International Journal of
*Geo-Information*

MDPI

*Article*

# School Commuting Mode Shift: A Scenario Analysis for Active School Commuting Using GIS and Online Map API

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Received: 14 July 2020; Accepted: 29 August 2020; Published: 31 August 2020

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**Abstract:** Active school commuting provides a convenient opportunity to promote physical activity for children, while also reducing car dependence and its associated environmental impacts. School–home distance is a critical factor in school commuting mode choice, and longer distances have been proven to increase the likelihood of driving. In this study, we combine open-access data acquired from Baidu Map application programming interface (API) with GIS (Geographic Information System) technology to estimate the extent to which the present school–home distances can be reduced for public middle schools in Jianye District, Nanjing, China. Based on the policies for school planning and catchment allocation, we conduct a scenario analysis of school catchment reassignment whereby residences are reassigned to the nearest school. The results show that, despite the government's 'attending nearby school' policy, some students in the study area are subjected to excess school–home distances, and the overall journey-to-school trips can be reduced by 20.07%, accounting for 330.8 km. This excess distance indicates the extent to which the need for vehicle travel can be potentially reduced in favor of active school commuting and a low-carbon lifestyle. Therefore, these findings provide important insights into school siting and school catchment assignment policies seeking to facilitate active school commuting, achieve educational spatial equity and reduce car dependence.

**Keywords:** school commuting; scenario analysis; urban informatics; active commuting; spatial equity; school catchment area

## 1. Introduction

To mitigate the pace of global warming, a consensus on carbon emission reduction has been reached all around the world. The Sustainable Development Goal 13 (SDG13) from United Nations calls for urgent actions, which should be included in national policy and planning, to combat climate change and its impacts [1]. It has been proved that government control and low-carbon lifestyles is the key to realizing energy saving and emission reduction [2–4]. Moreover, compared to government control, a low-carbon lifestyle has few negative effects on economic growth, and thus has become an economically friendly, healthy and sustainable lifestyle that has naturally enjoyed widespread popularity [5,6]. When coming to low-carbon lifestyle, suggestions for residents usually emphasize conservation of electricity and less dependency on motor vehicles, which calls for changing auto-oriented lifestyles and encouraging daily active travel behavior (i.e., walking or cycling) [7]. Previous research has documented that the global transport sector accounts for 20% of energy-related greenhouse gas emissions [8], and by reducing motor vehicle travel, 15.1% reduction of fuel consumption can be achieved by 2030 [9]. In light of the foregoing, school commuting, which has a strong relationship with the transport sector, can be regarded as an energy-intensive activity and active school commuting, therefore, can be advocated as a low-carbon lifestyle, although relevant estimations have been under-published.

To encourage active school commuting, it is believed that school siting and school catchment delineation should be considered carefully in order to ensure that school–home distances are within walking or cycling distances [10,11]. In some countries, such as China, policies for public school planning and school catchment have been formulated and implemented [12]. China's public schools, where more than 95% of students attend, are constructed and maintained by local governments [13]. School planning guidelines recommend the service area of a primary school to be around a 500 m radius buffer and middle school at 1000 m. Local governments also advocate the principle of "attending nearby school", which restricts school admissions to students living within defined catchment neighborhoods based on parental household registration and ownership [14]. Therefore, school–home distances theoretically cannot be overlong for students to walk to school. The school radius buffer guideline and the government's nearby school principle will come into play in different phases of urban development. Theoretically, the guideline should play a guiding role to ensure adequate public schools and a proper distance between (and distribution of) schools in an urban sprawl or new town developments. The principle plays an important role when the city begins to take shape and the government starts to consider school catchment delineation. However, due to poor implementation in some rapidly urbanized areas in China and the lack of relative policies in other countries [15,16], many students are still faced with overlong commuting distances, which continuously lower the rate of active school commuting [10,17,18].

Most previous studies focus on the transport mode choice of school commuting [19,20], which essentially pays attention to the physical activity of children or teenagers. School–home distance has been found to be the most influential factor in school commuting mode choice, as ascertained through interviews with parents who decide the commuting mode for their children [21,22]. Some quantitative studies performed further verification of the relationship between modal choice and distance, and discovered that there are clear distance thresholds for modal shift [16,20,23,24]. Given that, to a great extent, the dependency on motor vehicles in school commuting decreases the physical activity duration for students [15], the importance of reducing school–home distance and advocating active school commuting is emphasized. From the perspective of physical activity and the health of children or teenagers, optimal school catchment which guarantees walkable school–home distance is necessary. Some researchers have noted that motor vehicle dependency can be reduced by active school commuting, and environmental benefits can then be generated [11,25]. However, without accurate distance calculation, less studied is to what extent the school catchment reassignment can realize vehicle distance reduction by scenario analysis.

With the development of remote sensing (RS) and geographical information systems (GIS), fine-scale population distribution data, which has proved to have great accuracy, can be produced to describe urban population distributions and help policy makers improve the allocation of resources [26]. Online maps, as well as open-access data (such as travel time or travel distance) acquired by the use of application programming interface (API), can be combined with GIS to play an essential role in numerous fields and has received increasing acceptance [27,28]. It is believed that the most commonly used measures, including the Euclidean distance and the shortest network distance used as a proxy measure of travel distance, may not reflect real travel distance [29,30]. This problem has also emerged in studies of school commuting [31]. Through estimating school commuting distance using online map API, it is possible to more accurately estimate the potential reduction in the need-for-vehicle-travel by scenarios of catchment reassignment.

Using public middle schools in Nanjing, China as a case study, this study acquires the commuting distance between school and residence points within defined school catchments from open-access data of online map. Combining this information with school enrolment data, the present school commuting distances are evaluated. An argument is put forward that if policies for school catchment zones are strictly implemented, overall school commuting distances—and hence the need for vehicle travel—can be significantly reduced in favor of active commuting. Scenario analysis of school catchment reassignment is developed to verify the hypothesis, and estimate the extent to which vehicle travelled distances can be reduced in school commuting. Recommendations for school catchment assignment and school siting, as a complement for active school commuting research, are provided.

## 2. School Catchment Assignment

The mechanisms of school catchment assignment have been widely studied in many developed countries around the world. School catchment assignment policies are largely characterized by either a clear contrast or a complex trade-off between choice-based (competitive market-driven) and location-based (residential proximity) approaches [32]. Choice-based, 'quasi-market' school enrolment systems are credited for promoting choice and giving greater power to parents as service consumers [33,34], which in turn raises the accountability of schools to parents and stimulates competition—thus raising educational standards [35]. However, such liberal policies that provide parents with unrestricted choice of schools for their children often leads to excessive demand for popular and/or high performing schools [34], and consequently longer average school commutes. Over the past decades, an increase in the average distance travelled to school has been reported [36]. Moreover, studies have also noted a decline in the level of physical activity among children, an increase in car-based commuting and childhood obesity [37,38]. One common way of addressing these problems is to prioritize admission into the highly sought-after schools based on the pupils' residential proximity [34,37]. More radically, these trends have rekindled the advocacy for stricter location-based school allocation.

Arguments for location-based school catchment assignment are driven by a number of objectives, which include improving education accessibility [39–41], spatial equity [42,43] and containment of travel within neighborhoods or metropolitan subregions [41,44]. The long-term effects of spatially equitable access to education facilities and overall shorter school-trip distances have strong sustainability implications, notably from the aspects of urban development, public health and environmental protection. Therefore, even though the principle of 'attending the nearest school' can be criticized for stifling competition between schools [35,41,45], it is widely advocated in transport, urban planning and public health research as a 'silver bullet' that can reverse these trends by simply enabling active school commuting [46–48]. In China, the public education system has delineated school catchment areas through which the authorities seek to ensure that (1) school admission is restricted to children living within the defined catchment areas, and (2) children who live within walking distance of a school [12,14]. However, the "attending nearby school" principle advocated by the authorities through these catchment areas is not strictly adhered to. This creates excess travel distances and exacerbates car reliance in school commuting. This study estimates the extent to which overall school trip distances can be shortened in Chinese middle schools if the "attending nearby school" policy was strictly adhered to when assigning school catchment areas.

Numerous approaches can be used to estimate commuting distances and delineate catchment zones. The school planning guidelines in China recommend a service radius of 1000 m for middle schools. Moreover, it is generally believed that the threshold for active school commuting is around 1600 m [17,18,49–51], beyond which vehicle travel becomes the preferred option. Thus, this study employs both Euclidean (1000 m) and route distance (1600 m) thresholds in the scenario analysis. Studies which performed school catchment assignment fall within two broad categories; (1) those using school locations independently of actual pupils' locations (e.g., using radial buffers or census tracts) [52,53] and (2) those utilizing actual distributions of students [34,54]. This study adopts major elements of these two categories. It combines route distance (and radial buffers) and actual residence points to determine current commuting distances, and then estimates the decreases in the distance after catchment reassignment. It takes advantage of open-source data and web-map API to perform scenario analysis using GIS technology. Given that longer distances increase the likelihood of driving, it is assumed that the reduction in home-school distances in the new scenario represent the distance that would have been travelled by car, referred henceforth as the "shortened vehicle-travelled distance".

## 3. Materials and Methods

### *3.1. Study Area and Data Collection*

The study area is located in Jianye District, an administrative district in Nanjing, China with a population of around 600,000 residents and a land area of 83km$^2$ [55]. According to the Baidu Map data, there are currently nine public middle schools and one private middle school in the study area, serving 210 neighborhoods. This study area was selected because it contains a good mix of old and new developments. Some of the newer developments in the area were the first to be constructed under the unified planning in Nanjing. These are located more sparsely towards the south-western part of Jianye District, while the older developments are more concentrated in the north-east and closer to the old town in Nanjing (see Figure 1). Thus, the study area also contains a good mix of dense developments (closer to Nanjing City) and relatively low density, newer developments which are located further south-west from Nanjing City. This mix is important for this study in order to inform school catchment allocation policies in low density as well as high density settings. Additionally, we selected public middle schools due to middle school students, as opposed to primary school students, having more independent mobility, and therefore, the former group is more likely to choose active commuting.

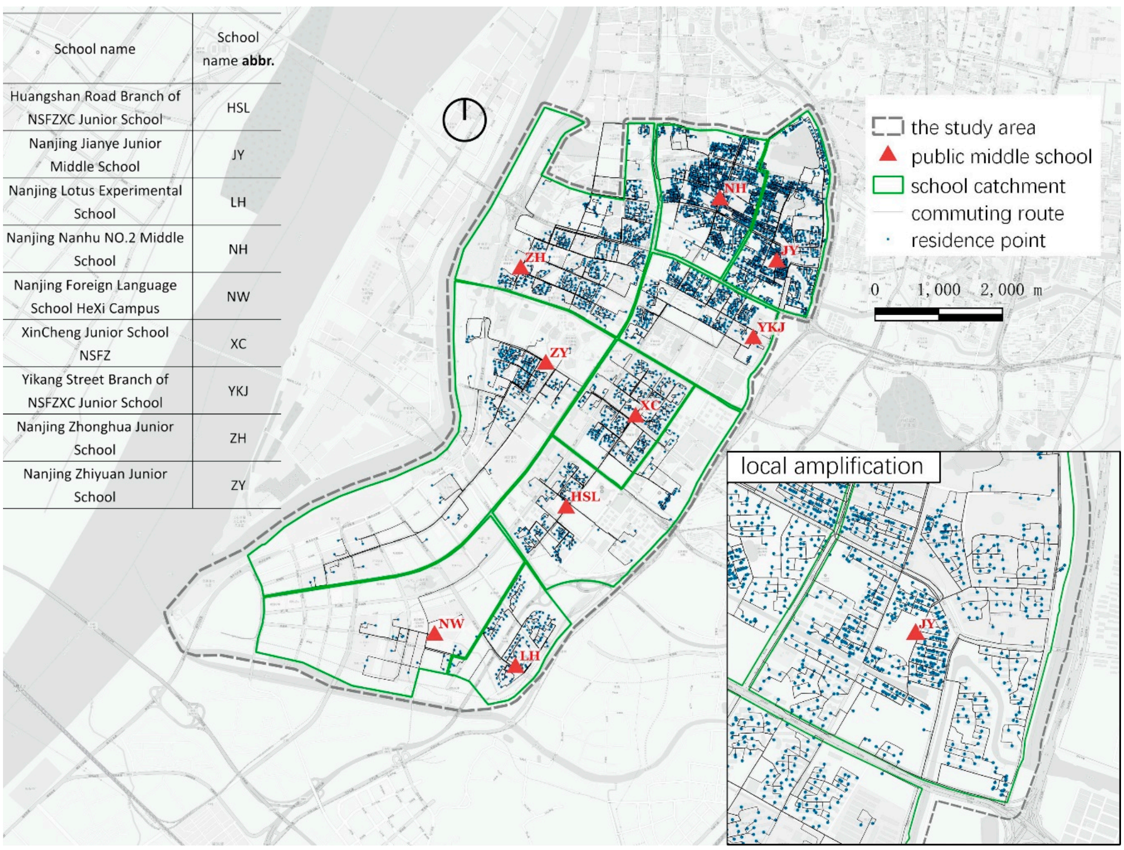


**Figure 1.** The study area showing residence distribution, school locations and catchment areas.

According to the Chinese educational system, each public middle school has its own defined catchment and there must be no overlapping catchments with different schools. Students living in any given school's catchment should be enrolled in that school unless opting out for private schools.

The shapes of these catchments in many areas, and in Jianye District in particular, are quite irregular because linear features such as streets or rivers define their boundaries.

In this study, catchments of middle schools in the study area were visualized in ArcGIS, using information obtained from the respective schools. Geographical coordinates of the schools and residence points, as well as walking routes between each residence point and the corresponding school gate, were acquired through Baidu Map API using Python tools, and mapped in ArcGIS, as shown in Figure 1. Euclidean and route distances between school and housing points within each catchment were calculated, both of which would be utilized for scenario analysis. Neighborhood boundaries were also acquired from Baidu Map API. Since the specific neighborhood population data are not available from the government's population census, the population of middle school students in each neighborhood is estimated based on the 100 m*100 m-resolution population distribution data from the Sixth National Census of China (2010) and students' enrollment in each public middle school in 2018, sourced from the schools' official websites.

### 3.2. Analysis Indexes

#### 3.2.1. Euclidean Distance

Following the government's recommended service radius for middle schools, a 1000 m binary threshold was applied as the crow flies. Students living further than 1000 m from the nearest school are deemed to be subjected to excess commuting distances, and therefore, are unlikely to use active commuting modes.

#### 3.2.2. Route Distance

The Euclidean distance approach is quick and easy to apply, but it can be grossly misleading because travel routes are hardly ever straight. Even with straight-line distances that are short enough, maneuvering around buildings, highways, rivers, etc., can extend "actual" distances to levels unfavorable for active commuting. Using route distances is a more reliable approach. According to previous literature on school commuting mode, it is assumed that students with route distances within 1600 m will choose the active commuting mode for their school trips in this study. This threshold was used in both the present school–home distance evaluation and as a basis for estimating shortened vehicle-traveled distance in the scenario analysis.

### 3.3. Scenario Adjustment

The neighborhood is used as the basic unit for school catchment reassignment and the boundaries were delineated in ArcGIS so that the centroid of each neighborhood could be computed. Walking routes between all the neighborhoods and middle schools in the study area were acquired through Baidu Map API and mapped in ArcGIS, as shown in Figure 2. Given that the government-defined school catchment areas do not strictly adhere to the "attending nearby school" principle, it is possible that some students who live in one school's defined catchment were actually closer to another school. A scenario was developed that students in each neighborhood would be assigned to the school that had the shortest route distance from the neighborhood centroid. Present walking routes, which link schools with neighborhood centroids within the defined catchments, and scenario walking routes, which link neighborhood centroids with the nearest schools, were compared to determine if the neighborhoods were in optimal catchments. If the nearest middle school to a neighborhood was not the recommended school (i.e., the neighborhood was not in the nearest school's government defined catchment), then this neighborhood was reassigned to a new catchment that attached it to the closer school. For the neighborhoods that were not in optimal catchments, students living in these neighborhoods had the chance to reduce travel distances to school through catchment reassignment.

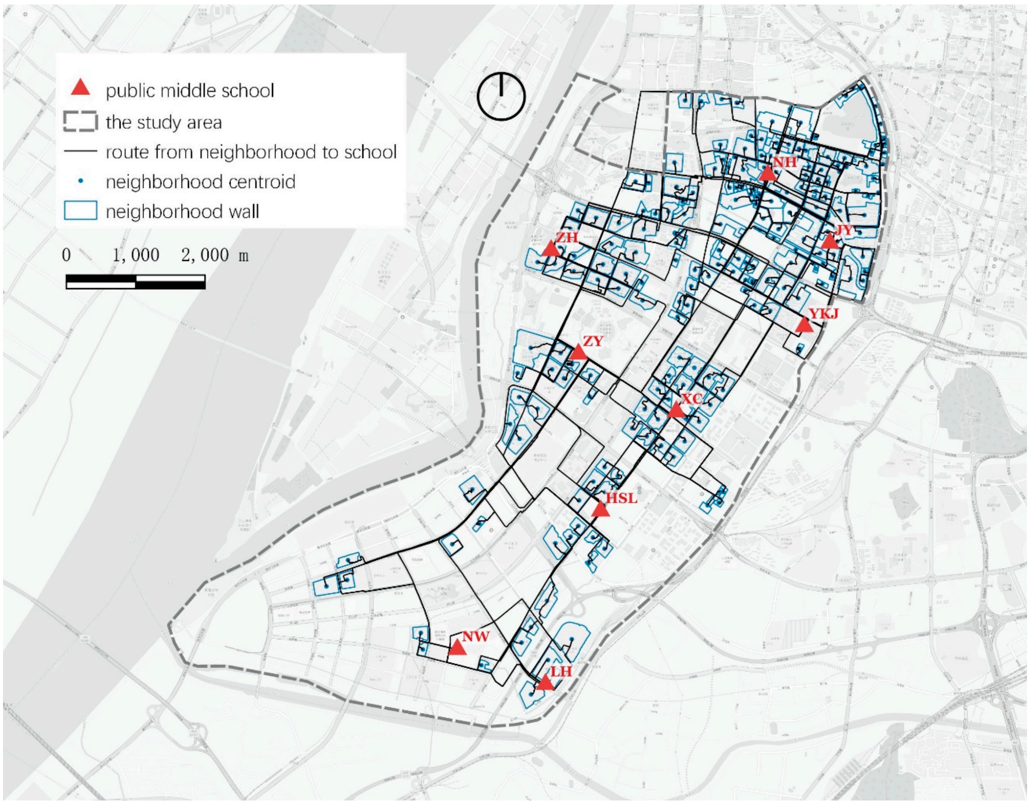


**Figure 2.** Routes from the centroid of each neighborhood to each public middle school.

After school catchment reassignment: Some neighborhoods may still have school route distances longer than 1600 m. For the route distances reduced to 1600 m or shorter, it was hypothesized that this can lead to a modal change in school commuting, i.e., from car-dependence to active commuting. For route distances still exceeding 1600 m after reassignment, it was hypothesized that the transport mode would remain unchanged, i.e., by motor vehicles. Thus, the total of shortened vehicle-distance traveled in the scenario reassignment could be calculated as follows:

$$DS = \sum_{m} DPm{\cdot}Pm + \sum_{n} (DPn - DMn){\cdot}Pn$$

where *DS* stands for shortened distance in the scenario reassignment in a single school commuting, *DP* is the route distance at present condition, *DM* represents new route distance after reassignment, *P* refers to the middle school student population in a certain neighborhood, which is identified as one of the two scenarios described above, i.e., mode changed, *m* and mode unchanged, *n*. It should be noted that pedestrian sidewalks are usually along the motorways in the study area. Thus, walking route distances acquired from Baidu Map are also used to estimate shortened distance of vehicle travel in the scenario analysis.

## 4. Results

To evaluate the present school–home distance in the study area, route distances, as well as Euclidean distances, from each middle school to all the residence points in its defined catchment were analyzed, as shown in Table 1. The descriptive statistics of the Euclidean and route distances from home to school are also presented in the table. In addition to the present home–school distance situation, scenario analysis results are also presented. These are based on the new route distances after school catchment reassignment.

**Table 1.** Present school–home distance within defined school catchments.

| School Name (abbr.) | Euclidean Distance (m) | | | | Route Distance (m) | | | | Number of Residence Points in Each Catchment [1] | Residence Points with Euclidean Distance > 1000 m | | Residence Points with Route Distance > 1600 m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD. | Min. | Max. | Mean | SD. | Min. | Max. | | Counts | Proportion * | Counts | Proportion |
| XC | 535 | 190 | 128 | 1010 | 794 | 245 | 180 | 1543 | 248 | 1 | 0.40% | 0 | 0 |
| NH | 574 | 239 | 25 | 1491 | 794 | 318 | 40 | 2155 | 1365 | 68 | 4.98% | 39 | 2.86% |
| LH | 649 | 343 | 100 | 1419 | 1025 | 431 | 148 | 1902 | 113 | 17 | 15.04% | 12 | 10.62% |
| NW | 687 | 302 | 362 | 1491 | 1085 | 406 | 631 | 2017 | 24 | 5 | 20.83% | 3 | 12.50% |
| ZY | 877 | 940 | 151 | 5020 | 1231 | 1050 | 215 | 5735 | 208 | 46 | 22.12% | 35 | 16.83% |
| HSL | 803 | 492 | 144 | 2080 | 1169 | 706 | 225 | 2700 | 162 | 39 | 24.07% | 36 | 22.22% |
| JY | 720 | 481 | 53 | 2294 | 1073 | 610 | 70 | 3096 | 1146 | 338 | 29.49% | 174 | 15.18% |
| YKJ | 1092 | 507 | 138 | 2000 | 1506 | 544 | 364 | 2704 | 342 | 184 | 53.80% | 143 | 41.81% |
| ZH | 1348 | 682 | 59 | 2984 | 1827 | 940 | 116 | 4147 | 490 | 336 | 68.57% | 276 | 56.33% |
| Total | 775 | 536 | 25 | 5020 | 1100 | 684 | 40 | 5735 | 4098 | 1034 | 25.23% | 718 | 17.52% |

[1] residence points: one point refers to one residence building. * Table sorted by this column.

### 4.1. Present School-Home Distance Analysis

Table 1 clearly shows that there were big variations in the percentage of overlong school–home distance among the different schools. For example, XinCheng Junior School (abbr: XC. Full list of school names and their abbreviations in Figure 1. The same below.) had just one residence point (out of 248 inside its catchment) beyond the Euclidian distance of 1000 m and none beyond the route distance of 1600 m. However, Nanjing Zhonghua Junior School (ZH) had the majority of its catchment residences beyond both the 1000 m Euclidian distance (68.6%), and the 1600 m route distance (56.3%). Nonetheless, most school–home distances were found to be within a proper range to support active school commuting. The average Euclidean and route distances for all schools were 775 m and 1100 m, respectively. Total route distance stood at 4507.9 km. The frequency graphs in Figure 3 also confirm that the bulk of residences lie within the given thresholds and could support active commuting if school catchments were properly defined.

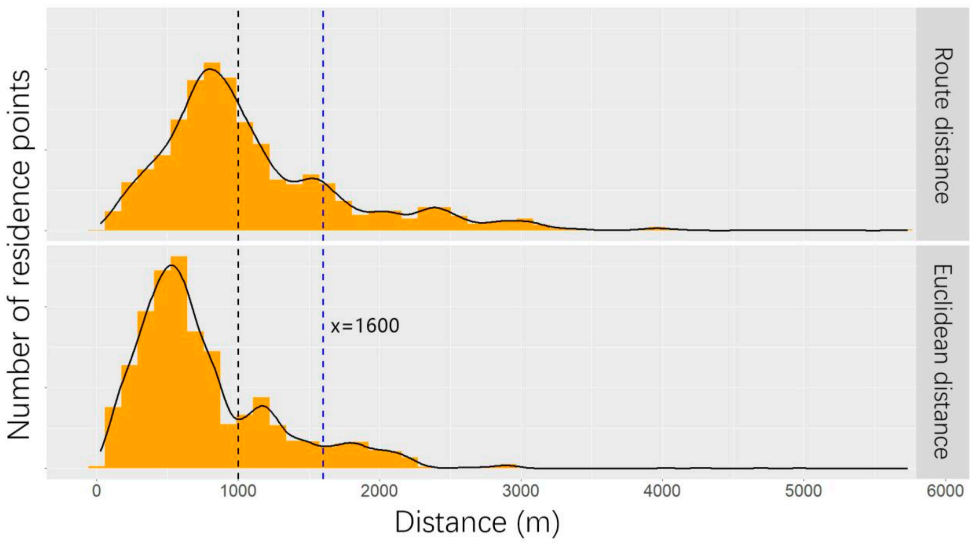


**Figure 3.** Number of residence points in two kinds of distances for middle schools.

There were, however, still some residence points that were beyond the proper distance range from corresponding middle schools, i.e., with route distances more than 1600 m or Euclidean distance more than 1000 m. The total proportions of these make up 17.52% and 25.23% of all residence points in the study area, respectively (Table 1). Even though the policies suggest that Euclidean distance from public middle schools to the residence should be kept within 1000 m, 25.2% of neighborhoods could not meet this requirement, which may lead to route distances being too long for students to walk to school.

The theoretical service scope (1000 m radius) of each school was mapped in ArcGIS, together with the locations of residence points, as presented in Figure 4. The dots in black represent residence points that are within a Euclidean distance of 1000 m from school. In contrast, dots in red represent residence points that are not within the service scope of their present middle school (1034 in number, accounting for 25.23% of the total). It can be seen that some schools are too close to each other (especially for NH, JY and YKJ), which results in an overlap of their 1000 m radius service scopes. Such overlaps can be a redundant distribution of educational resources spatially, especially considering that there are some residences that are not within the service scope of any school. In addition, it was also found that some residences were within the catchment of one school but falling under the service radius of a different school. These residences, which were 158 in number, accounting for 3.86% of the total, despite being within a 1000 m school radius, are also shown in red (Figure 4) because the students residing there were not enrolled in the nearest school. Thus, it can be concluded that, for the purpose of nearby enrollment, the present locations of middle schools and catchments delineation should be reassigned to facilitate active commuting and promote spatial equity of travel.

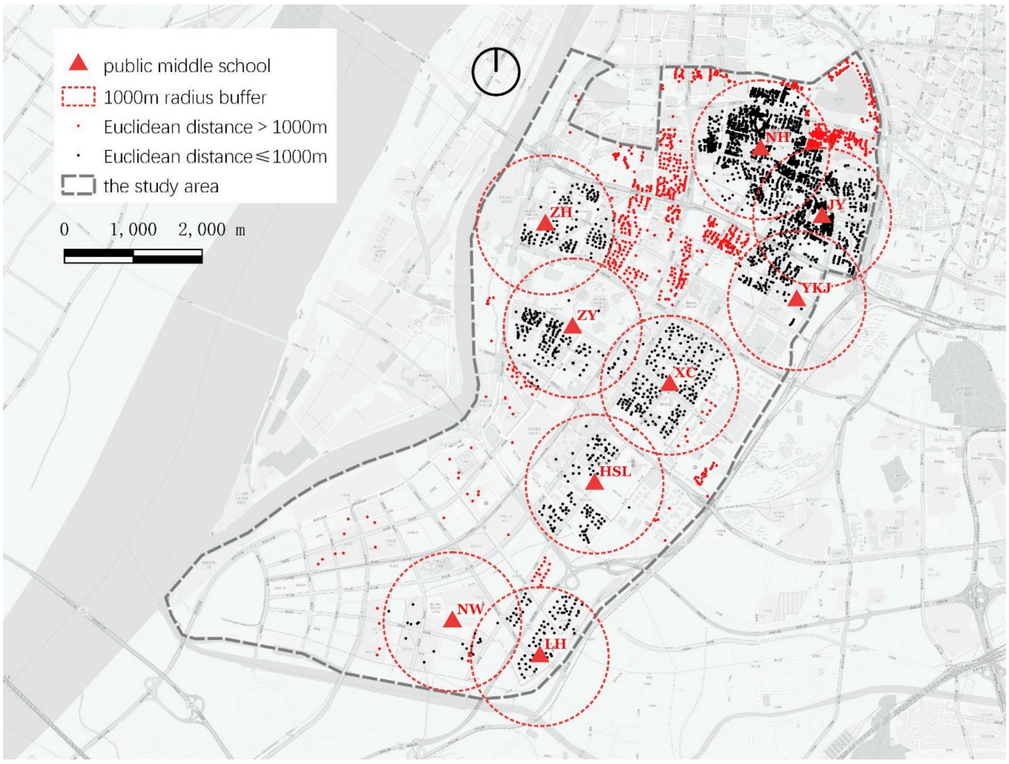


**Figure 4.** Residence points division by threshold of Euclidean distance (1000 m).

Figure 5 shows the relative locations of schools within their respective catchment areas/zones, and the corresponding residences inside those catchments. In this case, the dots in black represent residence points within the route distance threshold of 1600 m to school, while the red dots are residences beyond the route distance thresholds. Observing the spatial relation between each school location and its defined catchment, it is clear that several schools are located peripherally within their catchments and other catchments expand too large, and scenarios lead to students being subjected to overlong school–home distances.

*4.2. School-Home Distance Analysis in Scenario School Catchment Adjustment*

As previously indicated, scenario analysis for school catchment reassignment was performed based on neighborhood units. In catchment re-assignment, a total of 40 neighborhoods (19%) could be reassigned to a closer school. This implies that students in these neighborhoods have a better option for school admission from the perspective of "attending nearby school", through which shorter school–home distance could be achieved if policies for school catchment were strictly implemented. It should be noted that some neighborhoods that needed no reassignment were not within the 1600 m route distance—they were already in the catchment of their nearest school. This means that there were 28 neighborhoods (out of the 40 that were reassigned to nearest school) that remained with route distances longer than 1600 m from their nearest existing public middle school (colored red in Figure 6). These neighborhoods were also all outside the service radius of 1000 m, as Figure 6 clearly shows. Overall, a total school commute reduction of 330.8 km (one way), or 20% decrease, could be achieved in the study area.

The descriptive statistics for the nine schools after catchment reassignment (neighborhood unit scale) are presented in Table 2. Overall, in all the nine schools, more than 10% of neighborhoods inside the defined catchments remained at more than a 1600 m route distance from the nearest school. The best results were at LH and HSL with 12.5% and 15.4% of neighborhoods lying beyond the route distance threshold, respectively. The worst was NW, with as much as 50%, followed ZH with 33.3%. These were also randomly distributed across the district with no obvious spatial pattern. In fact, the best and worst schools were both located furthest south, and in closer proximity to each other than to the rest of the schools.

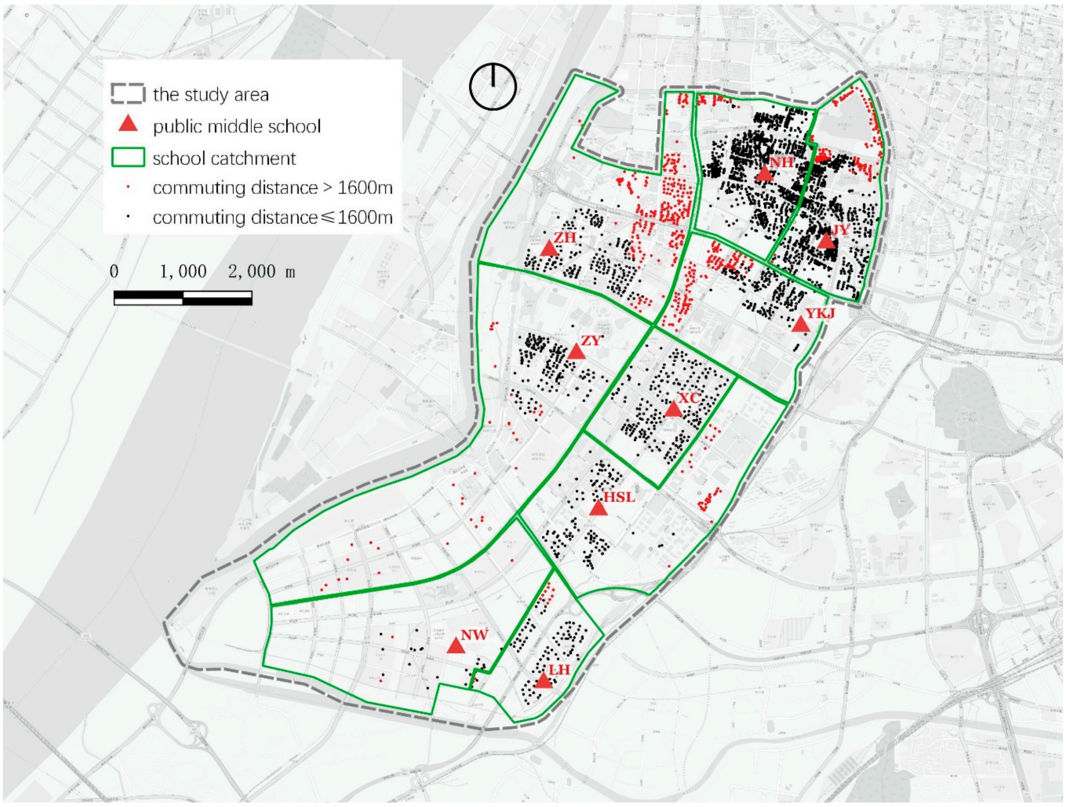


**Figure 5.** Residence points division by threshold of commuting distance (1600 m).

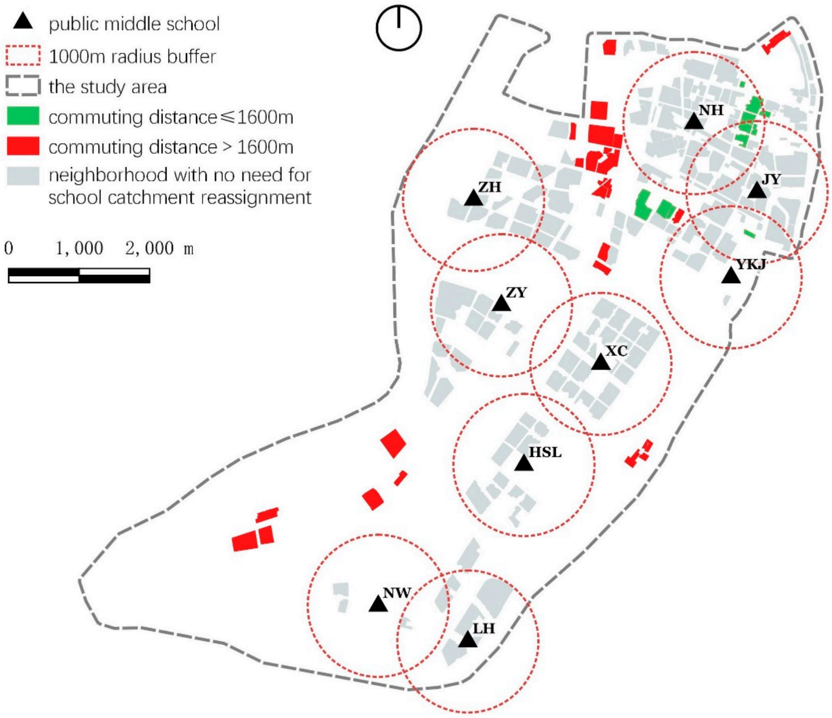


**Figure 6.** Neighborhoods classification in scenario analysis. (Neighborhoods colored in red represent commuting distances that were still longer than 1600 m after adjustment.).

**Table 2.** Results of school catchments reassignment at the neighborhood level.

| School Name (abbr.) | Euclidean Distance (m) | | | | Route Distance (m) | | | | Number of Neighborhoods in Each Catchment | Neighborhoods with Euclidean Distance > 1000 m | | Neighborhoods with Route Distance > 1600 m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ave. | SD. | Min. | Max. | Ave. | SD. | Min. | Max. | | Counts | Proportion | Counts | Proportion * |
| LH | 923 | 671 | 255 | 2407 | 1266 | 713 | 416 | 2778 | 8 | 2 | 25.00% | 1 | 12.50% |
| HSL | 719 | 492 | 269 | 1873 | 1140 | 753 | 536 | 3058 | 13 | 2 | 15.38% | 2 | 15.38% |
| ZY | 735 | 418 | 180 | 1483 | 1149 | 537 | 384 | 2134 | 12 | 3 | 25.00% | 2 | 16.67% |
| XC | 717 | 425 | 182 | 1569 | 1052 | 572 | 238 | 2145 | 25 | 6 | 24.00% | 6 | 24.00% |
| NH | 852 | 462 | 103 | 1820 | 1154 | 599 | 179 | 2404 | 73 | 24 | 32.88% | 19 | 26.03% |
| YKJ | 1022 | 474 | 329 | 1775 | 1449 | 458 | 899 | 2296 | 15 | 6 | 40.00% | 4 | 26.67% |
| JY | 853 | 511 | 106 | 2065 | 1207 | 609 | 136 | 2623 | 37 | 14 | 37.84% | 10 | 27.03% |
| ZH | 918 | 484 | 136 | 1802 | 1265 | 646 | 274 | 2483 | 21 | 10 | 47.62% | 7 | 33.33% |
| NW | 1243 | 752 | 420 | 2085 | 1771 | 1020 | 673 | 2997 | 6 | 3 | 50.00% | 3 | 50.00% |
| Total | 854 | 500 | 103 | 2407 | 1205 | 636 | 136 | 3058 | 210 | 70 | 33.33% | 54 | 25.71% |

* Table sorted by this column.

## 5. Discussion

In many countries around the world, a choice-based system is practiced, which allows parents to decide which school their children can be enrolled in. While this is a "system by default" in many cases, it is often a result of deliberate policy action, particularly in developed countries in Europe and North America [34,56]. This may bring about overlong school–home distances in search for better educational resources. In China, government-led policies recommend specific service scopes for public schools and emphasize the principle of "attending nearby school", which aims to ensure that children live within walking distance from school. However, a lapse in implementation of these polices means overlong school–home distances still remains an issue in many neighborhoods, which consequently reduces the opportunities for active school commuting. This necessitates a reassignment of school catchments in these areas. Indeed, overlong school–home distances in some cases could also be a result of the unequal distribution of educational resources, which disadvantages certain areas/neighborhoods.

The results of this study showed that reassigning the school catchment areas to cover neighborhoods based on the shortest distance could shorten the total home-school distances in Jianye District by up to 20% (330.8km). There was no obvious spatial pattern of excess home-school distances across the nine schools. For instance, the least proportions of residences beyond the threshold distance in respective school catchments were found in XC, NH and LH, respectively (Table 1). These three schools are distributed evenly across the breadth of Jianye District from North to South, with their catchments covering both older and newer settlements of high and low density (Figure 5). The worst performing schools (with highest proportions of catchment residences beyond threshold distance) were located towards the northern and north-eastern parts of the study area (ZH, YKJ and JY), which are closer to the older Nanjing town, but does include lower density developments, particularly around ZH to the West.

After the school catchment reassignment, 28 neighborhoods (out of the 40 total) still remained at over 1600 m route distance from any existing public middle school (Figure 6). Most of these were located towards the peripheries of Jianye District, both in the more compact areas in the northern part, as well as further south where development is dispersed at a relatively lower density. This could indicate an unequal distribution of school locations due to deficiencies in aligning school planning with other urban developments. It could also signify an insufficient number of public middle schools in the study area, which may be attributed to a slow pace of school development that cannot keep up with the speed of urbanization. The result of this is an inequitable access to educational resources, which can disadvantage families who are forced to live on the peripheries for one reason or another (e.g., affordability or availability). To improve the equity of educational resource distribution and facilitate the more sustainable travel patterns, it is necessary to ensure that newer residential developments are accompanied with both adequate planning for and timely provision of educational and other urban facilities/services. Polices ensuring the availability of public schools near residences and enrollment of pupils from the nearest neighborhoods should be adopted and firmly implemented.

It is worth noting that measures imposed by government control and not closely connected with daily life cannot help individual behavioral change for a low-carbon lifestyle [57]. Furthermore, recent literature has suggested that very little effect can be produced when behavioral change programs calling for low-carbon lifestyle focus on single citizens, because they do not account for the socially grounded nature of human behavior [57]. In this regard, proximity planning can play a facilitating role that benefits the individual (through reduced travel costs, physical activity), while also enabling a low-carbon lifestyle. The measures and indicators generated from scenario analysis in this study are directly linked to daily life behavior, and can be seamlessly practiced in society.

However, previous research has proved the great effects of the transport sector on energy saving and emission reduction [58–60]. In the recent COVID-19 epidemic period, traffic restrictions due to the lockdown of many cities significantly reduced the use of motor vehicle, and the air quality has improved with a notable drop in PM2.5 levels detected [61,62]. Besides, the promotion of air quality is conducive to active school commuting [63], which in turn can reduce the use of motor vehicles. Additionally, in the COVID-19 era where travel is discouraged—notably by mass transit systems—to limit the spread of the disease, containing school travel within shorter distances could help limit exposure to the virus and its spread across larger areas. Similar positive effects may also be attained through enhancing the proximity of other urban facilities and services (e.g., jobs, health care and recreation).

Another peculiar problem in China is the high circuity of walking routes due to the low permeability of urban form, which is often a result of neighborhood walls and limited gates of gated dominated. This can increase school–home distances, even if neighborhoods are located within the school's service scope. Even though all neighborhoods that remained beyond the 1600 m route threshold after catchment reassignment were also outside the service radius of any school, reducing super blocks can improve pedestrian permeability and reduce route distances for both neighborhoods outside and within the service areas. Planning policies should also promote mixed land-use and evenly distributed multi-center (or polycentric) developments, which can help improve the spatial equity of access to services as well as to reduce travel distances, particularly for peripheral residences [64]. Furthermore, the current planning agenda of 15 min neighborhoods in China (similar to 20-min neighborhoods in Australia or low-carbon communities in other countries) advocates for distances from residences to public facilities accessed in daily life to be within 15 min of travel time, and can be the context for urban proximity improvement and the basic unit of low-carbon city planning.

## 6. Conclusions

In this study, it was hypothesized that excess school–home distance, regardless of how it is measured, i.e., route distance or Euclidean distance, can cause unnecessary motor vehicle travel. Scenario analysis was developed to estimate the extent to which home–school distances could be shortened to reduce car-dependence and facilitate active commuting. After school catchment reassignment, a total one-way commute reduction of 330.8 km (20.07%) was achieved. It is assumed that this excess distance indicates the extent to which the need for vehicle travel can be potentially reduced in favor of active school commuting and a low-carbon lifestyle. This result suggests that the difference in motor vehicle travel between the current situation and the proposed scenario could be substantial. Moreover, it demonstrates the potential of school commuting's contribution to reducing the use of motor vehicles. Thus, the results of this study provided considerable evidence that school catchment reassignment is needed in the study area. This study also provides important insights into school siting and school catchment assignment policies seeking to facilitate active school commuting, achieve educational spatial equity, and reduce car dependence.

There are some notable limitations in this study. First, the prediction of school commuting mode is purely based on theoretical evidence. Second, other factors that may influence mode choice were not considered in this study. These include the built environment factors such as sidewalks, lighting and tree shading along the route [12], weather conditions [65], traffic volume [66] and other perceived factors such as security. Third, only public schools, and no private schools, were considered for analysis in this study. This means that some areas that appeared to be underserved and subjected to overlong school–home distances might actually be within recommended distances from a private school. Lastly, the Modifiable Areal Unit Problem (MAUP) emanating from the use of the neighborhood as the unit of analysis. This is mainly because distances from various residence points across the neighborhood are averaged, which may not accurately represent distances, particularly for students living further from the center of the neighborhood. Future work can take these factors into consideration, augmented by a survey to understand the commuting modal choice of students more clearly. A quantitative estimation of energy saving and emission reduction levels (resulting from the reduced commuting distances) can also be performed to make the results more compelling for policy adoption and environmental intervention.

## 7. Patents

1. Computer software copyright: Peripheral walking routes extractor software [abbreviation: Lines] V1.0
2. Computer software copyright: POI extractor software [abbreviation: POIs] V1.0
3. Computer software copyright: AOI extractor software [abbreviation: AOIs] V1.0
4. Computer software copyright: Walking simulation trip generator software [abbreviation: Walking] V1.0

**Author Contributions:** Conceptualization, Anqi Liu and Zhen Xu; methodology, Anqi Liu and Zhen Xu; software, Anqi Liu and Zhenqi Zhou; validation, Anqi Liu, Keone Kelobonye, and Zhen Xu; formal analysis, Anqi Liu and Qiuxia Xu; investigation, Anqi Liu and Qiuxia Xu; data curation, Anqi Liu and Zhenqi Zhou; writing—original draft preparation, Anqi Liu, Keone Kelobonye; writing—review and editing, Keone Kelobonye and Zhen Xu; visualization, Anqi Liu, Keone Kelobonye and Zhen Xu; supervision, Zhen Xu and Lingyun Han; project administration, Zhen Xu and Lingyun Han; funding acquisition, Zhen Xu and Lingyun Han. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by Humanity and Social Science Foundation of Ministry of Education (18YJCZH043, 20A10298008) and the Priority Academic Program Development of Jiangsu Higher Education Institutions.

**Conflicts of Interest:** The authors declare no conflict of interest.

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