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For whom the trains roll? An equity analysis of rail enhancement in Israel

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Rail has enjoyed somewhat of a renaissance in recent decades, with substantial new investments made therein. Justification oftentimes rests on rail's non-transport benefits, particularly the idea of opening-up new prospects for the carless. While many studies focus on accessibility to opportunities, this study attempts to evaluate the equity of investments. To that end, it is particularly pertinent to assess the degree to which rail is accessible to the carless, to identify exactly who benefits from the investment in rail, and who does not. As inter-city rail is inherently spatially inequitable, feeder bus services are sometimes added to mitigate these inequities. In this paper, we analyzed the equity facets of the enhancement of inter-city rail, including feeder bus services, in Israel, by examining the siting of rail stations, and mapping out all bus routes reaching heavy rail stations nationwide. Subsequently, we analyzed the attributes of the cities and towns serviced by rail, and of the population residing near bus stops on the feeder routes, as well as the frequency of service in those stops. Access to inter-urban rail in Israel was investigated, in terms of equity, at an unprecedented level of detail, thereby enabling us to assess which population groups stand to potentially benefit from the very substantial current investments in rail. We found that the Arab minority benefits the least, with adverse implications on women's motility, largely due to limited bus feeder lines to the rail system.

KEYWORDS

equity of investments, rail, minorities, policy packages, feeder buses

1 Introduction

Rail has enjoyed somewhat of a renaissance in recent decades, with substantial new investments made therein. However, rail rarely passes cost–benefit (CBA) tests (Proost et al., 2014). The justification for these investments thus largely rests on rail's non-transport benefits (Banister and Thurstain-Goodwin, 2011). As the purported environmental and congestion alleviation benefits may be offset by the rebound effect (Odeck and Johansen, 2016; Wang et al., 2012), perhaps the most important non-transport benefit is the expansion of the activity spaces offered by rail, and particularly the opening-up of job, education and housing prospects for the carless, and enhancement of their motility (Hodge, 1995; Sanchez, 1999; Lucas, 2004). While some studies have found evidence of such benefits in urban areas, where transit services indeed improve the accessibility and motility of the carless (Sari, 2015; Tyndall, 2017; Allen and Farber, 2019), other studies fail to find such positive effects (Sanchez et al., 2004), especially when it comes to inter-urban rail, where the evidence is even less clear (Levinson, 2012). Moreover, the challenges of transportation equity extend beyond rail systems to intermodal connectivity, encompassing bus networks, pedestrian pathways, and other last-mile solutions (Gronau, 2008; Igreja et al., 2024; Cheng and Chen, 2015). Intermodal investments are critical for ensuring equitable access to opportunities, particularly for disadvantaged groups (Gao and Li, 2024). This is not unique to Israel; similar gaps in intermodal networks disproportionately exclude low-income populations and rural communities (McDaniels et al., 2018), as transportation systems are essential for enabling participation in social and economic activities but often fail to provide equitable access (Karner et al., 2024).

Motility (Shliselberg and Givoni, 2018) and access to opportunities (Martens, 2017) are viewed as the most significant advantages, allowing people to fulfill their potential (Hananel and Berechman, 2016). Motility is defined as the ability of entities, goods, information, or persons, to move within social and geographical spaces. It can also refer to the way entities access and utilize the capacity for socio-spatial mobility, based on their specific circumstances (De Vos et al., 2013; Kaufmann et al., 2004). Motility can be regarded as an individual's capacity for mobility, thereby emphasizing the value of mobility not only as a means of movement but also as a resource with wider implications for self-realization (Shliselberg and Givoni, 2018). Hence it reflects personal and societal factors that enable or restrict the capacity to move, where transportation systems (mobility) and opportunities (accessibility) exist. Yet, multiple studies have shown that many households suffer from transport poverty or insufficient accessibility to opportunities (Allen and Farber, 2019; Martens et al., 2022). Expanding rail lines and services can potentially increase the motility of these households, thus benefiting them. However, the net benefit of rail is a function of the degree to which it provides such indirect benefits beyond what can be obtained using other modes of transport. The clearest benefit stemming from investment in upgrading rail services can therefore be achieved when rail serves the carless. The extent to which rail investments provide these critical benefits is indeed a function of access thereto (Murray et al., 1998; Brons et al., 2009). Accordingly, it is particularly pertinent to assess the degree to which rail is accessible to the carless.

Much of the research on equity facets of rail has focused on the accessibility of different population groups to opportunities, for which various accessibility measurements and criteria have been established (Allen and Farber, 2019; Da Silva et al., 2022; Farber and Fu, 2017; Kwan, 1998; Martens et al., 2022). Public investment in transportation significantly often influences women's access to labor markets and their potential earnings from remunerative employment (Di Ciommo and Shiftan, 2017). According to the International Labor Organization (ILO), in developing countries limited transportation options reduce women's labor market participation by up to 16.5 percentage points (Kühn et al., 2017). Women often face exclusion due to transportation systems that are poorly designed to accommodate their unique travel patterns, such as trip-chaining for caregiving and household responsibilities (Scheiner and Holz-Rau, 2017; Jahan, 2024). More broadly, individuals in low-income communities are frequently excluded from job, educational, and other opportunities due to the spatial mismatch between their residential locations and the availability of resources (Chapple, 2006).

However, little research has been conducted on the equity of the supply of inter-city rail services. It is consequently important to determine who can potentially benefit from investments in railway infrastructure. Much of the equity analysis of rail has focused on the intra-city level, where non-motorized trips can serve to access transit services (Foth et al., 2013). However, when analyzing the benefits of inter-city rail investments, the role of non-motorized access is reduced, as the number of access points to inter-city rail is much more limited than those within cities (Elson and Seth, 2019), which makes them farther from most origins or destinations. Inter-city rail is thus inherently spatially inequitable, as only those residing within a limited area can directly access inter-city rail stations. To access inter-city trains, other connection means are usually needed, which in the case of the carless is most often buses, since although taxis may also be available, they are less likely to be relevant to those from disadvantaged social strata due to their high cost. Feeder bus services may thus be promoted to mitigate inter-city rail's spatial inequity. While access to buses, and bus connections to rail transit, have received some attention (Benenson et al., 2017; Kaplan et al., 2014), access to inter-city trains via feeder buses has received only scant attention from an equity perspective. This gap is particularly notable in Israel, where the rail network operates primarily on a regional scale, connecting major urban centers with peripheral areas and smaller towns. Due to Israel's compact geography, inter-urban rail is essential for addressing equity and accessibility challenges nationwide.

The equity implications of transport have been receiving increasing attention in recent years (Di Ciommo and Shiftan, 2017), and have garnered much public support (Mouter et al., 2017). In the case of rail, it has been shown that High-Speed Rail (HSR) has splintered commuters, with higher-income, more mobile passengers shifting thereto, while lower-income passengers remain in "conventional" rail (Givoni and Dobruszkes, 2013). It is not surprising, since conventional rail is slower, cheaper, has more access points, and serves the nodes bypassed by HSR (Sánchez-Mateos and Givoni, 2012). Does this subsequently mean that conventional rail is progressive? On one hand, conventional inter-city rail has more access points than HSR, but on the other hand, these access points are still limited, and are often not accessible by non-motorized means to many parts of the city. One motorized mean that can potentially mitigate this inherent spatial inequity is feeder buses. Hence, to assess whether investments in inter-city rail serve the carless, access to train stations by feeder buses must be examined. This paper offers an analysis of the equity facets of the enhancement of inter-city rail services,[1] widely defined here to include feeder bus services, asking to what extent investments in inter-city rail can potentially benefit disadvantaged population groups. Yet, as central government fundamentally determines which settlements are served by rail, disregarding statistical units within the settlements, an analysis of the equity effects of rail investments should focus on the settlements served, including the complementary feeder services provided, rather than on individuals served. In Israel, substantial investments have been made in rail in the past two decades. As many of the proposed projects, and particularly those intended to connect peripheral areas to the country's core, do not pass Cost/Benefit Analysis (CBA) tests, the justification

1 Israel's rail system primarily consists of passenger rail, including intra-city rail, inter-city rail and freight rail services (not discussed in this paper). Intra-city rail, such as the Tel Aviv Light Rail, is designed to improve urban mobility by connecting neighborhoods and city centers, reducing congestion within cities. Inter-city rail, connecting major cities like Tel Aviv, Haifa, Jerusalem, and Beer Sheva with relatively fast, direct routes, as well as suburban rail, serving metropolitan areas with shorter distances between stations and higher frequencies for daily commuters.

for these multi-billion-shekel projects is the purported equity benefits of rail.[2] The question who can actually access the upgraded and extended rail services, however, has not been addressed. Given the substantial investments made, leading to the opening of several new lines and stations, and upgrading of other lines, Israel is a particularly apt case study for evaluating to what extent new inter-city rail services are geared to serve the more disadvantaged strata of society.

First, we provide an overview of the equity facets of rail, followed by an introduction about the Israeli rail system, in terms of transport and spatiality. Subsequently, we describe the comparison we conducted between locales that are served by rail and those that are not. Since many stations are located on the outskirts of cities or towns, their accessibility to the carless is largely determined by the bus system, which may or may not feed the rail stations effectively. Accordingly, we mapped all bus routes serving every major rail station across the country, potentially acting as feeder bus lines. The attributes of the population residing along those routes were analyzed. To the best of our knowledge, this is the most in-depth and detailed analysis of the equity facets of access to Israeli, inter-urban rail conducted so far, and it enables us to assess which population groups stand to potentially benefit from the very substantial investments in rail in Israel.

2 Equity facets of rail: a brief overview

Essentially, transportation equity means the provision of sufficient access to opportunities to all, thus minimizing social exclusion (Boschmann and Kwan, 2008; Sanchez et al., 2003; Tribby and Zandbergen, 2012; Wellman, 2015; Yeganeh et al., 2018). Transportation equity draws from the extensive literature on the concepts of equality, justice, and fairness that form the basis for equity analysis (Hananel and Berechman, 2016; Martens, 2017). Although the concept of equity is complex, the notion of need, and the question whether public transportation reaches those who are most in need, are central to it (Yeganeh et al., 2018; Deka, 2004). Those in need are identified as low-income individuals, children, the elderly, residents of the periphery, and those without access to a vehicle (Murray and Davis, 2001).

From an equity perspective, rail is often viewed as a means for opening up job opportunities for disadvantaged groups, thereby potentially improving equality (Fan et al., 2012). However, due to the inflexibility of rail, in terms of the location of rail stations, and the fact that access to inter-urban train services is restricted to stations, rail inherently generates spatial inequalities (Feitelson, 2019). Those in proximity to the stations enjoy better access than those living far from them. The extent of inequality is a function of the type of rail, since faster train lines imply fewer stops, and therefore greater spatial inequalities (Sánchez-Mateos and Givoni, 2012). The extent to which the spatial inequalities translate to social inequities is a function of the location of the stations, and the services provided at the various stations. If stations are located primarily in proximity to disadvantaged population groups, which commonly have lower motorization rates, rail may actually mitigate social inequities by providing such population groups a wider set of opportunities, as is the case in Toronto (Foth et al., 2013). However, in most cases it seems that equity considerations do not drive rail routing or station location (Taylor and Morris, 2015). Moreover, rail's distributional effects are a function of the services offered and types of trips. Evidence from Great Britain shows that the longer the trip and the faster the service, the more it serves high-income commuters (Banister, 2018). Thus, rail provision, or improvement, may well increase social disparities. Such disparities may be aggravated through pricing structures, as faster trains with a higher level of service are usually priced accordingly, and hence tend to serve travelers with a higher value of time, largely from richer communities, with limited use by lower income travelers (Da Silva et al., 2022).

The one mode that serves low-income households and the carless more than other groups, is buses (Banister, 2018; Taylor and Morris, 2015). Buses play a particularly important role in lower-income, car-less, population groups. In Israel, the disadvantaged stratum of society is associated with traditional populations, namely Arabs and Ultra-Orthodox Jews. These communities have lower motorization rate than the general Jewish population (about 340 vehicles per 1,000). The ultra-Orthodox are the population group with the lowest motorization rate in Israel (about 66 vehicles per 1,000),[3] and among the Arab population, the rate is 180 vehicles per 1,000. A limited number of studies examined the travel patterns of these groups. Kasir and Romanov (2018) stress that 50 percent of ultra-Orthodox households use public transportation, compared to 27 percent in the general population, and 20 percent of Arab households. Elias et al. (2008) indicated that the level of transit provided in Arab communities in Israel is very low, resulting in a low mode share. Moreover, this has significant equity implications in terms of accessibility, mobility and ability to participate in activities outside the community, particularly for women in traditional societies (Akyelken, 2013) and in peripheral settings (Beyazit and Sungur, 2019). Studies also suggest that Arab women in Israel tend to travel by car as passengers mostly, and tend to commute shorter distances and work more within their communities, compared to Arab men (Elias et al., 2015; Blumen and Kellerman, 1990). The motility level of Arab women, therefore, seems to be particularly low. Similarly, the ultra-Orthodox Jewish sector also exhibits a very local, community-centered lifestyle. This points to the traditional values at the core of both these population groups as one possible explanation for the gender gap in terms of motility (Vyas et al., 2015).

Bus services are more ubiquitous than other public transport services, as they are highly flexible (Feitelson, 2019). Thus, one way in which the spatial inequalities inherent in inter-city rail services, and particularly the more rapid train services, can be mitigated, is by

2 Israeli Government decision 1,421 from 2010. While most rail projects are subject to CBA, most of the new lines built servicing the periphery did not meet the 7% Internal Rate of Return (IRR) criterion used by the Israeli Treasury as a cut-off rate. Moreover, the CBA used in these analyses has been critiqued, as they did not take into account rebound effects, where improved accessibility can induce additional travel and thus negate some congestion or environmental benefits or the last mile issue, connecting passengers from their final transit stop, thus, further complicates the evaluation of rail projects through CBA (Shuki Cohen, personal communication).

3 The percentage of children under age 18 is higher among Ultra-Orthodox Jews than in other population groups.

feeder buses. Such services may be most important to low-income households, and particularly to women, as this population stands to gain the most from improved accessibility to job opportunities (Cui et al., 2019). Yet, the question to what extent exactly feeder buses mitigate rail-induced inequalities *in practice* has not received sufficient attention.

3 Background: passenger rail in the Israeli transport context

Until the 2000s, rail made up a trivial share of passenger trips in Israel. Upon its establishment in 1948, Israel inherited a dilapidated system, truncated at the borders, whose lines did not serve the main population and employment centers (Falkov, 1982). With the exception of the Haifa—Tel Aviv coastal line, rail development until the 1990s was geared toward freight (Feitelson, 1993). Consequently, the number of rail passenger trips declined. By 1990, the number of passenger trips by rail was lower than in 1960. Inter-city public transport was bus based, with an extensive bus network operated by two large cooperatives. However, as motorization rates rose, so did congestion, and the level of bus service deteriorated (Ben-David, 2003).

To address the growing congestion and falling public transport ridership, a new strategic plan was drafted for rail that called for a shift in rail investment toward passenger rail (Hashimshony, 2008). To this end, rail capacity in the core areas was to expand, and new lines built to peripheral locales. Approximately 55 billion NIS (15 billion USD) were invested in rail since 2000, with new lines built to several peripheral towns. Concurrently, capacity was raised by the doubling of rails (see Figure 1), leading to an increase in services. This rapid expansion led to a dramatic increase in ridership, from 8.8 million trips in 1999 to more than 69 million in 2019 (Central Bureau of Statistics (CBS), 2019).

As aforementioned, most of the new rail lines did not pass the 7% IRR threshold in CBA, which is the benchmark used by the Israeli Treasury to determine whether a project is beneficial. These investments were rationalized as both demand-creating and as extending non-transport benefits, mainly improving the accessibility of the periphery to Israel's center (Rotem-Mindali and Gefen, 2014). However, the extent to which the more disadvantaged towns and strata of the population may benefit from these new services has not been empirically evaluated previously.

4 Methodology

A prerequisite to benefitting from the enhancement of rail services is the ability to access these services. In this study, we ask who can potentially benefit from enhancement of inter-city rail services by analyzing the access to rail stations, rather than to final destinations, focusing on those areas from which there is direct access (by non-motorized means – active transport, or buses). Therefore, our supply-oriented study differs from demand-oriented studies that focus on the actual distribution of benefits, assessing the areas from which there is access to jobs and other final destinations by accessibility map isotims (such as Murray, 2001; Currie, 2010), or spatiotemporal measures, such as the travel time cube (Farber and Fu, 2017). Contrary to these studies, we ask toward whom investments are geared, rather than who uses rail and what are the benefits that accrue from rail usage.

Accessibility to rail is a function of two elements: the location of the rail stations; and the quality of service thereto, both of which can be quantified using an Accessibility Index. Rooted in Hansen (1959) gravity model, the index applies a distance decay function ($1/d_i$) to capture how accessibility decreases with increasing distance from transit stops. This is weighted by the frequency of feeder services (fi) (i.e., quality of service), as emphasized by Murray et al. (1998), and aggregated across all stops ($\sum$) to reflect cumulative accessibility. This is consistent with Benenson et al. (2017) high-resolution spatial approach. By integrating these elements, the index provides a framework for assessing how well rail and feeder bus services address spatial inequities and improve access for disadvantaged populations.

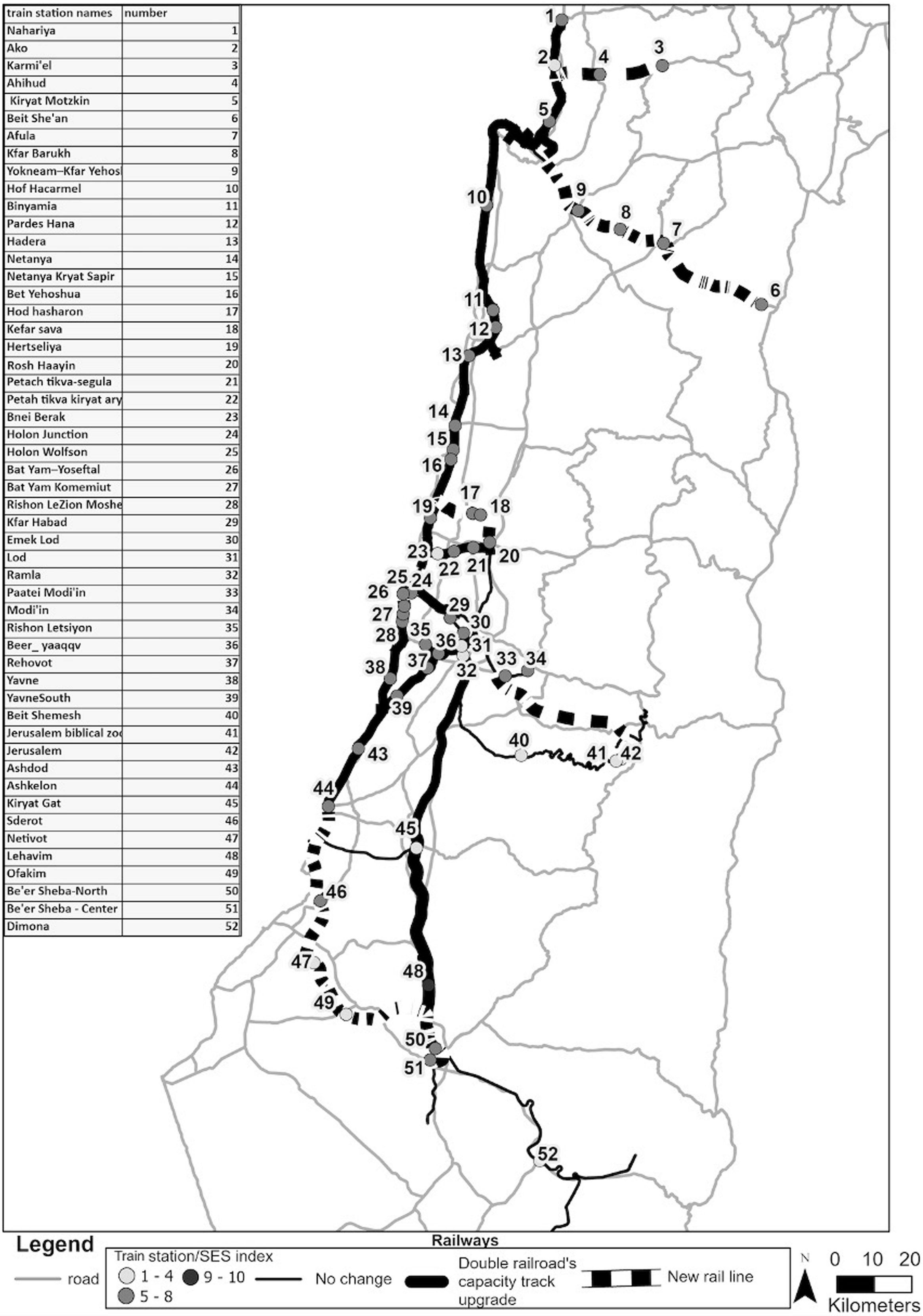
$$Accessblity\ Index = \sum_{i}^{N}\left(\frac{1}{d_i} * f_i\right)$$

Where d_i; Distance to the i-th train station (in km). f_i: Frequency of feeder bus services to the i-th train station. N: Number of accessible train stations via feeder bus services.

In Israel, only a limited number of cities contain train stations inside the city and adjacent to residential areas. Most passengers, thus, require a motorized means of transportation to access the train station, since walking is infeasible, and due to the absence of bicycle paths, so is cycling. For the disadvantaged strata of society not residing within walking or cycling distance, such access largely relies on the level of service of feeder bus lines. Therefore, to examine the attributes of the potential beneficiaries of the enhanced rail services, a two-stage analysis was conducted. First, the towns in which, or near which, rail stations are located were classified according to two criteria: the town's socio-economic ranking; and the town's ethnic composition. Then, the bus services to each of the 61 rail stations serviced at the end of 2016 were analyzed, focusing on the demographics of those residing near the bus stops.

The 61 heavy rail stations are placed in or near 42 cities and towns. Twelve of these (mainly the larger cities in the country's core) are served by more than one station. The Tel Aviv train stations were excluded from the analysis, as Tel Aviv is the destination to which accessibility is usually measured, as the prime locus of opportunities. Five stations are in the rural countryside, and one is at Ben-Gurion Airport, Israel's main international airport. The latter six stations were not included in the analysis of station locations, but were included in the subsequent analysis of accessibility to the stations. In cases of stations lying between two towns or cities, both were counted in the station location analysis. To assess the likelihood that a town with a certain socio-economic ranking has a rail station, the percentage of towns that have a station in each socio-economic cluster was determined. It should be noted that we only included towns whose population exceeds 6,000 in our analysis.[4]

4 Only towns within "the green line" were included in this analysis, and in the feeder bus analysis. Towns located in territories occupied since 1967 were not included.



train station names	number
Nahariya	1
Ako	2
Karmi'el	3
Ahihud	4
Kiryat Motzkin	5
Beit She'an	6
Afula	7
Kfar Barukh	8
Yokneam–Kfar Yehos	9
Hof Hacarmel	10
Binyamia	11
Pardes Hana	12
Hadera	13
Netanya	14
Netanya Kryat Sapir	15
Bet Yehoshua	16
Hod hasharon	17
Kefar sava	18
Hertseliya	19
Rosh Haayin	20
Petach tikva-segula	21
Petah tikva kiryat ary	22
Bnei Berak	23
Holon Junction	24
Holon Wolfson	25
Bat Yam–Yoseftal	26
Bat Yam Komemiut	27
Rishon LeZion Moshe	28
Kfar Habad	29
Emek Lod	30
Lod	31
Ramla	32
Paatei Modi'in	33
Modi'in	34
Rishon Letsiyon	35
Beer_ yaaqqv	36
Rehovot	37
Yavne	38
YavneSouth	39
Beit Shemesh	40
Jerusalem biblical zo	41
Jerusalem	42
Ashdod	43
Ashkelon	44
Kiryat Gat	45
Sderot	46
Netivot	47
Lehavim	48
Ofakim	49
Be'er Sheba-North	50
Be'er Sheba - Center	51
Dimona	52

FIGURE 1
Israel's rail system: rail projects (2000–2018) and stations in Israel. * Rail upgrades have been initiated on the main coastal rail line between Haifa and Tel Aviv and have continued outward. New rail lines were constructed between 2000 and 2010 toward Hod Hasharon, Ben-Gurion International Airport; between 2011 and 2018 toward Beit She'an, Karmiel, Jerusalem, Ashkelon-Be'er-Sheba.

We analyzed accessibility to rail stations via bus by mapping all bus lines that stop at one of the 402 bus stops located within a 200-meter radius of the entrance to a rail station. We chose 200 meters as the range based on empirical studies showing the range within which people are willing to walk from a bus stop to a rail station to be between 150 and 240 meters, after which the number of pedestrians drastically drops (Zhao et al., 2003; Taplin and Sun, 2020). Subsequently, we mapped all the bus stops along each route on a GIS. Of the 17,984 stops on all these lines combined, 12,389 are in residential areas to which population demographics can be attributed (the others are either in industrial areas, open spaces outside villages, or no data was available for the area near them). For each of the 12,389 stops, the demographics of the population near them (i.e., within approximately 400 m) was profiled. This was accomplished by relating the stop to the nearest census tract (i.e., a tract whose centroid is within 400 m of the stop). In the few cases where the centroids of two tracts were equidistant from a bus stop, and within the 400 m radius, one of them was randomly chosen.

The first attribute mapped for each bus stop is the socio-economic status of the proximate population, based on Central Bureau of Statistics (CBS) data derived from the 2008 census. Two groups are of particular interest in the Israeli case as their motorization rates are the lowest: the non-Jewish minorities (consisting of Arab Muslims and Christians, Druse, and Circassians); and ultra-Orthodox Jews. Moreover, their travel patterns differ markedly from those of the majority (religious, traditional, and secular Jews).

While minority groups are noted as such in the census, there is no official data identifying the Jewish ultra-Orthodox population. However, since this group tends to vote as a bloc for the ultra-Orthodox party (Agudat Yisrael), and virtually no one else votes for this party, the indicator normally used to map their spatiality is voting patterns (Cahaner and Shilhav, 2012). Based on the 10,119 polling booths in the 2015 elections, we were able to determine the percentage of ultra-Orthodox residing near 9,418 of the bus stops.

Both the Arab and Jewish ultra-Orthodox populations are characterized by high poverty rates. Thus, there is a high correlation between the percentage of low-income groups and minority or ultra-Orthodox populations. To avoid double-counting when analyzing the benefits to low-income groups, three analyses were conducted for each bus stop: 1. The percentage of minorities in the area served by the bus stop; 2. The percentage of ultra-Orthodox Jews in the area near the bus stop; 3. The percentage of low-income households that are not ultra-Orthodox or minorities in the vicinity of the bus stop. That is, for the third analysis, the ultra-Orthodox Jews and non-Jewish minorities were discounted from the population residing near the bus stop.

As many of the bus routes leading to inter-city rail stations are long, the actual level of service offered to residents along them is a function of the distance traveled (and hence in-vehicle travel time) and the frequency of service. Unless there is reliable frequent service, a bus line does not provide real feeder services (Yim and Cedar, 2006). Indeed, distance to bus stations and frequency of service, as well as car ownership, have been found to be major factors in public transport utilization in Israel (Suhoy and Sofer, 2019). Hence, a secondary analysis was conducted, taking into account the distance traveled by feeder bus to the "nearby bus stop" to a train station, and the frequency of bus service.

The criterion for a "nearby bus stop" is a bus stop within 200 meters of a train station. After locating the relevant bus stops, we used R code to extract all the bus lines that pass through each relevant bus stop using GTFS (General Transit Feed Specification) data files. For each bus stop, we extracted the number of trips for a defined period. For every train station, we compiled the data for all relevant bus stops, and labeled these bus stops as a cluster for that specific train station, with an identification number. For each bus stop, we obtained information on the departure times of each bus line. Bus frequencies were calculated for working days (in Israel, working days are defined as Sunday through Thursday) between 07:00. and 17:00. We converted departure times to frequency using a Python code. To identify the destination cities, we used a python code that scans the line number and intersects it with city polygons.

In the final stage, an Excel spreadsheet was consolidated for each city containing the following travel data: bus line number, destination city, distance in meters, and total frequency of travel (calculated according to the sum of feeder bus lines during the relevant period). We narrowed the number of cities down using a criterion of distance from a train station. Only cities located within 15 km of a train station were selected, and tagged according to their non-Jewish, ultra-Orthodox, and general (Jewish) populations.

5 Where are the train stations located?

Train stations have both practical and symbolic importance. A city with a train station is viewed as "being on the map". A train service is also viewed as providing a wider set of opportunities for the residents of the city, and serving as a locus for economic activities and development (Pels and Rietveld, 2007), causing mayors to often vie for train stations within their jurisdiction. The siting of stations is thus not only a technical decision but often largely a political one (Zhang et al., 2020). Therefore, the first analysis we undertook was to examine the distributional aspect of the cities and towns in Israel that contain train stations.

The 42 cities and towns containing, or near which there was a rail station at the end of 2016 were classified according to their SES (Socio-Economic Status) cluster, as determined by the CBS (Table 1). In 2017, the railway network was extended from Kiryat Motzkin toward the city of Karmiel. This city was thus added only to Table 1. For each cluster, the total number of cities and towns within the cluster were enumerated, thus enabling us to calculate the percentage of towns within the cluster ranking that are served by a rail station. As can be seen in Table 1, a much lower percentage of the towns that ranked in the bottom three SES clusters were served by rail than were towns in the next-highest five clusters. Actually, at least half of the towns in Clusters 5 and 6 were served by a rail station, compared to 10% of the towns and cities in the bottom three clusters. In other words, the rail system appears to be geared toward middle- and higher-income locales, rather than the lower ones. This statement can be somewhat qualified, as the more recently built rail lines connect several towns ranked in the lower clusters (2–4), at least among the Jewish towns.

As can be seen in the right-most column in Table 1, which shows the number of towns inhabited largely by minorities within each cluster, the bottom three SES clusters are dominated by minority-populated towns. Out of 58 such towns and cities, only one has a station near it. Yet, even in this case – the Rahat-Lehavim station – the

TABLE 1 Locale served by rail, by SES ranking.

SES rank	No. of towns served by rail	Total no. of towns[a]	% with rail station	No. of minority-population towns[a]
1	1	7	14	7
2	2	28	7	23
3	3	25	12	21
4	7	22	32	7
5	6	14	43	
6	5	8	63	
7	9	16	56	
8	9	22	41	
9	1	6	16.6	
Total	**43**	**148**	**29**	**58**

[a]Towns with more than 6,000 inhabitants within Israel (i.e., not including territories occupied in 1967).

station is closer to the Jewish suburban town of Lehavim (which is in Cluster 9) than it is to the Bedouin town of Rahat. Of the nine Jewish towns in the bottom three clusters, largely populated by ultra-Orthodox Jews, five have a rail station near or within them. Thus, this analysis shows rail stations to be located in sites that largely serve the Jewish population, with minority-dominated locales being largely overlooked. The only cities with a substantial number of minorities that have stations within them are the so-called mixed Jewish-Arab[5] cities (i.e., cities with at least 10% minority population). Of the seven cities considered mixed, five have rail stations.[6]

There are currently several new rail projects being advanced in Israel. One of them, the Eastern railway project, runs along the eastern part of the coastal plain. Along this line, five new passenger stations are planned, two of which—Taibe and Tira—will serve two large Arab localities. These localities will thus be served directly by rail. However, the main purpose of the Eastern line is to divert freight services away from the core of the metropolitan area, in Tel Aviv. Therefore, the level of service for passengers on this line is expected to be relatively low. The main rail projects advanced today in Israel, however, are the fourth rail station in Tel-Aviv, intended to increase capacity in the main rail bottleneck, and a high-speed link from Haifa to Tel-Aviv. These projects will thus serve primarily the stronger localities, potentially increasing the inequity in levels of service.

6 Equity aspects of access to the train stations

More than a third of Israel's rail stations lie outside or on the outskirts of built-up areas, even when they are within the city limits. This is particularly true in the more peripheral cities and towns. Hence, access to these stations requires an additional mode of transport. For the disadvantaged groups, this usually means a bus (Suhoy and Sofer, 2019). As buses operate on a regional basis, bus lines may enable access to rail stations also from towns that do not have a rail station, and each bus line may pass through more than one locality. Thus, it is necessary to analyze not only the rail stations' locations, but also the access thereto by feeder buses, based on the routes of those bus lines. As our focus is on the supply side, we do not assess the number of residents that are in proximity to the bus stations, but rather whether a certain locale has direct accessibility to the rail station via a feeder bus line.

As a further illustration of differences in access to bus stations by socioeconomic status, the distribution of bus stations based on the SES index for the entire population is presented in Figure 2. Yet, of these bus stations, 96.7% are in Jewish neighborhoods.[7] In contrast, only 3.3% of the feeder bus stops are in neighborhoods or towns inhabited by minorities, who make up about 20% of Israel's population. These results reflect the ethnicity disparities, in terms of access to rail. In middle SES clusters, feeder bus stops provide better service. A relatively high share of feeder bus stops are in Cluster 1 areas, making up 12.9% of the total feeder bus stops. Those are mostly located in ultra-Orthodox neighborhoods.

However, accessibility is not merely a question of the presence of bus stops. To evaluate accessibility, distance and frequency of service must both be considered. To this end, distance from towns (centroid) to rail stations, as well as frequency of bus services were calculated. Figure 3 depicts accessibility of bus feeder lines to rail stations for all towns within a maximum distance of 15 km. Towns were clustered into three groups, based on the majority population of each town: general Jewish population, ultra-Orthodox population, and non-Jewish population. As indicated by Figure 2, it is largely general Jewish locales that enjoy high accessibility, namely cities and towns within 5 kilometers of a rail station, and with a service frequency of over 80 buses per day. Only one ultra-Orthodox town lies in the high

5 Cities in Israel are largely homogeneous. Thus, cities identified as having a Jewish majority typically consist of over 90% Jewish residents. Similarly, cities with an Arab majority are those where more than 90% of the population is Arab. Cities where minority populations exceed 10%, were categorized as mixed cities.

6 Acre, Haifa, Ramle, Lod, and Jerusalem.

7 Where feeder bus lines run within a residential neighborhood, religion is calculated according to the majority religion in each neighborhood.

accessibility cluster: Netivot. Located in southern Israel, its distance from a train station is 1.71 kilometers, with a bus frequency of about 110 buses per day.

The two locales with the shortest distance to train stations are Binyamina and Beit Yehoshua, both of which are suburban/semi-urban, high-SES index locales, located on the main railway line between Tel Aviv and Haifa. Both locales have a station in or adjacent to them, and due to their small size, residents can access the train station by non-motorized means.

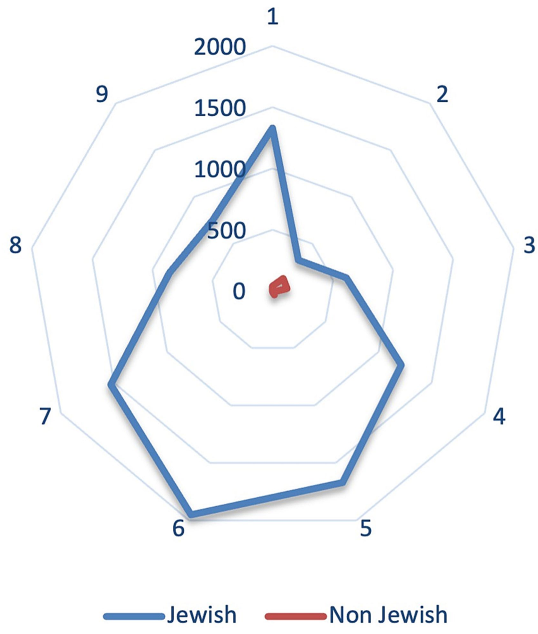


FIGURE 2
Bus stops according to SES index by religion (N = 10,596).

Since low-SES locales are frequently associated with low motorization rates, and hence lower mobility, (Suhoy and Sofer, 2019), they should receive priority in transport policies, from a transport justice perspective (Martens, 2017). Therefore, in Figure 4 we focus only on towns in the 1–4 SES clusters located within 15 kilometers from a train station, to better assess the extent that rail-bus services provide access to the less privileged groups in Israel. This figure, showing accessibility to trains by feeder buses, details the frequency of feeder buses to adjacent train stations. As can be seen in Figure 4, three towns stand out as enjoying high levels of feeder bus service: Netivot, which was discussed above; Qiryat Gat, and Ofakim.

Qiryat Gat, a largely Jewish town, is located about mid-way between the southern metropolis of Beer Sheva, and Tel Aviv. Its rail station is located 1.96 km from its centroid, with a bus service frequency of about 110 buses per day. Ofakim has a largely traditional Jewish population, like Netivot, and its train station is located 1.96 km from its centroid, with a relatively high frequency of feeder bus service (about 88 buses a day). However, as can be seen in Figure 4, most locales with lower SES indices, located close to a rail station, have infrequent feeder bus services (fewer than 20 buses per day). Three of these, Acre, Ramle, and Lod, are mixed Jewish-Arab cities that have a rail station, yet, in all three, bus frequency to the rail stations is very low (fewer than six per day), implying that they do not in reality provide feeder services. The low bus frequency in these towns may be partially explained by motorized transport or jitneys (shared taxis) providing access to the station, and in Ramle and Lod by relatively high accessibility through non-motorized means. Still, most low-SES towns are located relatively far from train stations, with a very low frequency of bus service.

Of the locales that lie in proximity to rail stations, only two are Arab locales: Kafar Qasem, in the central district, located about 3 km

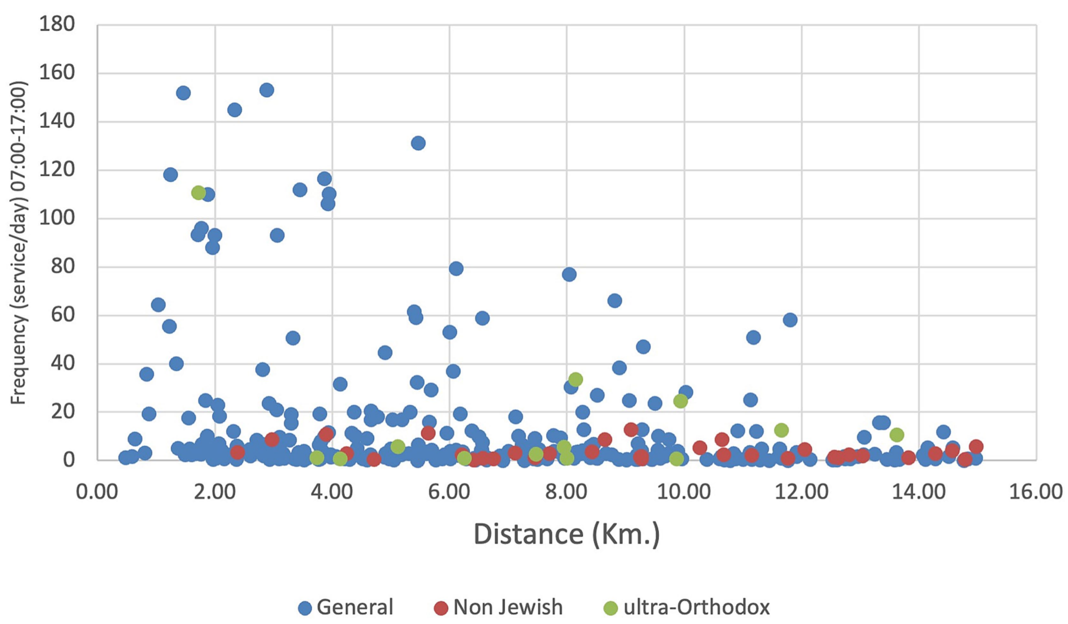


FIGURE 3
Frequency of bus feeder lines to rail stations for all towns within a maximum distance of 15 km.

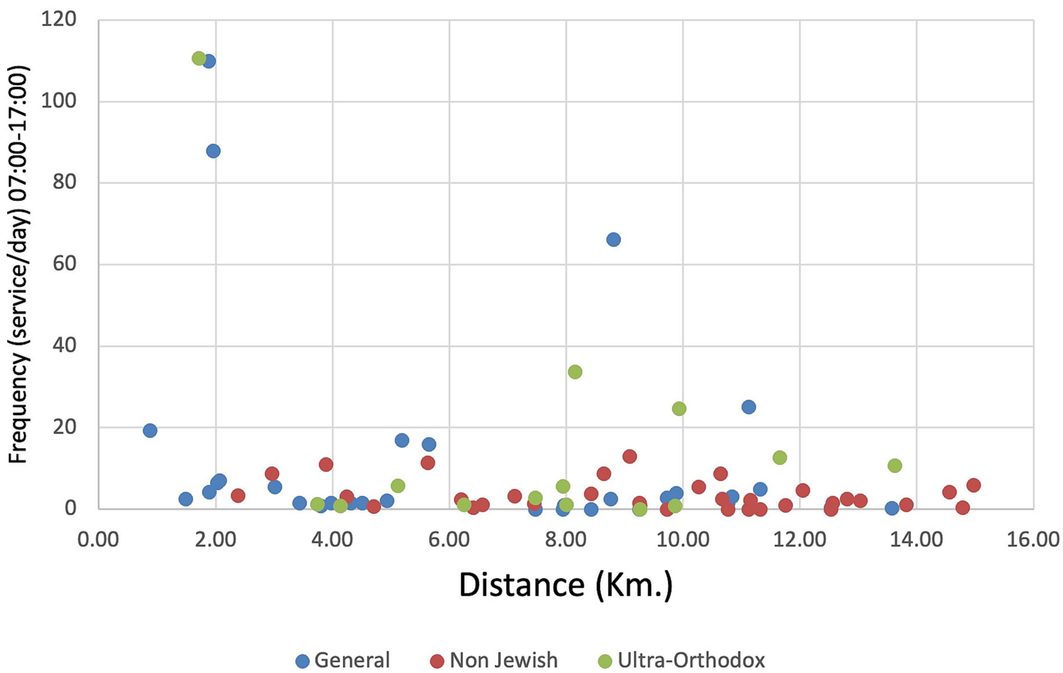


FIGURE 4
Frequency of bus feeder lines to rail stations for all towns within a maximum distance of 15 km, SES index 1–4.

from the Rosh Ha'ayin rail station, but with only 9 buses per day; and Mazra'a in the northern district, located only 3 km from the Nahariya rail station, but with only 3 buses per day.

A standalone case in Figure 4 is Qiryat Malachi, which has a rail station located 8 km from the town, serving both Qiryat Malachi and the adjacent rural communities of the Sde Yoav Regional Council. Qiryat Malachi enjoys relatively frequent bus service to the rail station, at 66 buses per day.

Figure 5 examines the locations of low SES towns (1–4 SES clusters) with low accessibility to rail by feeder bus lines. As in Figure 4, the map in Figure 5 illustrates the frequency of feeder bus lines, and not accessibility by either private car or non-motorized means. As can be seen in Figure 5, most of these towns are in the northern and southern peripheries. In the northern periphery, the vast majority of these locales are comprised of largely non-Jewish populations (for example Mazra'a, Yirka, Kefar Yasif). In the southern periphery, the non-Jewish locales with low accessibility are located mainly east of Be'er Sheva (including Tel Sheva, Laqye, Hura, Umm Batin). These are Bedouin towns built by the state. Most low-SES Jewish ultra-Orthodox and general Jewish towns in the southern periphery are located along the rail line to Be'er Sheva (Netivot and Ofakim). Unlike non-Jewish locales, the rail stations are located within these towns, and are closer to their centroids. They are, however, also characterized by a relatively low frequency of feeder bus services. In contrast, Israel's central region is largely characterized by high accessibility to rail. The only low-accessibility locales with low SES indices can be found in the outer ring of metropolitan Tel Aviv. Most of these are non-Jewish locales northeast of Tel Aviv (this include Kafar Qasem, Jaljulya, Tira, Kalansawa). Additionally, there are four Jewish locales with low rail accessibility due to inadequate bus feeder lines in the southern outer ring of the Tel Aviv metropolitan area.

7 Discussion

This paper examines the equity aspects of the vast investments aimed at enhancing rail services in Israel. It thus focuses on the policy implications, rather than on rail's contribution to individuals' access to opportunities. As rail is inherently spatially unequal, we analyze feeder bus services, rather than merely the location of train stations and non-motorized access to them, to gain some insights on the accessibility to rail stations by low socio-economic groups that are largely less mobile and more dependent on public transport. These feeder bus services are analyzed as they provide a complementary service to rail that the state can implement, potentially mitigating the spatial inequalities inherent to rail. Based on our analysis, we assess who can potentially benefit from the extended and upgraded rail services following the substantial investments in Israel's rail system in the past two decades, and who is left behind. While much of these investments were aimed at linking Israel's periphery to its core, thus ostensibly increasing equity, we ask to what extent were these investments indeed geared to serve the disadvantaged groups of society.

In Israel, there is a high correlation between low-SE clusters and minority, largely Arab, populations (Barlev-Kotler and Sandler-Loeff, 2018). Cluster 1, and most of Cluster 2 jurisdictions, are in fact minority towns. We find that the percentage of locales in the bottom three SES clusters that had a rail station in or near them, is much lower than the percentage of towns in the next-higher five SES clusters. A gap thus exists between low-SES towns and mid-SES jurisdictions in terms of direct access to train stations. As medium and high socio-economic strata populations tend to have high motorization rates (Alperovich et al., 1999), they can well access rail stations via private transportation. In contrast, lower SES populations face greater

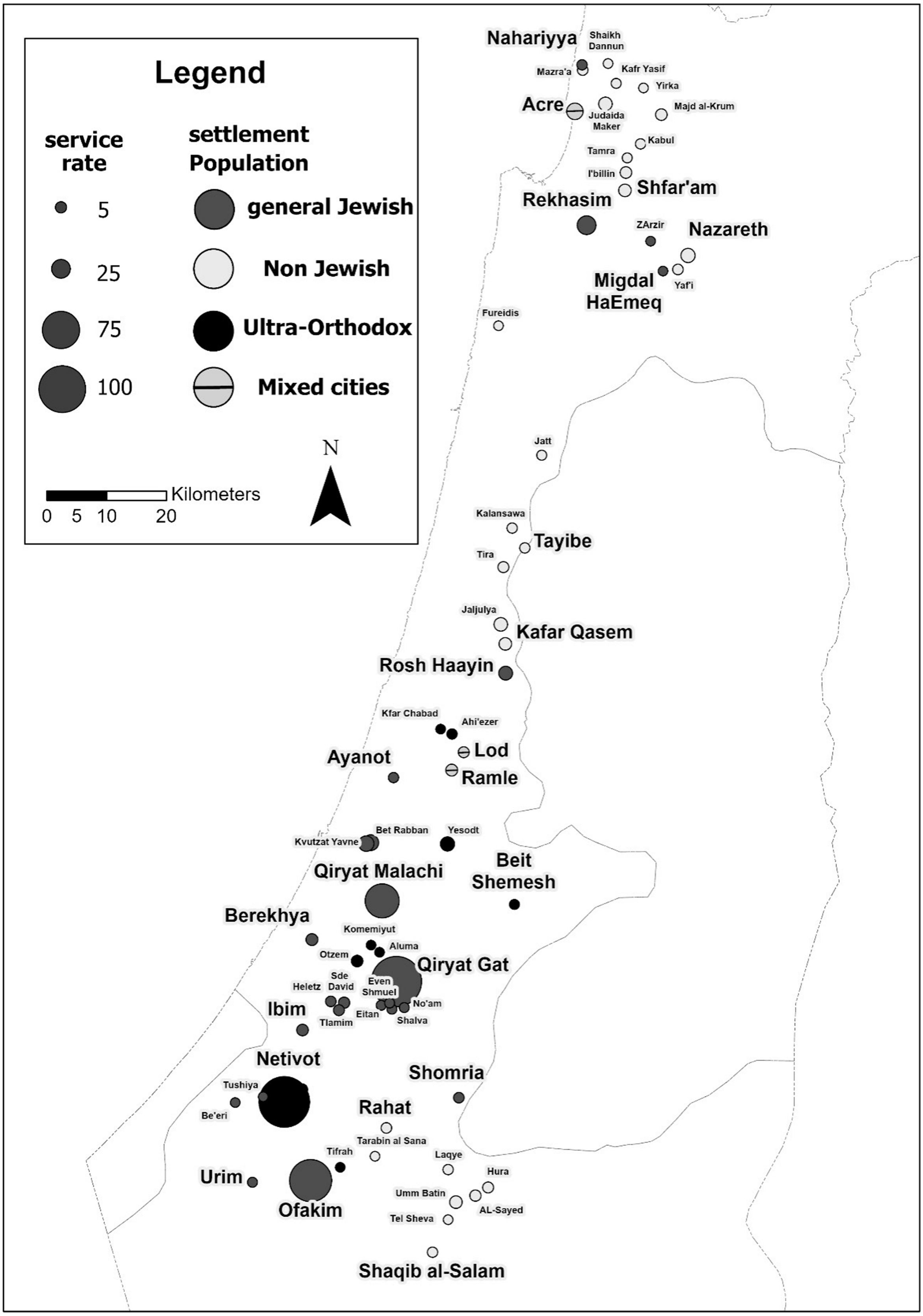


FIGURE 5
Low SES localities' feeder bus accessibility to rail at the national scale.

mobility constraints, and are often dependent on public transportation (Suhoy and Sofer, 2019). Their access to rail is thus largely dependent on the availability of high frequency feeder bus lines. This result underscores the importance of assessing the degree of accessibility to train stations by bus these populations have.

Our analysis clearly shows that accessibility to rail stations via feeder bus lines (taking into account distance and frequency of service) is poorer in lower SES locales than in medium-high SES locales. High levels of accessibility to rail are therefore associated with the general Jewish populations in Israel's core. At the same time, many locales that lie a relatively short distance from a train station, but beyond access by non-motorized means, do not enjoy the complementary bus service. Lack of adequate feeder bus services compels a high reliance on private vehicles or taxis to access train stations, which of course disenfranchises the more disadvantaged carless residents. As a result, rail users in Israel do not differ from car users, while lower SE commuters largely rely on bus or jitney services (Suhoy and Sofer, 2019). It seems thus that middle-income, mostly Jewish, households are the main beneficiaries from the massive investment in rail infrastructure in Israel.

The geographical distribution of lower-SES locales indicates that despite the investments in railway lines to peripheral areas, transportation services available to low-SES locales in the periphery are largely lacking. While some cities, such as Kiryat Malachi and Netivot in the south, have a relatively frequent feeder bus line, other localities may have improved rail services, but without these supplemental measures they do not provide a transportation policy package that enables equitable mobility. This is conspicuous in the southern region, where the lower SES cluster locales have low accessibility to trains via buses. This is true of ultra-Orthodox, Bedouin, and a few socio-economically disadvantaged groups among the general Jewish locales. In the northern region, the inequity between populations is even starker: the majority of low socio-economic locales are largely minority populated, yet, the Arab minority is largely excluded from train use, except in the case of mixed cities, such as Acre. However, with the extension of rail to Karmiel, which is surrounded by Arab towns, it is likely that the access these towns have to rail has improved.[8] In the central region, the minority-populated locales in the eastern outer ring of metropolitan Tel Aviv are not served by trains, or by feeder buses with minimal frequency to enable substantial use of rail.[9] This lack of both stations in proximity to minority towns and of high frequency feeder services is indicative of the inadequate public transport services in minority towns and villages, and was critiqued by a State Comptroller special report (State Comptroller, 2019).

The lack of adequate access to rail services obviously limits the opportunities available to minority populations. This limitation on opportunities is particularly detrimental to minority women, as they are less likely to drive than their male counterparts (Elias et al., 2015; Elias et al., 2008). The lack of public transport has been noted by various NGOs, as well as the State Comptroller, as a major impediment to the employment opportunities of minority women, whose employment rate is lower than that of Jewish women (Yashiv and Kasir, 2013). These impediments to employment disempower minority women, as it reduces their motility. Hence, the lack of access to rail from minority towns and villages can be viewed as transport injustice, according to both Martens (2017) criteria and to the capability approach perspective (Hananel and Berechman, 2016). Our findings indicate that in Israel, the disadvantaged sectors, and particularly the Arab sector, benefitted least from rail improvements, thereby perhaps contributing to the perception of Israel being an ethnocracy (Yiftachel, 2016).

While the upper strata locales, with relatively high motorization rate, also do not benefit directly in terms of the location of stations and feeder bus service from rail investments, they are less dependent upon public transport to access train stations. Moreover, the country's core region around Tel Aviv, which is largely dominated by high-SES groups, is the best-served by rail. Thus, it appears that the substantial investments in rail in Israel were detrimental from an equity perspective. However, following the State Comptroller's report, as well as due to the government's declared goals of increasing minority women's participation in the labor force, some improvements have been made to public transport in minority locales. But the extent to which they will reduce the inequalities identified in this study remains to be seen.

8 Conclusion

Inter-city rail inherently generates spatial inequalities. These can either mitigate or exacerbate societal inequities, depending upon the location of access points to rail (train stations), and the existence and level of service by feeder buses. If train stations are located near low SES locales, or locales populated by minority groups, and/or are accessible by high-level feeder services from low SES locales, rail can potentially broaden the set of opportunities for such groups, and thereby reduce inequities.[10] However, this is not the case in Israel, where the potential benefits accrue mainly to low-middle-income, largely Jewish, jurisdictions and neighborhoods. These are the population groups that benefited most from the substantial investments in rail in the past two decades. In contrast, the Arab, and to a lesser extent the Ultra-Orthodox communities, which are the low-SES communities with the lowest motorization rates, barely benefited from these heavy investments in rail. This leads us to the conclusion that despite the framing of rail investments as reducing spatial inequalities by bringing the periphery closer to the country's core, these investments have been detrimental from an equity perspective.

The importance of incorporating equity aspects in analyses of transport policies has been widely acknowledged in recent years, and

8 Due to data limitations regarding the changes in bus service from the Arab towns to Karmiel rail station and the prevalence of jitney services within the Arab sector, the extent to which the accessibility to the Karmiel train station has indeed improved was not quantified in the present study.

9 As noted above, at present the British Mandate-built eastern line is being renovated. This line will have stations near two of the Arab towns in the region.

10 In this study, we do not analyze the effects of rail investments on accessibility by rail to opportunities. However, as the set of opportunities offered by rail has widened, so has the difference between those who have access to rail and those who do not, thereby exacerbating inequities.

several approaches to analyzing these aspects have been advanced (Lucas et al., 2016; Thomopoulos and Grant-Muller, 2013). These approaches largely suggest that the benefits of transport policies should be differentiated, to account for the effects on various population groups. However, empirical studies that do so are quite rare. In this paper, we have conducted one such empirical study of the equity implications of rail investments in Israel. More importantly, we have shown that it is insufficient to analyze only the direct equity impacts of rail improvements (i.e., in which localities rail stations are located, and the level of service they provide). Rather, it is necessary to analyze the equity impacts from a policy package perspective. We have shown that it is insufficient to merely invest in railway infrastructure in order to improve accessibility for the carless. Rather, it is important to determine specifically for whom accessibility is to be improved, and conduct empirical evaluation studies to assess whether the accessibility of the target population has in fact improved as a result of these investments. Such evaluations should include the supplementary measures – feeder buses, in our case, as feeder services can conceivably mitigate the spatial inequalities generated by rail.

However, taking such an integrative approach to equity analysis raises difficulties. In our case, data on bus routes and schedules is not compiled systematically in Israel, and hence a long painstaking data-gathering effort was necessary to conduct the analysis presented in this paper. Moreover, given the flexibility of bus routing and scheduling, they are constantly being modified. Hence, it is almost inevitable that by the time the analysis is complete, it will be somewhat dated. Similar situations are likely to arise also in other cases where complementary policies are easily modified. Still, it is important to undertake such analytical efforts, to identify the directions in which these complementary measures should be modified. In the Israeli case, following the State Comptroller's report, we are indeed witnessing some initial efforts to ameliorate the negative equity impacts we identified. Still, much remains to be done.

In the Israeli case, we have shown that the lack of access to rail prevents the amelioration of the spatial entrapment of Arab women. Such entrapments are typical in many traditional societies, particularly in the Middle East (Elias et al., 2008). This insight raises a methodological challenge as it implies that it is insufficient to identify the groups that benefit or do not benefit from a transport policy (rail service enhancement in our case). Rather, to understand the full implications of the equity effects, they have to be discussed within the societal context of the different groups. In the Israeli case, such entrapments pertain mainly to Arab females, as Jewish females have higher levels of mobility, and thus motility (Yashiv and Kasir, 2013).

From a methodological perspective, the need to incorporate multiple policy measures in equity analyses of transport policies and to ground them in specific societal settings, raises new challenges. As demonstrated in this research, biased infrastructure investments merit further investigation, either as a predictor of access for specific segments of the population on the scale of residential neighborhoods, or by conducting a behavioral analysis of access to opportunities in practice. In this paper, we show that feeder bus lines can serve as complementary measures to the enhancement of rail services, and are thus important to the promotion and provision of equitable transportation services, particularly for the carless. The extent to which the approaches proposed so far to incorporating equity aspects into transport policy assessments can address this challenge remain to be studied.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

OR-M: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. EF: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. YM: Data curation, Methodology, Software, Visualization, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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