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How accessibility to schools is not (just) a transport problem: the case of public school choice in the city of Malmö, Sweden

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Abstract

There is currently a lack of studies exploring how transport investments and school admission policies in a city can affect the distribution of accessibility to schools. The aim of this study is to investigate if, for whom, and the ways in which, accessibility to schools can change following (1) a change to the city's public school admission policy and (2) investments in public transport infrastructure and adjustments to the public transport system. We draw on the case of Malmö, Sweden to examine the potential effects of these changes. This study is focused specifically on those in grades 7–9 (aged approximately 13–15), a group whose independent mobility is starting to take form. A geospatial analysis was carried out in order to compare the change in demographic makeup between school catchment areas (real and hypothetical) before and after the changes were made. The geospatial analysis utilises a cumulative opportunity accessibility model that takes into account typical public transport travel times both before and after these new measures were implemented. Findings indicate that the (hypothetical) school catchment areas have been redistributed to a considerable extent following both interventions, but particularly following the change to the public school admission policy. These redistributions have in turn resulted in changes in the socio-economic characteristics of the hypothetical school catchment areas. While the redistribution of school catchment areas could potentially change the socio-economic composition of schools in Malmö, the effects are not equally distributed throughout the city. While the addition of the new train line was the main focus of this study, it was found that other changes in the public transport system between 2018 and 2019 also played a role in determining which schools students could and could not access. The findings from this study highlight the importance of carefully considering the interaction of different effects when assessing policy alternatives.

Keywords Accessibility to schools, Children's mobility, Mobility of teenagers, Independent mobility, Public transport, Transport equity, Sweden

1 Introduction

1.1 Background

A lack of focus on school admission policies in the analysis of accessibility to schools has been problematised, with some calling for an increased focus on the integration of transport justice and school segregation perspectives [3]. As a result of this lack of focus, the knowledge regarding which measures (transport, school policy admission or other) have the greatest propensity to affect the type and number of schools that can be accessed by school children is limited.

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Investments in transport infrastructure as a means of improving accessibility can indeed be undermined by other forms of policies. At the same time, travel distances to schools usually increase for those attending schools of choice (see Bierbaum et al. [3] for a discussion), with (shorter) distances to schools associated with greater use of sustainable modes of transport [27].

Children's and teenagers' independent travel to school—long neglected as a research and policy area—has in recent years been receiving increasing attention, albeit from low levels. This attention has been largely focused on modal choice, with a particular emphasis on the (declining) use of active travel modes (e.g. [6, 9, 12]). The mobility carried out during childhood has been found to shape mobility habits and preferences for adulthood [35], while the benefits of independent mobility during childhood have been highlighted in a range of studies (e.g. [17, 36]). Such benefits include gaining a knowledge of the city's transport system and gaining experience in navigating the city [16, 28, 37], see [10]. Nonetheless, travel to school has in many contexts seen an increasing dependence on the car, most often in the form of lifts from parents, and corresponding declines in active, independent travel (e.g. [5, 10, 12]). However, while most studies emphasise the many benefits of active and independent travel, few consider the systematic mechanisms behind these modal choice trends. Accessibility is an important pre-condition for mobility (in the form of transport mode, distance, speed, etc.). Further insights into (changes in) accessibility to schools over time are therefore vital to better understand these trends.

There has been relatively little emphasis on the potential of public transport (combined with active travel) to meet children's and teenagers' travel-to-school needs in the literature to date. This is with the exception of e.g. Jones et al. [16]. Furthermore, the literature to date has been overwhelmingly focused on the travel of primary school children, with rather few studies focusing on teenagers in particular. This is again with the exceptions of e.g. Westman et al. [37], Westman et al. [38], Jones et al. [16]. Lastly, most studies addressing accessibility to schools have had a focus on factors such as residential location and distance to schools, with the implicit assumption that residential and school locations remain constant. There has so far been little or no reference to other factors such as school admission policies (see also Bierbaum et al. [3]). Furthermore, there is a lack of studies exploring how the interaction between other factors such as school admission policies and the (changing) provision of public transport affect accessibility to schools, and for teenagers in particular.

1.2 Study aims

For the current study, we examine the potential effects of changes to the public school admission policy and investment in public transport infrastructure. We draw on the case of Malmö, Sweden where this combination of changes is likely to change accessibility to schools. Since the academic year of 2019–2020, changes to the public school admission policy have meant that adolescents/teenagers aged approximately 13 (starting in grade 7) have been assigned a school place according to what is termed the 'relative proximity principle' (Malmö [20] (if these grades are not provided for in the school the student has attended thus far), instead of being assigned a school place based on the school catchment area (SCA) in which they live, as was previously the case. This change to the public school admission policy is also likely to have generated the need for teenagers to travel or be transported greater distances to school (see [3]).

During the academic year 2018–2019, the Malmö Ring Railway Line was opened in the city (in December 2018). The argumentation for the investment in this railway line was largely based on its anticipated positive social effects and the expected inducement of travel between the eastern and western parts of the city of Malmö, so as to help counteract socioeconomic segregation, with trips to work and education specified as particularly relevant in this instance (Malmö [22]).

These interventions – and the interaction between them – are likely to have had a considerable effect on accessibility to schools for different groups of teenagers in the city. This study highlights the intertwined relationship between school admissions policies, public transport investment, and accessibility. The new school admissions policies allow for children to attend schools that are further away. This could in theory help address segregation since the students do not need to stay in their home neighbourhood. Instead, they might attend a school in another neighbourhood. In Sweden, it is not uncommon for children, especially those aged approximately 13–15, to make trips on their own [4]. This means that the outcome of the changed school admissions policy could depend in part on the ability of the public transport system to move children from their homes to different schools since children cannot drive and some schools may be too far away to access on foot or by bike. This study is focused specifically on those in grades 7–9 (those aged approximately 13–15), as the independent mobility and travel habits of this group are starting to take form [16].

2 Literature overview

2.1 Public transport investments and social issues

Infrastructure investments have in recent years been increasingly justified by social sustainability arguments [15]. Such arguments often frame investments in transport infrastructure and assumed improvements in accessibility as a means of alleviating social issues such as transport-related social exclusion (see [18]). However, some have argued that there is a lack of ex post studies of transport investments (e.g. [2, 11]). This leads us to question whether such transport investments do improve accessibility for those intended, and alleviate social issues, as intended. Ex ante studies often seek to simulate and capture potential effects and serve as an indication of what to expect in terms of effects, before the effects have been felt and before enough data on such effects is readily available.

2.2 Children's mobility

Striving to provide accessibility by public transport for all groups (particularly at-risk groups) could help to alleviate serious societal issues such as transport disadvantage and transport-related social exclusion [18, 19], and forms of segregation. Providing accessibility for all is emphasised in Sweden's national transport-political goals, with the importance of children's independent mobility explicitly stressed (prop.2008/09:93) [31]. However, while the relationship between accessibility and social inequalities has been receiving increasing attention in recent years, this focus has been almost exclusively on the accessibility of adults [36], most commonly with a focus on accessibility to jobs in particular. The accessibility of children has been overlooked. It has been argued that this is most likely due to an implicit assumption that improving accessibility for adults will de facto mean improvements for accessibility among children, which is not necessarily the case (see the argumentation in Waygood et al. [36]. It has also been argued that, while the mobility of children is often framed as rather straightforward and simple in the literature, this is not actually the case. This is due to the complexities and intricate interdependencies inherent in the mobility of children [23].

The positive aspects of independent mobility by public transport among children and teenagers have been studied by a limited number of researchers, with the benefits of socialisation and gaining a knowledge of the city (and its public transport system) and how to navigate it highlighted [16, 28, 37], see [10]. This implies that the instrumental value of mobility for reaching a specific destination is not the only benefit. The intrinsic value of mobility and the knowledge and experiences gained in transit are likely to be just as – if not more – important.

Another study, based in the Stockholm region of Sweden, details the mobility 'licenses' (permits to carry out different kinds of activities) secondary school children have been granted by their parents or legal guardians, finding that 94 per cent of secondary school children (in grades 7–9, aged c. 13–15) had been granted the license to come home from school independently, while only 78 per cent were allowed to go out after dark [4].

Travel to school has in many contexts during the last number of decades seen a trend of increasing dependence on the car and a corresponding decreasing share of active travel. It was for instance found that the modal share for walking to school had declined 8 percentage points among those aged 14–15 for the period 1986–2001 in the Greater Toronto Area [5]. Several have investigated the factors and socio-demographic aspects involved in this decline (cf. [10]). Guliani et al. [12] highlight that several studies report a strong negative correlation between school travel distance and active travel to school (see also Rothman et al. [27]). While some literature does explore the potential for children to use public transport to access schools [13, 24, 26, 39], very few have taken admission policies, (administrative and functional) school catchment areas and their combined potential to change school locations among populations into account in the analysis of such trends.

3 Research gaps

We usually know relatively little about how accessibility is distributed as a result of public transport investments [19], often owing to a lack of ex post studies. However, we know even less about how accessibility is redistributed following changes in school admission policies [3]. While it may be straightforward to measure and predict the accessibility implications of an infrastructure intervention, the combined accessibility implications of an infrastructure intervention and a policy intervention are even more complex. By measuring accessibility to schools prior to and after (1) the change to the school admission policy and (2) the opening of the Malmö Ring Railway Line, we can examine what kinds of changes have taken place and for whom. As such, we can then examine what such changes might mean in terms of accessibility to different schools, and for different groups. This study aims to fill the identified gap in research about how changes in school admission policies are related to accessibility to schools while simultaneously taking into account the effects of the Malmö Ring Railway Line. The railway line and the school admission policies might seem unrelated, but it is important to keep in mind that in the Malmö context, the two measures are both viewed as means to address segregation and both affect who has access to which schools. Furthermore, the two measures

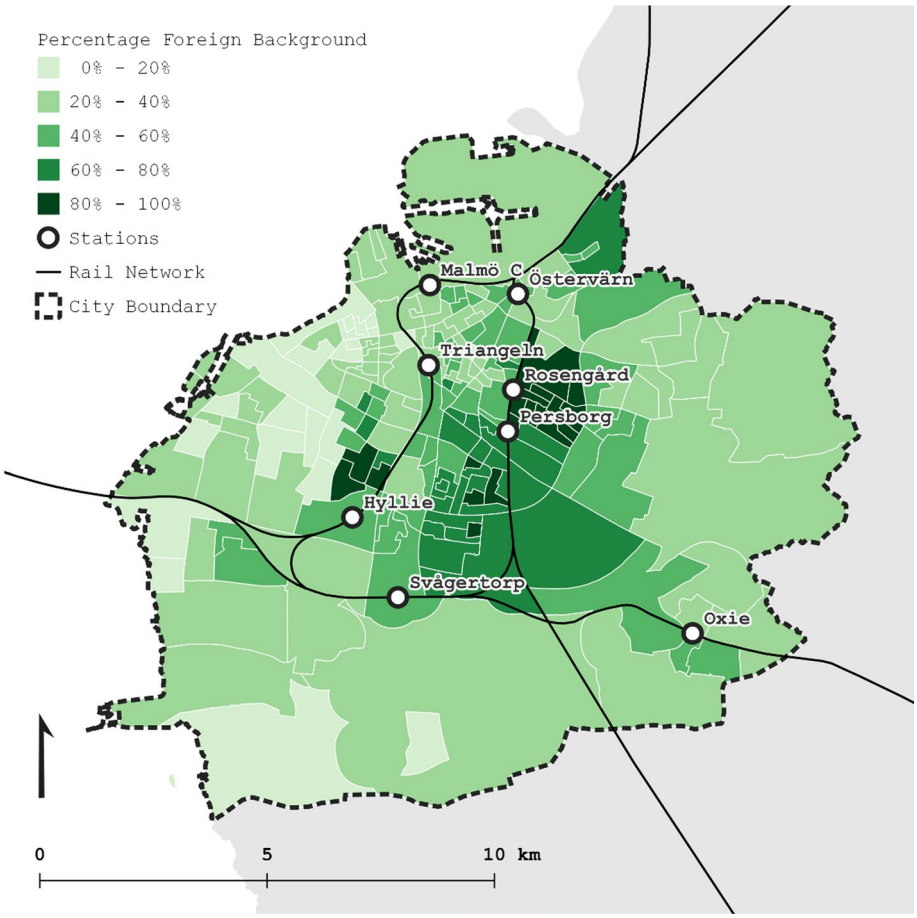

Fig. 1 Context map of Malmö showing the proportion with a foreign background in each area. Data source: Statistics Sweden [29]

were implemented within a year of each other, meaning it is difficult to see how each measure affects accessibility unless they are both considered.

4 Malmö case study

Malmö has a population of around 350,000 and is Sweden's third largest city. Almost half of the population have a background from outside of Sweden [30]. Demographically, Malmö's population is relatively young, with almost half of the population under the age of 35 (Malmö [21]). It is located in the Southwest of Sweden in the Greater Copenhagen polycentric region, physically connected to Denmark with the Öresund fixed link (tunnel and bridge) which includes a railway line and motorway. While the economy and labour market were previously dominated by the shipbuilding industry until the 1980s, Malmö is transforming and has in recent years had the ambition of re-establishing itself as a knowledge economy city [1]. The city has experienced rapid population growth since the 1980s and experiences elements of segregation. In general, higher income groups and those with Swedish backgrounds are overrepresented in the western neighbourhoods, and lower income groups and those with foreign backgrounds are overrepresented in the eastern neighbourhoods and in the outskirts of the city (see Fig. 1).

A number of measures and initiatives intended to address segregation and facilitate integration in the city have been implemented, some being more successful than others (see e.g. [14]). Some neighbourhoods have experienced and continue to experience gentrification processes, especially during the last two decades. This study examines the effects of two interventions: the change to the city's public school admission policy, and the opening of the Malmö Ring Railway Line in the city.

The change to the city's public school admission policy took place following a change in the national legislation governing school admission.[1] Previously and up until the

[1] The School Law'*Skollagen'* in Swedish (*9 chapter 12 and 15 §§, 10 chapter 24 and 30 §§, 11 chapter 24 and 29 §§*).

academic year 2017–2018, children were automatically admitted to a public school (if their parents had registered for them to attend a public school) according to the SCA in which they lived. However, the school admission policy was liberalised in 2018. These changes were legislated for in The School Law. Since then, parents/legal guardians have the right to state a preference for, and rank in order of preference, several schools in any part of the municipality, not just in the area in which the child lives.[2] School admission is then guided by the 'proximity principle', which means that one child's right to choose a school should not infringe on the right of another child to attend a school in close proximity to their home [32]. The term 'proximity' is not defined in the legislation, and it is up to each municipality to set out the applicable criteria for school admission (ibid.). Municipalities have, as such, considerable scope to form their own public school admission policies.

The 'relative proximity principle', applied in the city of Malmö, means that if two children apply for the same school place, the child with the greatest relative distance to the alternative (next selected by legal guardians/parents) school will have the right to the place. Distance is measured using the route from the child's home to the school, and to the next alternative school, and so forth. The difference between the two is the relative distance. Relative proximity is compared for all who apply to the same school [20]. There are relatively large disparities between the schools in Malmö on a number of parameters [33], own analyses), meaning that measures to counteract school segregation are treated as imperative.

In December 2018, the Malmö Ring Railway Line was opened in the city. The ambition was to induce travel between the eastern and western parts of the city of Malmö with trips to work and education specified, whilst also aiming to densify the station areas [22]. One of the explicit intentions with the opening of this railway line was largely focused on its socioeconomic effects (cf. [14]). While it is unlikely that children will go on very long train journeys to get to school, it is important to keep in mind that this rail line only operates within Malmö and can easily be used to connect one part of the city to another, especially when combined with other public transport services. It is not unreasonable that a child could use the rail line as part of a journey to school in less than 30 min.

5 Methods

5.1 Estimation of school catchment areas

For this study, we compare accessibility to schools for the school catchment areas (SCAs) in cross-section 1 (academic year 2017–2018, with pre-defined SCAs, depicted in Fig. 2) to the hypothetical accessibility-based SCAs in cross-section 2 (academic year 2018–2019, had the school admission policy changed[3] but the railway line not yet opened), and compare them to those in cross-section 3 (academic year 2019–2020, after the introduction of school choice among public schools for grade 7, and after the opening of the ring railway line). The SCAs for cross-section 1 were provided by the city's School Authority (see Fig. 2). The socio-economic characteristics of these SCAs were then estimated by aggregating micro-data from the LISA (Longitudinal integrated database for health insurance and labour market studies) database,[4] organised in a 250 m grid (and in some cases, a 1000 m grid due to privacy issues) to approximately correspond to the pre-defined SCAs.

The geospatial analysis involved three main steps. First, the study area was split into smaller geographic units. In this case, grid cells were used (see the grid cells in Fig. 9). The grid cells acted as the basic unit for the analysis. In this particular case, the grid cells and the socio-economic data associated with them were extracted from the LISA database. However, a similar approach could be used with a different geographic unit if socio-economic data is available.

Next, travel times were calculated between all possible school and grid-cell OD pairs. For example, travel times were calculated between School A and the grid cells, then travel times were calculated between School B and the grid cells and so on. This process was done twice, once for cross-section 2 (after the change to school admission policies, but before the opening of the Malmö Ring Railway Line) and once for cross-section 3 (after the opening of the Malmö Ring Railway Line). See description above.

Calculated travel times were used to estimate the redistributed SCAs on foot and by public transport for cross-section 2 (selected date: 16 October 2018), and cross-section 3 (selected date: 15 October 2019), respectively. This was done by taking the median travel time of estimates with departure times at five-minute intervals within the 07:20–07:40 timeframe, with arrival at school

[2] Since the academic year 2018-2019 (2019-2020 for grade 7), parents/legal guardians of children living in Malmö have had the option to choose and rank preferred schools in the municipality. Some students do not however (need to) avail of this option when attending schools that provide for students up to grade 9. In this study this effect is not accounted for. Instead, it is assumed all students could select/rank preferred schools.

[3] Although the change was not actually introduced for grade 7 until 2019–2020 it was necessary to simulate before the opening of the railway line in order to isolate the two effects.

[4] All data used from the LISA database was the most recently available data (from 2017) but was reorganised to reflect the new SCAs as produced from the accessibility estimates for the different cross-sections. In this way, the changing socio-economic situation in different parts of the city is not captured. Instead, constant values are used.

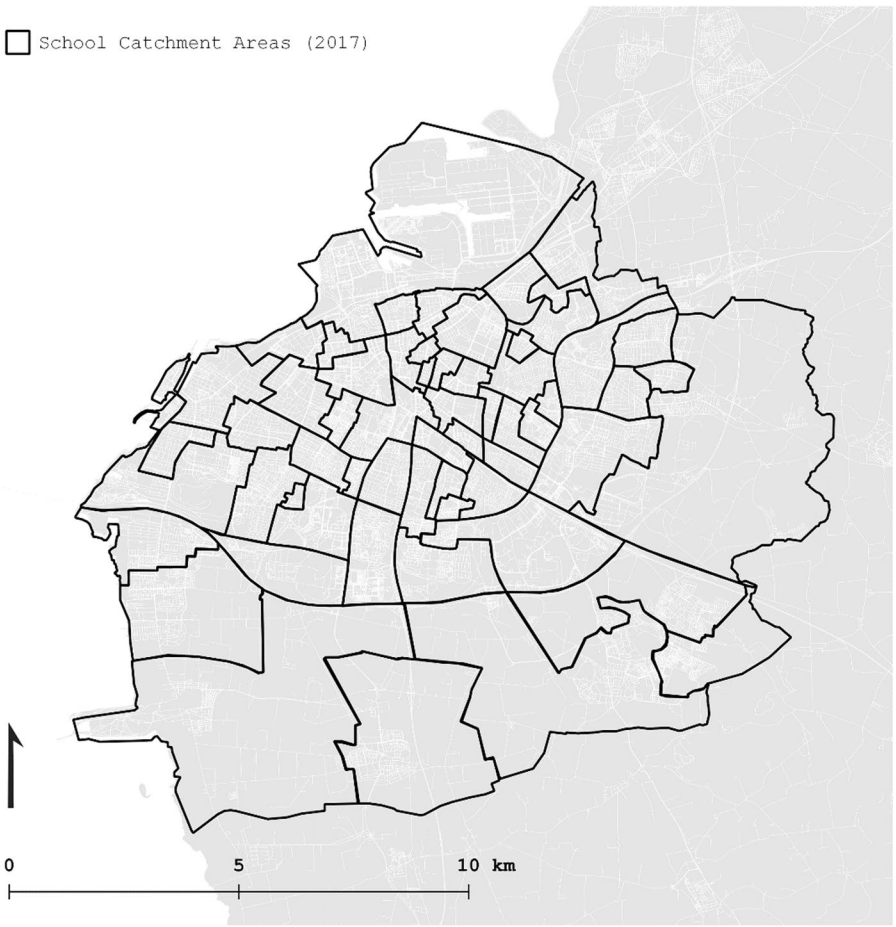

Fig. 2 Map of Malmö with the pre-defined SCAs outline. Data source: provided by Malmö Municipality

estimated to be concentrated around 08:00.[5] The maximum trip duration of 30 min was applied, including both public transport and walking segments. These estimates were derived using General Transit Feed Specification (GTFS) data, OpenStreetMap (OSM) data and the r5r package in R [25]. The GTFS data and the OSM data are both necessary inputs for the r5r package. Two different sets of GTFS data were used, one corresponding to the cross-section 2 date and one corresponding to the cross-section 3 data in order to take into account the public transport schedule before and after the implementation of the Malmö Ring Railway Line.

[5] School starting times differ but are usually concentrated around 08:00–08:10 for grades 7–9, with arrival at school estimated to be concentrated around 08:00. Schools generally open from 07:30. Some generalisations and assumptions regarding the locations and operation of schools have been applied. It is thus acknowledged that the location and operation of a limited number of schools e.g. using temporary facilities in a different location at the time could be misrepresented. The locations of some planned schools have also been included in the analysis.

Finally, the new population catchment areas for schools were then estimated by aggregating all cells with centroids falling within these parameters in order to reflect the redistributed SCAS. The SCAs in cross-section 2 and cross-section 3 are used to show (1) the number of schools accessible from each grid cell within 30 min (see Fig. 8), and (2) the number of students who can access each school within the same 30-min time frame (see Fig. 6). The first measurement is calculated by using the centroid of each grid cell as an origin point, then measuring the travel times to all schools. The schools that can be reached within 30 min are counted and the schools that cannot be reached within this time constraint are not counted. The second measurement (number of students who can access each school) can be calculated from the output of the first measurement (number of schools accessible from each grid cell) since it is known which schools are within 30 min of which grid cells and vice versa. This means that, for each school, it is possible to create a list of grid cells that can be used as origin points and reach the school within 30 min. The sum of

		Post school admission policy change		Post Malmö Ring Railway Line	
		Percentage change in proportion of SCA born in Sweden	Percentage change in median disposable income of SCA	Percentage change in proportion of SCA born in Sweden	Percentage change in median disposable income of SCA
N	Valid	52	52	57	57
	Missing	5	5	0	0
Mean		11.3649	1.0123	.7300	-.0384
Median		-5.5456	-.3261	1.0445	.2180
Std. Deviation		56.02411	15.52808	12.13111	2.51515
Range		267.40	71.48	89.36	18.39
Minimum		-44.40	-32.84	-41.91	-11.44
Maximum		223.01	38.64	47.46	6.95

Fig. 3 Descriptive statistics of hypothetical changes to SCA composition

the student populations in each of these grid cells can be calculated, thus showing how many students can reach each school within 30 min. This is essentially a cumulative opportunity measure since the number of students who live within 30 min of each school are counted as having access to the school and those who are outside of the 30-min catchment area are not counted as having access to the school.

It is important to note that the SCAs for cross-section 2 and cross-section 3 are based on travel times and are not confined to clear administrative boundaries. Unlike the SCAs for cross-section 1, these SCAs are not mutually exclusive. It is entirely possible, and likely, that a child lives within multiple SCAs if multiple schools are within 30-min the child's home. Unlike the SCAs in Fig. 2, the SCAs from cross-section 2 and cross-section 3 overlap and are not easy to clearly visualise.

5.2 Analysis of the changes in composition of the hypothetical school catchment areas

The analysis focused on identifying the overall accessibility to schools based on a hypothetical situation in which a combination of public transport and walking is exclusively considered as the access mode(s). The analysis assesses how accessibility has changed and how many schools could be reached from each grid cell after the opening of the Malmö Ring Railway Line.

Proxies used to reflect socio-demographic characteristics included disposable income[6] and demographic data (the numbers of children living within the grid cells and the proportion of the population born in Sweden). For the former, we studied the changes in the median disposable income following (1) the change in the city's public school admission policy and (2) the opening of the Malmö Ring Railway Line. This was in order to give an indication of the level of segregation/integration of different income groups and students from different socio-economic backgrounds in the different cross-sections' hypothetical SCAs. For the latter, we examined the percentage change in the number of children aged 11–15 living in the hypothetical SCAs between cross-sections 1, 2 and 3, and the percentage change in the proportion of the population born in Sweden (Fig. 3).

6 Results

The findings show that the hypothetical SCAs have been redistributed to a large extent in both cross-sections. This impact can be seen to a greater extent with the change to the school admissions policy (see Figs. 4 and 5) and to a lesser extent with the opening of the Malmö Ring railway line (see Figs. 6 and 7).

[6] Disposable income in this instance consists of income and positive and negative social transfers. Tax rebates for pension payments are counted as a negative social transfer. The disposable income value is then divided by the household's respective consumption weights.

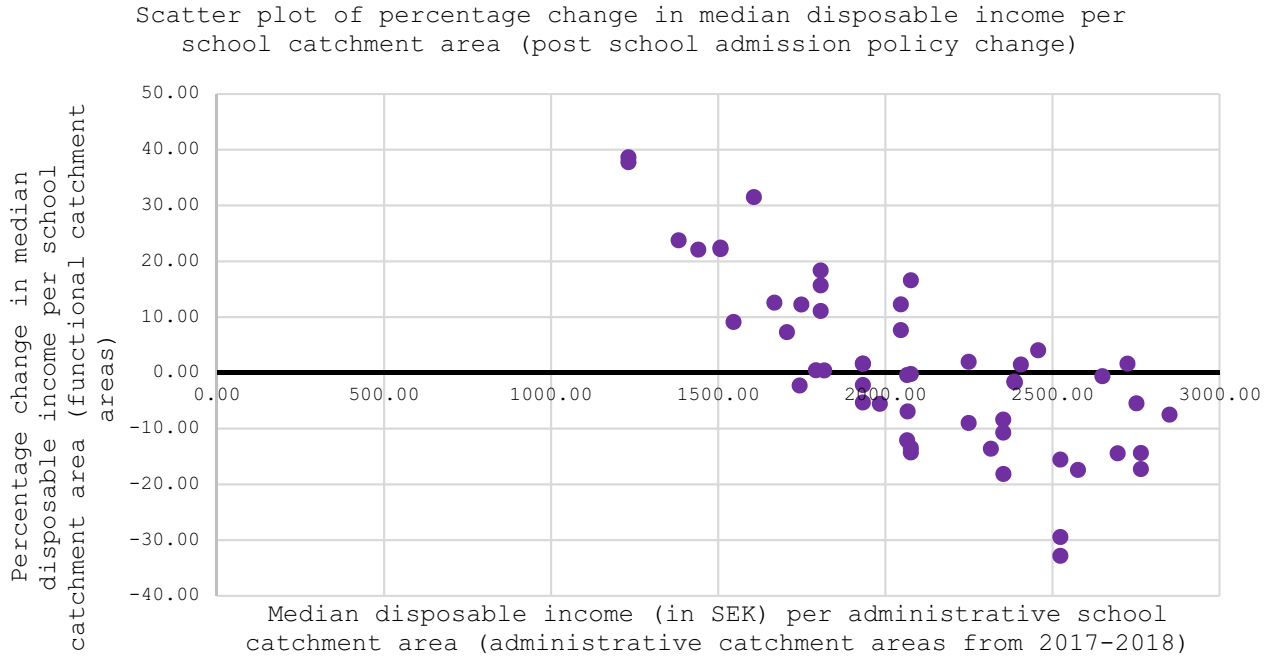

Fig. 4 The hypothetical changes in median disposable income per calculated accessibility-based SCA (after the change in the public school admission policy)

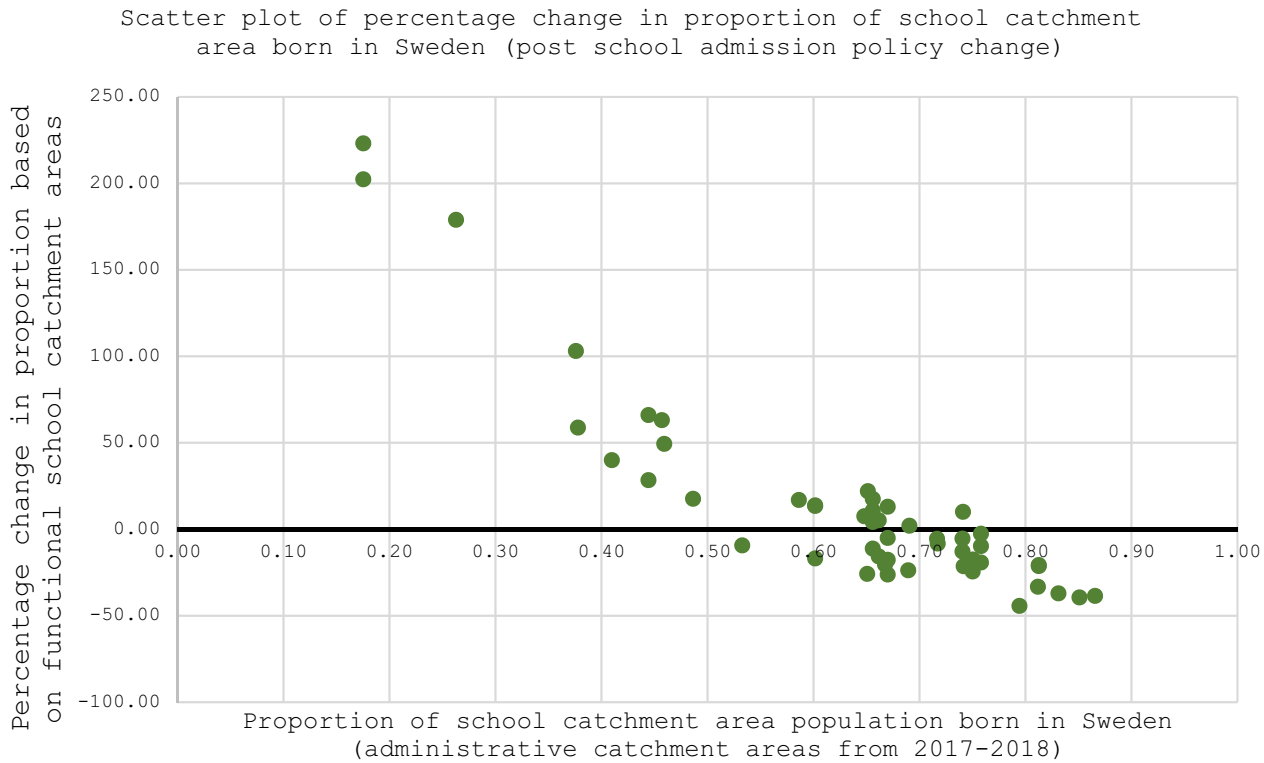

Fig. 5 Scatter plot of percentage change in proportion of school catchment area born in Sweden (post school admission policy change)

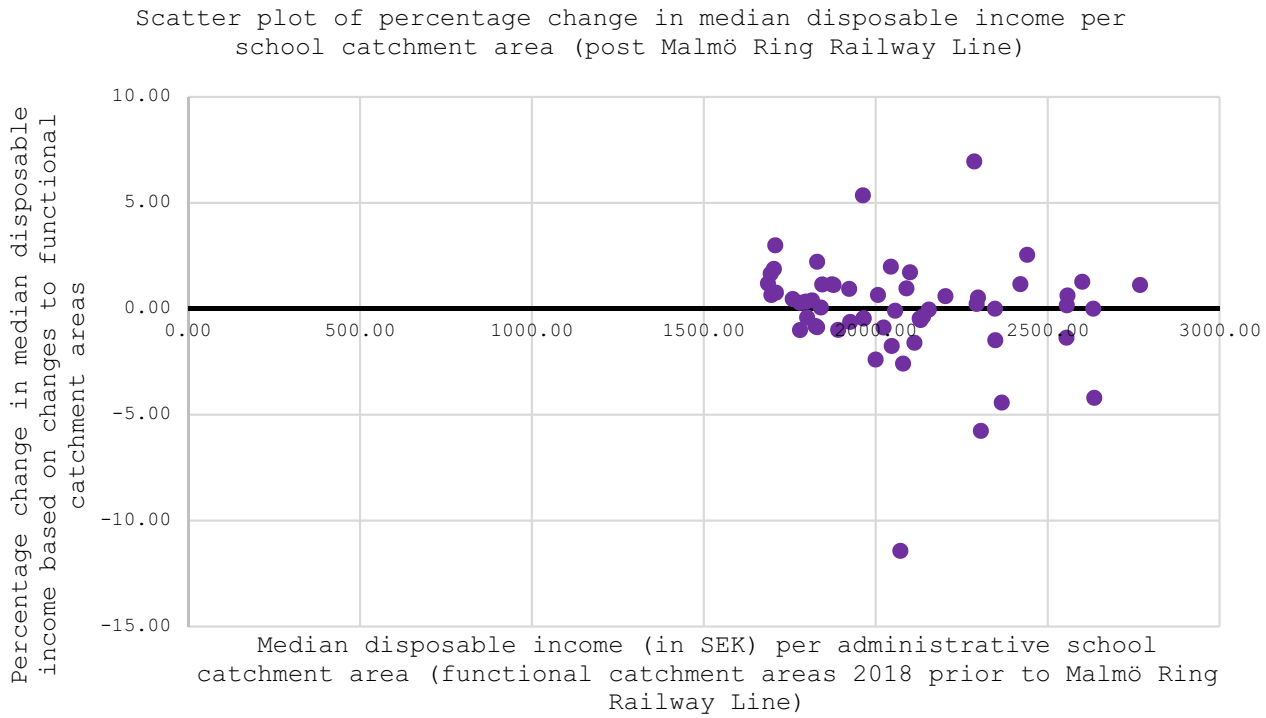

Fig. 6 Scatter plot of percentage change in median disposable income per school catchment area (post Malmö Ring Railway Line)

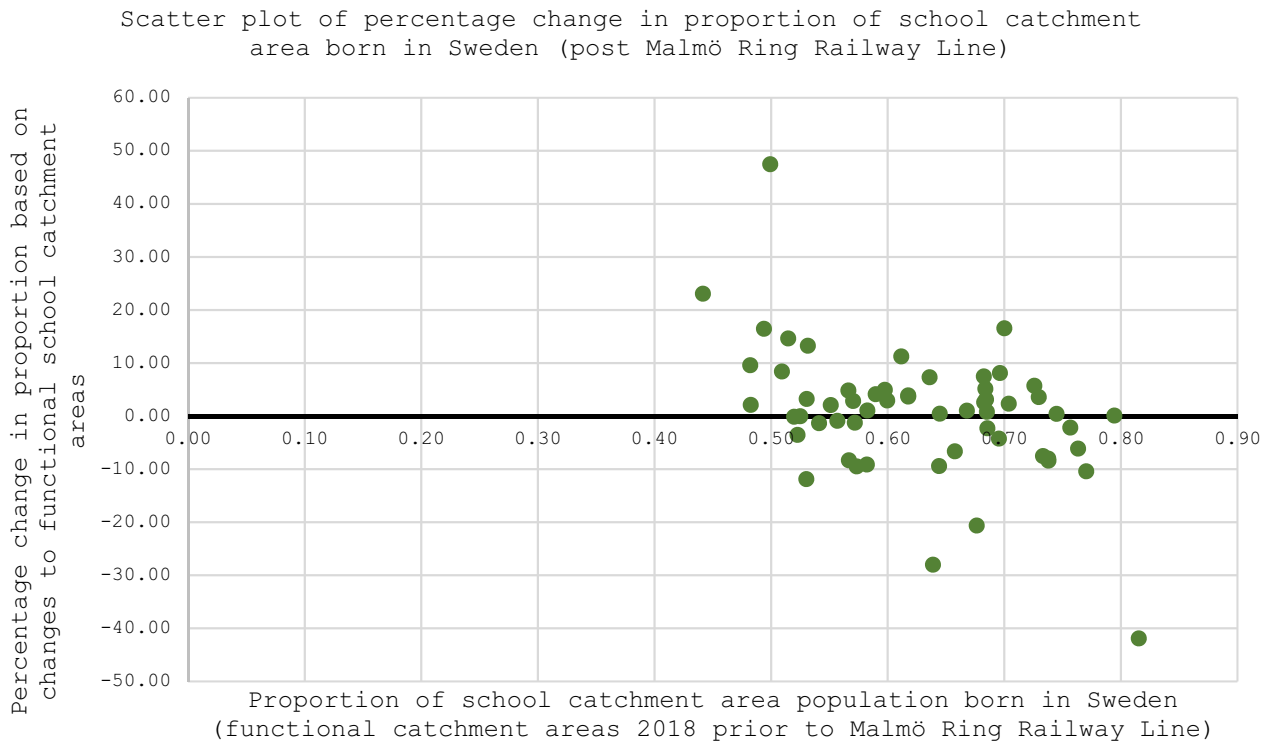

Fig. 7 Scatter plot of percentage change in proportion of school catchment area born in Sweden (post Malmö Ring Railway Line)

The results indicate that the possibility to attend different schools changes the socio-economic/socio-demographic composition of the hypothetical SCAs (relative to the pre-defined SCAs) and that this could potentially change the socio-economic and socio-demographic composition of the schools themselves.

Figure 4 shows the hypothetical percentage change in median disposable income in the SCAs after the change in school admission policy was implemented (cross-section 2). Generally speaking, SCAs with lower median disposable incomes in cross-section 1 experienced positive changes in the median disposable income and SCAs with higher median disposable incomes in cross-section 1 experienced negative changes in the median disposable income. In other words, there is potential for the median disposable income of households in each SCA to become less segregated after students are given the opportunity to travel to a school of their choice (cross-Section 2) instead of attending the school in their neighbourhood (cross-section 1). Figure 4 suggests a considerable potential to counteract segregation. However, the concentration of social, financial and transport resources among some (higher income) groups and in some parts of the city, mean that these opportunities are not in reality distributed in the ways depicted here. Opportunities to reach schools further from the child's/teenager's home are instead likely to be concentrated in groups with considerable mobility and time resources, potentially resulting in a concentration of students from more privileged backgrounds in more 'desirable' schools (see Bierbaum et al. [3] for a review of school choice effects). Similar effects can be seen when looking at how the changes in the SCAs affect the proportion of the population born in Sweden within each SCA (Fig. 5).

Figure 6 shows the percentage change in median disposable income within each hypothetical SCA between cross-sections 2 and 3 Here we see a similar, but much more subtle, trend to what was seen when comparing cross sections 1 and 2. The apparent effect of the opening of the Malmö Ring Railway Line seems to be considerably smaller than that of the change in the public school admission policy. A similar result can be seen when looking at changes in the proportion of the population born in Sweden within each SCA (see Fig. 7).

When we look closer at the geographical distribution of such changes we get a clearer picture of how they are distributed. The changes in the public transport system between 2018 and 2019 mean that accessibility to schools near the city centre and the train stations has improved, but accessibility to many other schools has either shrunk or remained largely unchanged (see Fig. 8).

As seen in Fig. 9, there are also some interesting changes in the number of schools that can be reached from different parts of the city. For example, the areas southwest of Persborg Station typically experienced a net increase in the number of schools that could be accessed when the public transportation system was changed. However, the areas immediately adjacent to Rosengård station typically experienced a net decrease in the number of schools that could be accessed after the public transportation system was changed. This is counterintuitive. One might expect similar patterns near both of these stations since they are very close to one another and on the same line. However, it is important to keep in mind that the addition of train services at these stations was not the only change in public transport services between 2018 and 2019. Changes in bus services could also be playing a significant role in the number of schools that are accessible. These changes may help to explain some of the results that were seen. For example, bus frequencies increased on one of the major roads (Ystadvägen) near Persborg Station from 2018 to 2019, but bus frequencies decreased along a road (Ellensborgsvägen) leading up to Rosengård Station. Additionally, between 2018 and 2019 bus services shifted from one street (Erikslustvägen) in the western part of the city to a parallel street (Limhamnsvägen) closer to the coast. This change is consistent with the changes in school accessibility illustrated in Fig. 9. The grid cells along Limhamnsvägen – where bus services increased between 2018 and 2019 – are shown to experience higher accessibility to schools because of the changes in the public transport system. This means that the role of the bus network should not be ignored when looking at accessibility to schools. Figure 10 visualises the exact changes in public transport services between 2018 and 2019. Hourly departures from each stop were counted between 07:00 and 08:00 on both October 16, 2018 and October 15, 2019. Most public transport stops showed no changes in the number of departures during this time period between 2018 and 2019. However, there were some changes in the number of departures at some of the public transport stops between these two years. Additionally, some stops were removed and others were added to the network between 2018 and 2019.

In 2017, school catchment areas primarily consisted of the surrounding neighbourhood, within administrative boundaries. However, in 2018 and 2019, the SCAs were based on public transport and walking functional accessibility. In our analysis, we used accessibility to grid cells to identify areas that are accessible by public transport. As seen in Fig. 11, some grid cells could be consistently accessed by public transport in both 2018 and 2019 (shown in purple), even when changes were made in the public transport system. Other areas were accessible by public transport in 2018 – before the changes in the public transport system were made – but were no longer

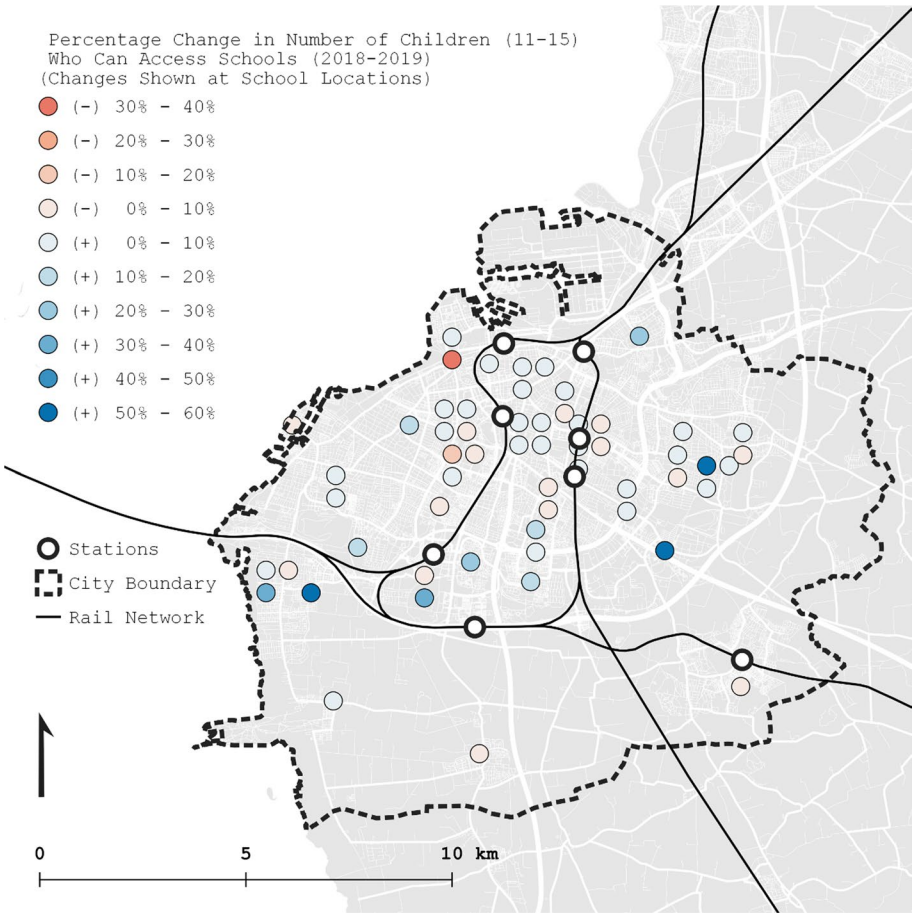

Fig. 8 The hypothetical changes in the proportions aged 11–15 per SCA (after the opening of the Malmö Ring Railway Line). Data source: Statistics Sweden [29]

accessible in 2019 (shown in blue). Additionally, some areas that were previously not accessible by public transport in 2018 became accessible in 2019 after changes had been made to the public transport system (shown in red). This shows that, while the policy changes generally allowed for more students to access schools from further away, changes in the public transport system between 2018 and 2019 played a critical role in determining from where students can and cannot access schools. Changes in the public transport system between 2018 and 2019 may have increased accessibility in some areas, but simultaneously decreased accessibility in other areas of the city.

7 Discussion

For this study, we investigated if, for whom, and the ways in which, accessibility can change following interventions such as changes to the public transport system and a change in the municipal public school admission policy. We drew on the case of Malmö, Sweden and examined the potential changes following (1) the change in the city's public school admission policy and (2) investment in public transport infrastructure. Findings indicate that the (hypothetical) SCAs have been redistributed to a considerable extent following both interventions, but to a much greater extent following the change in the city's school admission policy. These redistributions have in turn resulted in changes in the socio-economic characteristics of the hypothetical SCAs, as detailed in the Results section. While the redistribution of SCAs could potentially change the socio-economic composition of schools in Malmö, the effects of the redistribution and the propensity of different groups to deal with such effects are not evenly distributed throughout the city.

Malmö Municipality and other authorities responsible for school admission policies need to carefully consider policy alternatives, as the policies pursued can lead to considerable effects on accessibility, mobility, physical activity, and on social equality/inequality more broadly. Policies that contribute to stagnant or even increased car dependence for school trips, and indeed, a corresponding lack of independent mobility among children,

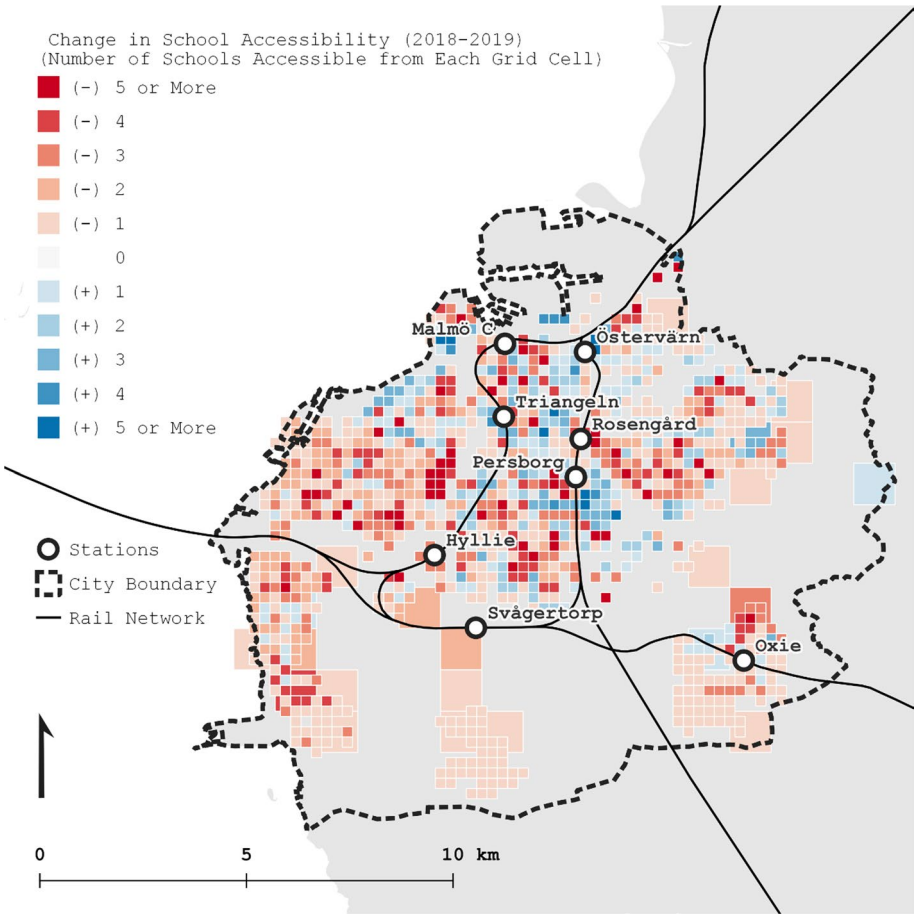

Fig. 9 The changes for accessibility to schools from 250 to 1000 m grid cells

work against the efforts of several aspects of sustainable development (see Bierbaum et al. [3] for a discussion). In Sweden, survey findings indicate that 50% of children between the ages of 13 and 15 attend a school within 3 km of their residence. However, 20% of these children attend a school more than 10 km from their home [34]. In line with findings from North America and elsewhere [3], creating the possibility and necessity to travel to schools further from home can contribute to less sustainable and less independent mobility for children.

Additionally, policies can lead to reduced opportunities among lower income households, and lead to forced travel if a school place is not secured in the vicinity of a child's home, which is possible with the relative proximity principle if the child's alternative school choice is also far from home. This could result in a significant temporal and/or financial burden for some households. Given that car access, in addition to flexible working hours and conditions, are typically concentrated in populations with higher incomes [7, 8], households with more freedom to choose a school further from their homes are also more likely to have higher incomes. In theory, policies can also promote integration, but in reality, may lead to increased segregation and a concentration of opportunities among the wealthiest households. Additionally, the analysis of accessibility to schools in the literature has been characterised by a focus on opportunities for active travel, with the justice implications of the distribution of these opportunities, and opportunities to choose and travel to preferred schools largely overlooked [3]. Amplifying this problem is the fact that the discourses on school segregation and transport justice rarely meet (ibid.).

As discussed in the literature overview, there is existing research on the topic of children's mobility, especially in the context of trips to school. While this topic is relevant for this research, this particular paper should act as a unique contribution to the existing body of work instead of a duplication of existing concepts in different geographical contexts. This work stands out from existing literature because it focuses on the use of public transport to access schools, which is often ignored, and focuses more on how the interaction between school

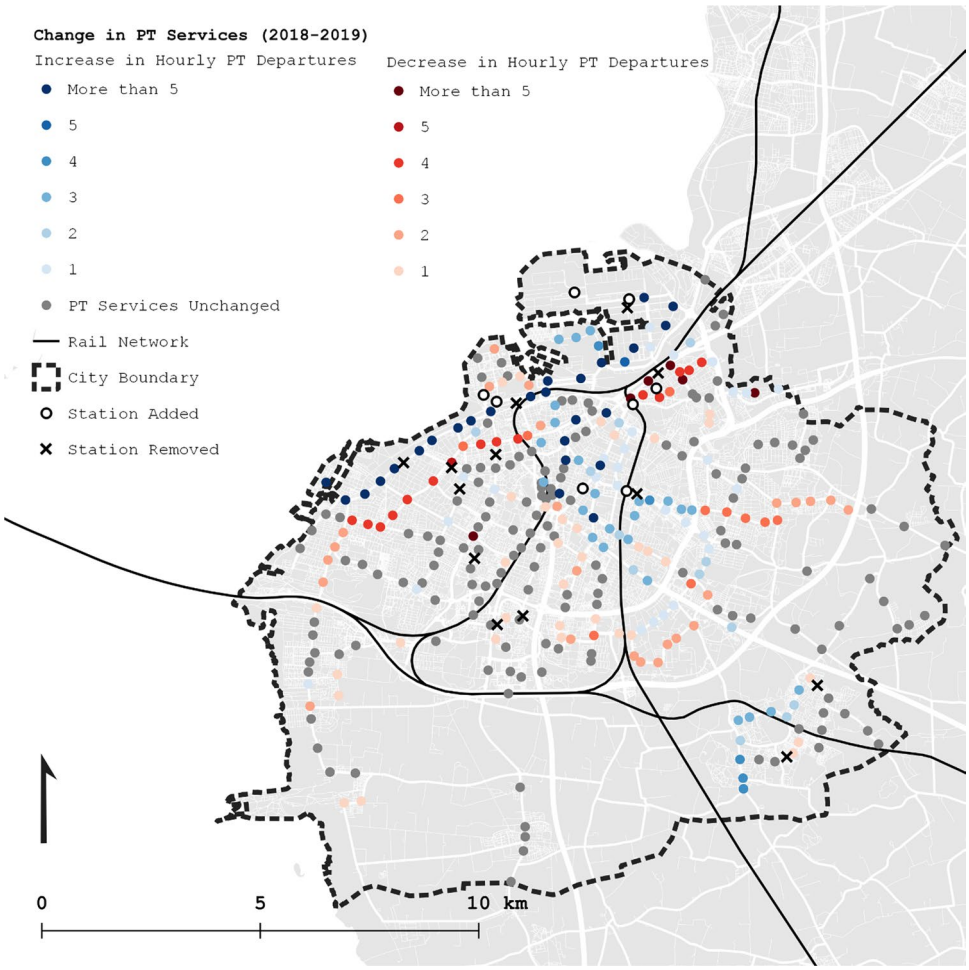

Fig. 10 Changes in public transport services from 2018 to 2019

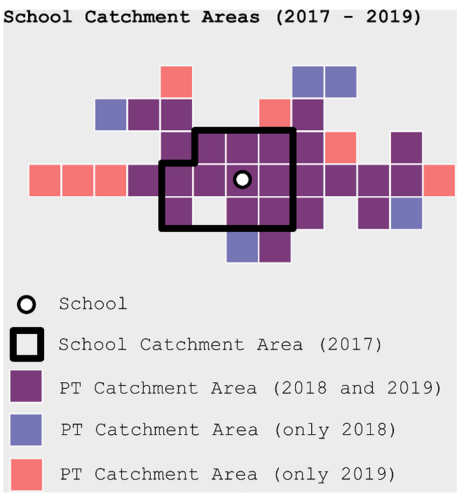

Fig. 11 Theoretical representation of how the SCAs changed over time

admission policies and public transport investments can affect accessibility rather than how built environment characteristics and the specific locations of schools can affect accessibility. When looking back at the work from Gross and Denise [13], which took a very similar approach to looking at public transport access to schools, there are a couple of notable differences between their research and what is presented in this paper. Gross and Denise [13] look at access to schools using public transport, but they do not look at the effects of specific policy changes or public transport interventions since there were none in this context. The current paper looks at the effects of two measures that were both partially justified as a way to address segregation in the city. Furthermore, the difference between public transport in the American context and the Swedish context produces different outcomes. Gross and Denise [13] ultimately conclude that the public transport services are not adequate to help children access desirable schools within 30 min, whereas the results in this paper show that hypothetical public

transport-based SCAs have the potential to change the demographic makeup of schools and address segregation but that any such potential is likely to be counteracted by a concentration of financial, temporal and transport resources in higher income households and areas.

8 Conclusions

This study has highlighted the ways in which accessibility can be redistributed following different policy and infrastructure interventions, and how different groups and geographical areas can be affected in different ways. These changes in accessibility and their resulting effects for different groups to reach schools can also have implications for school segregation/integration in a broader sense. This study has also detailed a precise method for calculating redistributions in catchment areas following policy interventions. This method can be used in the future to analyse effects of policy changes. While the socio-demographic data that were used are specific to Sweden, similar methods could be applied in almost any context if some sort of socio-demographic data are available since the geospatial data and GTFS data are generally easy to find in many cities.

This study shows that the populations in the hypothetical SCAs were redistributed to a considerable extent. However, the study may have been conducted too soon after these changes to the school admission policies and public transport system were made to be able to confidently state that these changes affected the population distribution and demographic makeup of the schools. Studies carried out further into the future may be more capable of measuring the long-term effects, such as overlaps between the effects of the measures and potential changes for modal distribution. A study like this could be conducted when the rail service frequencies on the Malmö Ring Railway Line are increased and the station areas become denser according to the plans set out for these areas.

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Author contributions
CRediT roles: AN: Data curation; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing—original draft; Writing—review & editing. JR: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Validation; Visualization; Writing—original draft; Writing—review & editing.

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Availability of data and materials
The datasets supporting the conclusions of this article are referenced (including links) within the article, where sharing is possible.

Declarations

Conflict of interests
None.

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References

1. Anderson, T. (2014). Malmö: A city in transition. *Cities, 39*, 10–20.
2. Antonson, H., & Levin, L. (2020). A crack in the Swedish welfare façade? A review of assessing social impacts in transport infrastructure planning. *Progress in Planning*. https://doi.org/10.1016/j.progress.2018.11.001
3. Bierbaum, A. H., Karner, A., & Barajas, J. M. (2021). Toward mobility justice: Linking transportation and education equity in the context of school choice. *Journal of the American Planning Association, 87*, 197–210. https://doi.org/10.1080/01944363.2020.1803104
4. Björklid, P., & Gummesson, M. (2013). Children's independent mobility in Sweden. *The Swedish Transport Administration, Report, 2013*, 113.
5. Buliung, R. N., Mitra, R., & Faulkner, G. (2009). Active school transportation in the Greater Toronto Area, Canada: An exploration of trends in space and time (1986–2006). *Preventative Medicine, 48*, 507–512.
6. Curtis, C., Babb, C., & Olaru, D. (2015). Built environment and children's travel to school. *Transport Policy, 42*, 21–33.
7. Elldér, E. (2020). Telework and daily travel: New evidence from Sweden. *Journal of Transport Geography, 86*, 102777.
8. Elldér, E. (2019). Who is eligible for telework? Exploring the fast-growing acceptance of and ability to telework in Sweden, 2005–2006 to 2011–2014. *Social Sciences, 8*, 200.
9. Ermagun, A., & Samimi, A. (2015). Promoting active transportation modes in school trips. *Transport Policy, 37*, 203–211.
10. Fusco, C., Faulkner, G., Moola, F., Buliung, R., & Richichi, V. (2013). Exploring children's qualitative narratives about their trip to school. *Children, Youth and Environments, 23*, 1–23.
11. Geurs, K. T., & van Wee, B. (2006). Ex-post evaluation of 30 years of compact urban development in the Netherlands. *Urban Studies, 43*, 139–160.
12. Guliani, A., Mitra, R., Buliung, R. N., Larsen, K., & Faulkner, G. E. J. (2015). Gender-based differences in school travel mode choice behaviour: Examining the relationship between the neighbourhood environment and perceived traffic safety. *Journal of Transport & Health, 2*, 502–511.
13. Gross, B., & Denice, P. (2017). *Can public transportation improve students' access to Denver's best schools of choice?* Center on Reinventing Public Education.
14. Grundström, K. (2018). Kollektivtrafik i Malmö: Målbilder och stadsutveckling. *K2 Research, 2018*, 4.
15. Holden, E., Gilpin, G., & Banister, D. (2019). Sustainable mobility at thirty. *Sustainability, 11*, 1965. https://doi.org/10.3390/su11071965
16. Jones, A., Steinbach, R., Roberts, H., Goodman, A., & Green, J. (2012). Rethinking passive transport: Bus fare exemptions and young people's wellbeing. *Health & Place, 18*, 605–612.
17. Leung, K. Y. K., & Loo, B. P. Y. (2017). Association of children's mobility and wellbeing. *Travel Behaviour and Society, 9*, 95–104.
18. Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy, 20*, 105–113.
19. Martens, K., & Di Ciommo, F. (2017). Travel time savings, accessibility gains and equity effects in cost-benefit analysis. *Trans. Rev., 37*, 152–169.
20. Malmö Municipality, 2021. Principen om relativ närhet, https://malmo.se/Bo-och-leva/Utbildning-och-forskola/Grundskola/Att-soka-grundskola/Regler-for-placering-i-grundskola/Principen-om-relativ-narhet.html, last accessed: 29 September 2021.
21. Malmö Municipality, 2022. Befolkning. https://malmo.se/Fakta-och-statistik/Befolkning.html#:~:text=Befolkningstillv%C3%A4xt,Malm%C3%B6bor%20(1%2C1%20%25), last accessed 13 May 2022.

22. Malmö Municipality 2018. Översiktsplan för Malmö: Planstrategi. Antagen av Kommunfullmäktige 31 Maj 2018.
23. Mikkelsen, M. R., & Christensen, P. (2009). Is children's independent mobility really independent? A study of children's mobility combining ethnography and GPS/mobile phone technologies. *Mobilities, 4*, 37–58.
24. Moreno-Monroy, A. I., Lovelace, R., & Ramos, F. R. (2018). Public transport and school location impacts on educational inequalities: Insights from São Paulo. *Journal of Transport Geography, 67*, 110–118. https://doi.org/10.1016/j.jtrangeo.2017.08.012
25. Pereira, R. H. M., Saraiva, M., Herszenhut, D., Braga, C. K. V., & Conway, M. W. (2021). r5r: Rapid realistic routing on multimodal transport networks with R5 in R. *Findings*. https://doi.org/10.32866/001c.21262
26. Pizzol, B., Giannotti, M., & Tomasiello, D. B. (2021). Qualifying accessibility to education to investigate spatial equity. *Journal of Transport Geography, 96*, 103199. https://doi.org/10.1016/j.jtrangeo.2021.103199
27. Rothman, L., Macpherson, A. K., Ross, T., & Buliung, R. N. (2018). The decline in active school transportation (AST): A systematic review of the factors related to AST and changes in school transport over time in North America. *Preventive Medicine, 111*, 314–322.
28. Saarinen, Y., Ihlström, J., Wallsten, A., 2020. Jag vill inte ha reseersättning jag vill komma fram i tid": Ungas upplevelser och behov av mobilitet i Norden. The Swedish National Road and Transport Research Institute. VTI rapport 1036.
29. Statistics Sweden, 2018). Open Data for Demographic Statistical Areas. Available at https://www.scb.se/en/services/open-data-api/open-geodata/deso--demographic-statistical-areas/, last accessed 24 February 2023.
30. Statistics Sweden, 2021. Demographics, statistikdatabasen. Available at www.scb.se, last accessed 29 September 2021.
31. The Swedish Government, 2009. Mål för framtidens resor och transporter, Prop. 2008/09:93, last accessed: 14 August 2021.
32. The Swedish National Agency for Education, 2022. Välja förskoleklass och grundskola eller grundsärskola. https://www.skolverket.se/regler-och-ansvar/ansvar-i-skolfragor/valja-forskoleklass-och-grundskola-eller-grundsarskola, last accessed 13 May 2022.
33. The Swedish National Agency for Education, 2018. Skolverkets statistik läsår 2017–2018. https://www.skolverket.se/skolutveckling/statistik/sok-statistik-om-forskola-skola-och-vuxenutbildning?sok=SokA, retrieved 6 May 2021.
34. The Swedish Transport Administration, 2018. Attitydundersökning Barns skolvägar 2018. The Swedish Transport Administration 2018-12-14
35. van Acker, V., Mulley, C., & Ho, L. (2019). Impact of childhood experiences on public transport travel behaviour. *Trans. Res. Part A, 130*, 783–798.
36. Waygood, E. O. D., Friman, M., & Olsson, L. E. (2017). Editorial: Transport and Child Well-Being. *Travel Behaviour and Society, 9*, 29–31.
37. Westman, J., Olsson, L. E., Gärling, T., & Friman, M. (2017). What drives them to drive? Parents' reasons for choosing the car to take their children to school. *Frontiers in Psychology, 8*, 1970.
38. Westman, J., Olsson, L. E., Gärling, T., & Friman, M. (2017). Children's travel to school: Satisfaction, current mood, and cognitive performance. *Transportation, 44*, 1365–1382.
39. Yenisetty, P. T., & Bahadure, P. (2021). Spatial accessibility measures to educational facilities from public transit: A case of Indian cities. *SASBE, 10*, 258–273. https://doi.org/10.1108/SASBE-11-2019-0153

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