Table 3.

**Table 3.** Summary of the pedestrian survey data.

| Variable | Category | Frequency | Percentage |
|---|---|---|---|
| Gender | Male | 600 | 80.0 |
| | Female | 150 | 20.0 |
| Age | 18–29 | 375 | 50.0 |
| | 30–39 | 248 | 33.1 |
| | 40–49 | 68 | 9.1 |
| | 50–64 | 42 | 5.6 |
| | >64 | 17 | 2.3 |
| Education level | Primary School | 77 | 10.3 |
| | High School | 85 | 11.3 |
| | College | 134 | 17.9 |
| | Bachelor's | 334 | 44.5 |
| | Master's and Above | 120 | 16.0 |
| Profession | Student | 122 | 16.3 |
| | Business | 80 | 10.7 |
| | Government Employee | 194 | 25.9 |
| | Private Employee | 289 | 38.5 |
| | Other | 65 | 8.7 |
| How often do you cross at this location? | Less than once a week | 295 | 39.3 |
| | 1–2 times a week | 160 | 21.3 |
| | 3–4 times a week | 130 | 17.3 |
| | 5–6 times a week | 106 | 14.1 |
| | 7 or more times a week | 59 | 7.9 |
| How often would you cross at this location if proper pedestrian infrastructure is provided? | Less than once a week | 108 | 14.4 |
| | 1–2 times a week | 170 | 22.7 |
| | 3–4 times a week | 257 | 34.3 |
| | 5–6 times a week | 126 | 16.8 |
| | 7 or more times a week | 89 | 11.9 |

### *5.3. Principal Component Analysis (PCA)*

PCA with Varimax rotation was conducted to group the highly correlated variables into principal components for further analysis (Table 4). PCA brought out two principal components, also referred to as factors in this text, and explained about 51.494% of the total variance. The factors explained about 31.778% and 19.716% of the variance, respectively. A factor loading cut-off of 0.4 was used [39]. KMO's measure of sampling adequacy was satisfactory (=0.716). Bartlett's test of sphericity was significant (<0.001). The determinant was 0.427. The factor scores for both factors were computed. The Cronbach alpha values for the factors were 0.592 and 0.644, respectively. These alpha values are satisfactory [40] in social sciences; however, values greater than 0.7 are more desirable.

**Table 4.** Results of principal components analysis with Varimax rotation.

| | Factor | |
|---|---|---|
| | **Pedestrian Safety** | **Car Priority** |
| Vehicular traffic is high. | 0.716 | |
| It takes a long time to cross the road. | 0.683 | |
| Vehicular speed is high. | 0.652 | |
| It is difficult to cross the road. | 0.614 | |
| The design increases the crash propensity for pedestrians. | | 0.763 |
| Signal-free roads are aimed at facilitating the car owners only. | | 0.756 |
| Signal-free roads encourage speedy drivers. | | 0.746 |

### *5.4. Comparison of the CCPs*

The Kruskal–Wallis test indicated a significant difference between the factor scores for the three locations, indicating that different CCPs have different influences on pedestri-

ans' perception of pedestrian safety ($\chi^2 = 89.289$, $p < 0.001$) and car priority ($\chi^2 = 22.088$, $p < 0.001$). Additional post hoc tests (Mann–Whitney-U) were conducted to identify the differences between perceptions about the three CCPs. The Bonferroni correction (alpha/n) was applied to reduce Type-I errors. In this particular case, alpha and n were set as 0.05 and 3, respectively. Hence, the new significance level is 0.017. The results of the Mann–Whitney-U tests comparing all three CCPs in terms of pedestrian safety and car priority are shown in Figures 11 and 12, respectively.

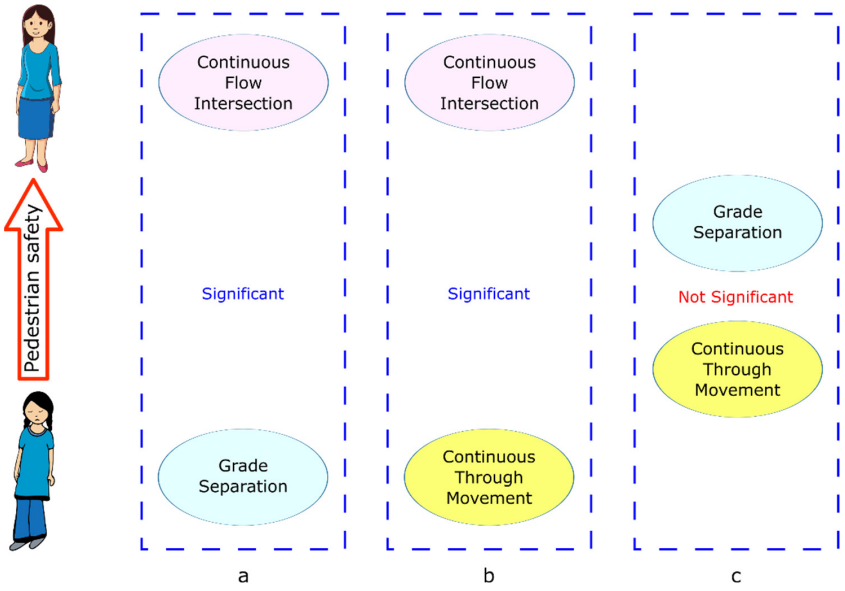



**Figure 11.** Results of Mann–Whitney-U tests comparing the three CCPs in terms of pedestrian safety: (**a**) Continuous Flow Intersection is perceived to be significantly safer than grade separation (U = 17,872.50, $p < 0.017$); (**b**) Continuous Flow Intersection is perceived to be significantly more safe than continuous through movement (U = 18,530.00, $p < 0.017$); (**c**) No significant difference between the perceptions about pedestrian safety at grade separation and continuous through movement (U = 27,965.50, $p > 0.017$).

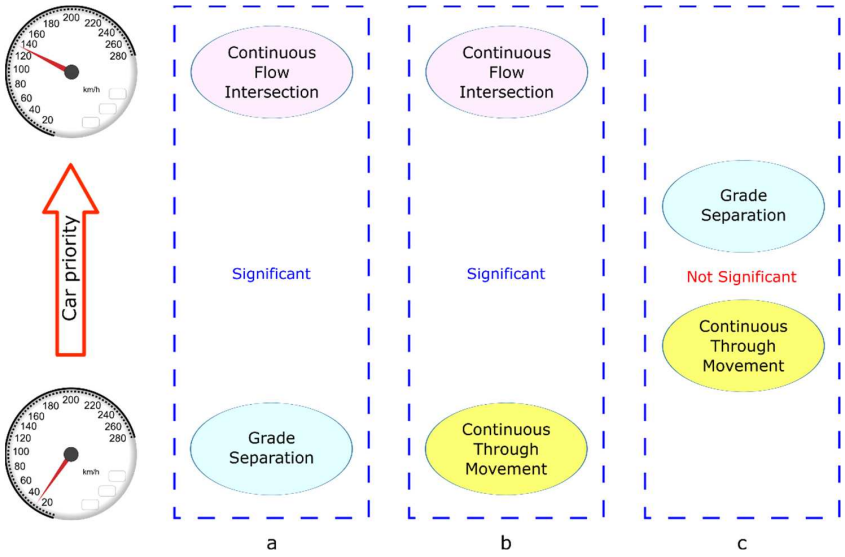



**Figure 12.** Results of Mann–Whitney-U tests comparing the three CCPs in terms of car priority: (**a**) Continuous Flow Intersection is perceived to be prioritizing cars significantly more than grade separation (U = 25,235.50, $p < 0.017$); (**b**) Continuous Flow Intersection is perceived to be prioritizing cars significantly more than continuous through movement (U = 24,202.00, $p < 0.017$); (**c**) No significant difference between the perceptions about car priority at grade separation and continuous through movement (U = 30,494.50, $p > 0.017$).

### *5.5. Crossing Frequency*

The respondents were also asked about their current crossing frequency and their future crossing frequency if the crossing facilities are improved at these CCPs. A Sankey diagram was plotted to visualize how pedestrian crossing frequencies would change at the CCPs if proper pedestrian facilities were provided in the future (Figure 13). It is evident that pedestrians are more likely to cross at these locations once improvements are made. As expected, the Mann–Whitney-U test indicated that the expected crossing frequency at the CCPs in the future is significantly higher than the current crossing frequency ($U = 204{,}667.50$, $p < 0.001$).

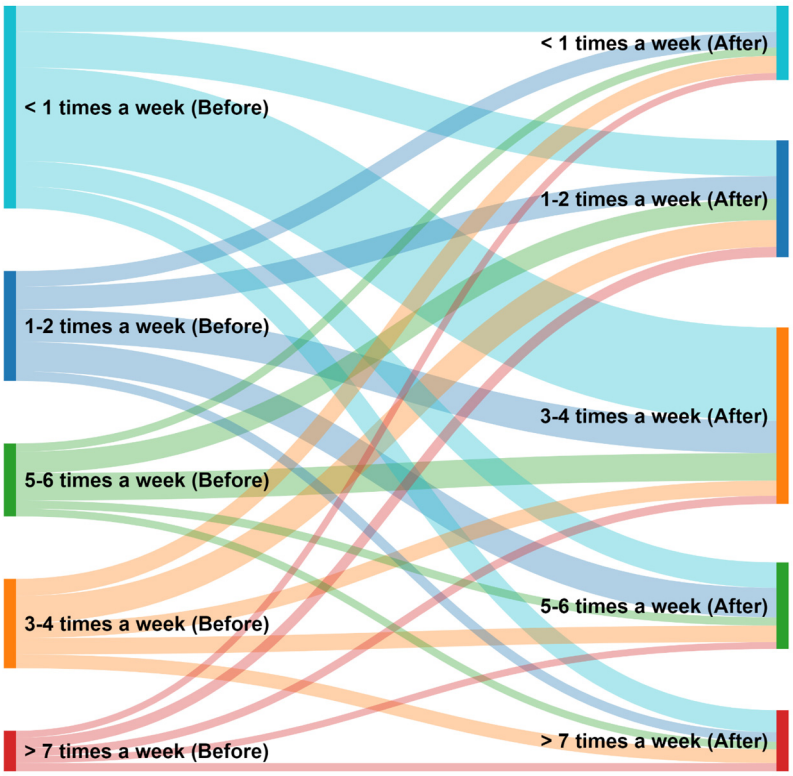



**Figure 13.** Sankey diagram showing the current and expected crossing frequency at the CCPs before and after improving pedestrian facilities.

## 6. Discussion and Policy Implications

SFCs are being created throughout Lahore to meet the growing demand of private vehicles. An SFC may contain various CCPs located anywhere along its length. Recently, several CCPs were completed, which can be categorized into three broad categories: (1) conversion of roundabouts to continuous through movement, (2) conversion of at-grade intersections to grade separation, and (3) conversion of signalized intersections to continuous flow intersections. These CCPs aim at serving private vehicles and generally ignore the requirements of active mobility. As a result, unsafe circumstances arise at such locations for pedestrians.

There was a lack of an integrated transport policy in Pakistan, which was recently filled by a national transport policy approved in 2018. The policy outlines the directions aimed at prioritizing active mobility; however, it is too soon to reap its benefits. On the contrary, the recent completion and launch of new CCPs indicate an unwritten car-oriented transport policy. These CCPs create SFCs that negate several policy directives mentioned in the national transport policy.

Considering the expanding network of SFCs in Lahore and the fact that limited literature exists on the adverse effects of these SFCs on pedestrians, this study aimed to fill this research gap. Initially, SFCs and CCPs were properly defined. Then, the existing SFCs in Lahore were identified via desk and field studies. A total of 6 SFCs were identified in

the city, whose lengths varied from 4.10 km to 22 km. Each SFC consisted of various CCPs. Further, a detailed study of these SFCs indicated that all these SFCs lacked basic pedestrian infrastructure. It must be highlighted that several of these SFCs pass through famous market areas where pedestrian demand is significant. For example, the Main Boulevard Gulberg (an SFC) passes through a big electronics market. However, there are no at-grade pedestrian crossings.

An expert survey was then conducted to understand the purpose of creating these SFCs, their effects on pedestrians, and the way forward. Ten transport planners and engineers with relevant expertise from various organizations were interviewed for data collection. The collected data was analyzed using a qualitative approach known as thematic analysis, which helped extract the themes behind the primary questions asked during the interviews. The theme regarding the purpose of creating these SFCs was the prioritization of private cars, while the theme behind the effects of these SFCs on pedestrians was pedestrian safety. Two themes were extracted for the way forward, which seemed contradictory. The first theme was grade separation, and the second was policy shift. Regarding grade separation, several studies reported that overhead bridges are inconvenient for pedestrians, especially for pregnant women, sick people, old population, and physically challenged individuals [41]. In addition, the location of the overhead of overhead bridges may also affect their utilization rate [42]. It was shown in this study that the overhead bridges are located quite far from CCPs. The provision of escalators may increase the utilization rate [43]; however, this solution seems implausible considering the current energy shortage issues in Pakistan. Hence, the reasonable solution seems to be the policy shift. Since the national transport policy was already approved, the way forward now is to implement this policy to prioritize non-motorized transport.

Since active modes are the direct affectees of these SFCs, it is important to understand their point of view. Bicycle volume is very low in Lahore; therefore, only pedestrians were targeted in this study. A questionnaire survey was conducted to evaluate the perceptions of pedestrians about the two themes identified via the expert survey, i.e., pedestrian safety and car priority. The survey was conducted at three CCPs located along three different SFCs. Principle component analysis helped extract two components labelled pedestrian safety and car priority. Component scores were computed, and the three CCPs were then compared using non-parametrical tests in terms of both these components. It was found that continuous flow intersections were declared to be significantly safer than continuous through movement and grade separation. It can be attributed to the fact that continuous flow intersections contain U-turns for vehicles where they typically slow down, allowing sufficient gaps for pedestrians to cross the road. In addition, there are multiple medians in such designs where pedestrians can take refuge. However, in the case of continuous through movement, there are a huge number of lanes where vehicles move at a high speed, making the location unsafe for pedestrian crossings. Similarly, grade separations may be considered complex locations, which may be unsafe for pedestrians and lead to crashes [44,45]. On the other hand, it was found that continuous flow intersections were found to prioritize vehicular traffic over pedestrians significantly more than continuous through movement and grade separation. It is reasonable since continuous through movement presents a scenario similar to a through road, and the construction of flyovers has been an old practice, whereas continuous flow intersections are unusual and complex in their layout; therefore, pedestrians perceive such projects as unusually special treatment for meeting vehicular demand.

### *6.1. Policy Implications*

As the results of the expert survey depict, the construction of SFCs is not pedestrian-friendly. They increase the speed of the vehicles and hinder pedestrian accessibility. This increased speed, coupled with high traffic volumes, can make the roads increasingly hostile to pedestrians and may lead to crashes. It can be seen clearly from the design of CCPs that they are discouraging and not well designed for the accessibility of pedestrians. These

poor designs are predictably deadly in urban areas where pedestrians feel the need to cross the roads. Such designs are being continuously followed, especially in the developing regions where the decision making is sometimes carried out on a political basis without fully considering or even including the feedback from the experts [28]. While in some countries such as Italy, Japan, and Norway, the peers have worked hard to improve the safety of pedestrians, and it has yielded significant improvements [46], the statistics show that the rate of fatalities or crashes is much higher in the developing regions as compared with the developed countries [47]. Therefore, there is an urgent need to increase awareness among the decision makers to play an active role in the propagation of designs that are safe for pedestrians and discourage the expansion of road networks.

#### 6.1.1. Safe System Approach

The absence of an integrated transport policy for several decades indicates a great need to adopt a Safe System Approach (SSA) where the holistic feedback from the designers, local and federal transport planning agencies, academics, and active participants should be included, and their agreed upon suggestions and recommendations be considered for formulating transport policies. Hence, SFCs must be evaluated from vehicle as well as pedestrian viewpoint. Such measures require the identification of the function of the road at the planning stage, and both expert as well as users' opinions should be taken into account before construction. As highlighted in several previous studies, active travel modes are being discouraged due to concerns about road traffic accidents, particularly in developing countries [48]. SSA has the potential to address the safety issue of users on the road and can reduce the vulnerability and fallibility of pedestrians on high-speed SFCs.

#### 6.1.2. Implementation of National Transport Policy

The current development of CCPs indicates that the transport policy of Pakistan discussed in Section 1.3 and other similar policies are only prepared for documentation purposes. Their implementation remains a challenge. Despite the policy directives aiming at promoting active mobility, cars remain one of the most dominant and encouraged modes of transport in Lahore. This reflects the poor commitment to the implementation of the national transport policy and, as a result, poor and unsafe accessibility of pedestrians on the roads. The implementation of the national transport policy in true letter and spirit may result in pedestrian prioritization. The implementation of sustainable strategies that promote active mobility (instead of accessibility) can stimulate the greater portion of the population to adopt active transport as their first mode of choice, especially in urban regions. One of the case studies of the Aberdeen city [49] can be successfully implemented in Lahore if tailored according to the local contexts considering the socio-cultural factors. However, it is to be noted that transferring the whole policy package may not be feasible and thus, a thorough evaluation and analysis of the local traffic environment propagated by the socio-cultural factors should be conducted at the planning stage.

#### 6.1.3. Well-Connected and Accessible Roads

As evident from the theme identified via the expert survey, a policy shift is needed where pedestrian accessibility is improved. The new roads should be shifted from "well-connected" to "well-connected and accessible roads", where pedestrians can move around easily while feeling safe. The provision of at-grade signalized pedestrian crossing at intersections with higher pedestrian use is among the viable options. Another effective way in this regard is to reduce the speed of vehicles. A person who is hit by a car at 35 mph is likely to die, with a probability of five times higher than a person hit by a car at 20 mph [50]. This accessibility-based approach should be prioritized over a mobility-based approach, which in turn would regulate the design choices and prioritize pedestrians over vehicles. It is a well-established fact that pedestrians weigh the costs and risks when choosing how to cross the road. It was observed that pedestrians do not prefer the use of overhead or underground bridges, especially if the origin and destination of crossing do not match

the desired point of access and detours are needed in order to use them. In this case, the provision of the at-grade signalized intersections is a viable and attractive option, but strong measures should be imposed for the discouragement of jaywalking along SFCs if they are necessary.

#### 6.1.4. Safer CCPs

As understood from the pedestrian survey, certain CCPs were safer for pedestrians than others. Further, revealed preference data about pedestrian behavior must be collected at such locations to ensure their safety for pedestrians, and recommendations should be incorporated in the planning stage of the road infrastructure before the actual construction of these SFCs. In addition, safety audits conducted for new and already constructed roads by road safety experts could be used to evaluate the projects not only in terms of driver safety aspects but from pedestrian perspectives as well. These recommendations will not only help urban and transport planners to devise sustainable and safe road infrastructure, but rather they can also offer to reduce the impact of cost-related variables in the construction of new corridors in the city. If inevitable, in the case of extreme necessity, these relatively safer designs should be implemented rather than those CCPs that compromise pedestrian safety.

## 7. Conclusions

Due to the increasing demand for traveling and motorized transport, governments around the world are trying to make necessary modifications to the existing transportation infrastructure to accommodate the travel demand. In Pakistan, the authorities focused on creating signal-free corridors (SFCs), which adversely affect pedestrians' safety on roads. These corridors aim at prioritizing car flow over other modes and consist of various car-centric projects (CCPs) such as continuous flow intersections, grade separation, and continuous through movement. These projects often ignore pedestrian requirements and thus reduce pedestrian safety.

In this research study, expert and pedestrian surveys were conducted to explore the purpose of creating SFCs and their effects on pedestrians. The thematic analysis of the expert survey data indicated that the primary purpose of creating these SFCs is car priority, and their consequences include negative effects on pedestrian safety. After the expert survey, three CCPs, i.e., continuous flow intersections, continuous through movement, and grade separation, were identified along different SFCs to explore the perceptions of users on car priority and pedestrian safety. According to the results, continuous flow intersections were declared to be significantly safer than continuous through movement and grade separation, whereas continuous flow intersection was found to be prioritizing cars over pedestrians significantly more than continuous through movement and grade separation. Based on the findings of the research study, four policy measures are proposed for improving the safety of pedestrians on such corridors: safe system approach, implementation of National Transport Policy, well-connected and accessible roads, and safer CCPs. It is expected that if these policies are implemented in both their true letter and spirit, they can improve pedestrian safety along such corridors. Therefore, this research study provides valuable insights for improving pedestrian safety along such corridors for the policymakers and decision makers.

This study has some limitations. For example, one limitation of this study is the lower representation of older pedestrians. Moreover, there is a possibility that certain pedestrians may not be fully informed about their rights, pedestrian safety standards, and regulations. Consequently, their perceptions of pedestrian safety in a car-oriented project may not accurately align with the actual safety concerns associated with that project.

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