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15-, 10- or 5-minute city? A focus on accessibility to services in Turin, Italy

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ABSTRACT

The concept of the 15-minute city is receiving increasing attention, both in planning practices and in the academic literature, especially now that the pandemic has made evident the need for a minimum set of proximity-based services accessible by active travel. Most issues of this concept can be traced back to more or less past planning ideas such as the garden city, the neighbourhood unit, the superblock etc.; however, further studies are needed, as many theoretical and methodological questions for its implementation remain unresolved. The paper presents a methodology to operationalise the concept of the 15-minute city, in order to show which parts of the city and what percentage of its population can access a location of a given service on foot within three time thresholds (5, 10 and 15 minutes). The methodology is tested on the Italian city of Turin. The results show that, at least in dense European cities such as the case study, the 15-minute threshold cannot always be assumed as the necessarily most appropriate target, since many services can already be reached by foot within this time, or even less, by the majority of the population. Moreover, the levels of accessibility to services are significantly determined by the number and spatial distribution of the locations of these services. Finally, a recovery of the operational research on accessibility measures and indicators that was developed in the field of regional sciences in the second half of the last century and in the last twenty years is recommended to complexify the operationalisation of the 15-minute city concept.

1. Introduction

In recent years, the concept of the 15-minute city (and its variations, such as the 20-minute neighbourhood) has gathered great momentum and has been embraced in a growing number of scholars' and city mayors' agendas (Moreno et al., 2021). Launched in the 2010s, this model was first proposed in the framework of research on walkability as a factor of urban quality of life and accessibility to services (Barton et al., 2012; Talen & Koschinsky, 2013; Van Dyck et al., 2009); but it has gained further traction during the Covid-19 pandemic, when the introduction of stringent health protocols, social distancing, lockdowns and movement restriction revealed the vulnerability of many urban environments (Allam & Jones, 2020). On the one hand, public transport services have been reduced or suspended across the globe, as overcrowded buses, trams and subways were pointed out as a high-risk factor in spreading Covid-19 (Das et al., 2021); on the other hand, the pandemic highlighted the importance of freeing up outdoor public spaces from circulating and parked cars, where to perform some of those activities that turned out to be no longer feasible in restricted closed spaces (Abdelfattah et al., 2022), and prompted recognition of the value of active travel for exercise (Nurse & Dunning, 2020). The convergent pressures from this twofold emergency have made evident the necessity of a minimum set of proximity-based services that should be accessible by walking or cycling, so to allow citizens to meet some of their basic needs at the neighbourhood level without using motorised transport means (Marin-Cots & Palomares-Pastor, 2020).

As a few authors have pointed out, the 15-minute city is not an entirely new idea. On the contrary, it is quite rooted in history, as it re-interprets several ideas from earlier planning practices, such as Howard's Garden city (Gower & Grodach, 2022), the neighbourhood unit by Clarence Perry (Balletto et al., 2021; Kissfazekas, 2022), the Central place theory by Walter Christaller (Pozoukidou & Chatziyiannaki, 2021), the urban vitality approaches of Jane Jacobs (Ferrer-Ortiz et al., 2022), the geography of time by Torsten Hägerstrand (Ferrer-Ortiz et al., 2022), the human-scale urban design by Christopher Alexander and Jan Gehl (Moreno et al., 2021), the pedestrian pocket proposed by Peter Calthorpe around stations in the Transit oriented development approach (Abdelfattah et al., 2022), the principles of New Urbanism and Smart Growth (Calafiore et al., 2022).

At the same time, the 15-minute city concept is at risk of being reduced to a mere political slogan (Duany & Steuteville, 2021), an aspirational idea (Gower & Grodach, 2022), or even a sort of panacea which, quoting one of its main promoters (Moreno et al., 2021), "will lead to an economic boost, while bringing about social cohesion and interaction and help create sustainable ecosystems in cities" (p. 96). As a matter of fact, the adoption of the concept in practice is often limited to merely

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advocating planning principles such as walkability or those 5Ds (density, diversity, design, destination accessibility and distance to transit; Ewing & Cervero, 2010) of the built environment that encourage active mobility (Pozoukidou & Chatziyiannaki, 2021; Stanley et al., 2015). A recent comprehensive review (Gower & Grodach, 2022) has evaluated how the 20-minute neighbourhood concept has been operationalised in planning documents of 33 cities worldwide; the results show that the concept is generally employed with little measurability or benchmarks, as a city branding device which can create a favourable reputation of the city internationally, but does not facilitate plan implementation.

Even in the academic literature, further studies are needed, as many theoretical and methodological questions remain unresolved (Ferrer-Ortiz et al., 2022). In this sense, this paper proposes a methodology to operationalise the 15-minute city concept with reference to walking accessibility to basic services at the city level; this methodology is tested in the Italian city of Turin, in order to assess which share of the population can reach these services on foot in 15, 10 or 5 minutes. In particular, Section 2 introduces the concept of the 15-minute city and highlights some key elements for its implementation. Sections 3 and 4 describe the methodology and its application to the case study. Sections 5 and 6 discuss the obtained results and their implications for the implementation of the 15-minute city approach in dense European cities.

2. The concept of the 15-minute city

The 15-minute city is one of the variations of a more general concept, which refers to a (part of a) city whose residents can access the most essential activities within a given travel time. By coupling the spatial and temporal dimensions, this concept rides on the philosophy of "chrono-urbanism", which outlines that the quality of urban life is inversely proportional to the amount of time (and money) invested in transportation (Moreno et al., 2021). Assumed this semantic core, the concept has been interpreted and applied differently on a case-by-case basis, with reference to the spatial scale (neighbourhood/city), the travel means (walking, cycling, public transport, car), the set of activities to be accessed and the time threshold.

As regards the scale, both the neighbourhood and the city can be assumed as the spatial area within which the accessibility to main services should be achieved. Even if the two terms (associated with the chosen time threshold: e.g., 20-minute neighbourhood or 20-minute city) are often used as synonyms as they describe similar planning concepts, a semantic difference should not be ignored (Dunning et al., 2021). In the case of the neighbourhood, the focus is on the proximity of urban functions within each neighbourhood, which means providing a wide array of services locally. In this case, the city can be conceived as a system of neighbourhoods which are somehow self-sufficient for a certain set of services (Duany & Steuteville, 2021), and hierarchically dependent on higher-ranking services at the city level (similarly to Christaller's Central place theory). When the city is directly referred to, it is assumed that the walking or biking shed would not necessarily correspond to a single neighbourhood; the emphasis of planning is not on the proximity of functions within each neighbourhood, but on the proximity to local functions throughout the whole city (Pozoukidou & Chatziyiannaki, 2021).

Concerning the transport mode used for accessing the services, walking is regularly taken into account, as active mobility is at the core of the 15-minute city concept. Many papers propose indicators and indexes of walkability to evaluate pedestrian accessibility to neighbourhood facilities (Caselli et al., 2022; Gaglione et al., 2022; Harrison & Kohler, 2015). Similarly, McNeil (2011) introduces a bike ability index to assess how many services can be reached within 20 minutes in Portland's neighbourhood by cycling. Authors such as Roberts et al. (2018) and Schoon et al. (2018) recommend considering also public transport when accessibility not only to local services but also to job opportunities is pursued. A comparison between accessibility by different transport means is proposed by Capasso Da Silva et al. (2020), who measure the number of destinations that can be reached from each parcel in Tempe, Arizona, within 20 minutes by walking (along both the all-roads and the sidewalk-only pedestrian networks), by cycling (along both the all-roads and the low-stress biking networks) and by transit.

The classifications of the urban social functions that are supposed to be reached within the set time threshold vary in detail, but generally agree on certain broad categories of services, such as education, healthcare, commerce (food-related in particular) and entertainment (Calafiore et al., 2022). Some authors (see, for example, Thornton et al., 2022) include also the population density (i.e., the number of inhabitants that can be reached in 15 or 20 minutes), as a proxy of the accessibility to opportunities for social face-to-face interaction. Especially regarding low-density cities, sometimes accessibility to public transport stops is also taken into account, as trains, buses etc. are essential to reach job and education opportunities in other neighbourhoods or at a metropolitan level (Khor et al., 2013; Whitzman et al., 2013); other authors (see for example Moreno et al., 2021) suggest to include directly, in the case of European denser cities, also job opportunities among the destinations that have to be reachable in 15 minutes. Much less attention is paid to quantitative issues such as the number and spatial distribution of the locations of services (and jobs), despite the operational research on accessibility measures and indicators that were developed in the field of regional sciences in the second half of the last century offers tools and approaches to planning the 15-minute city concerning these issues.

As far as the time threshold is concerned, 15 and 20 minutes are the most commonly used. In particular, 20 minutes is the threshold generally assumed by American and Australian cities, which present a low density in their suburban areas; on the contrary, 15 minutes seems to be a threshold preferred by European and Asian cities, which are normally denser than Anglo-Saxon ones. However, the time threshold ranges from 5 minutes (proposed by New Urbanism as the right scale for the neighbourhood; Duany & Steuteville, 2021) to 30 minutes (as in the case of Sidney, where the threshold is adopted for metropolitan-level accessibility to strategic centres where jobs and services are concentrated). It is worth emphasising that in most cases, the choice of one or the other time threshold is neither theoretically nor empirically justified, also because – as highlighted by Mackness et al. (2021) – there is currently little underpinning research on how much time people (having different ages, abilities, ethnicities, socio-economic status and so on) allocate (or would like to allocate) to access services and amenities. Moreover, the adopted time threshold is often assumed to be the same for different mobility modes (walking, cycling, public transport etc.), despite their very different speed.

3. Aims and method

3.1. Aims

The paper aims to present a methodology which allows to operationalise the concept of the 15-minute city, showing which parts of the city and which percentage of its population can access a location of a given service within certain time thresholds and using a specific mode of transport. Therefore, this methodology can be useful:

- in the diagnostic phase, to assess how much a certain city can be considered a 15-minute city (or a 10-minute city, a 5-minute city etc., depending on the time threshold adopted) with respect to the actual spatial distribution of the locations of a given service;
- in the planning phase, after verifying which services are less accessible, to identify how to increase the number of their locations or to spatially re-distribute these locations in order to raise the percentage of inhabitants who can access them in a given time threshold.

In this article, the attention will be focused on the diagnostic application of the methodology, which will be tested on the Italian city of Turin. Walking accessibility to services will be assessed for three time

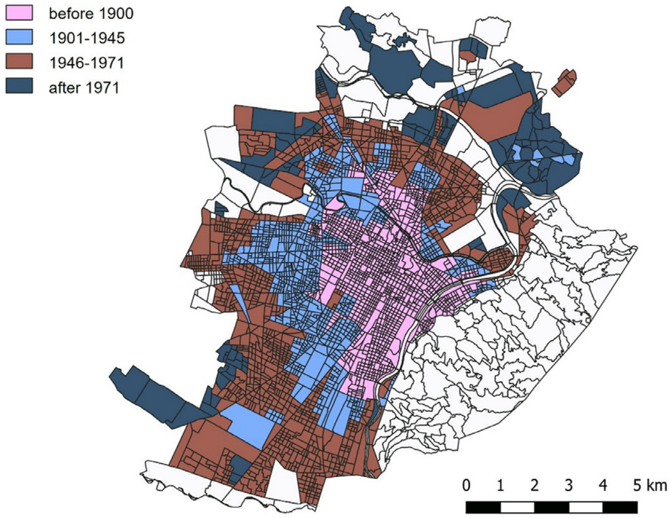

Fig. 1. Building age map of the residential areas in the city of Turin (the white areas are not residential, or data are not available for them).

thresholds, which seem appropriate for dense and walkable cities such as Turin: 5, 10 and 15 minutes.

3.2. Case study

The city of Turin (which is here considered in its administrative limits as a Municipality) is the capital of the Piedmont region, in north-western Italy, and the core of a functional urban area which includes nearly other 90 municipalities and accommodates over 1,750,000 inhabitants. It is the fourth most populated Italian city: it has about 864,000 inhabitants on 130 square kilometres and a total density of 66 inhabitants per hectare. Turin can be considered an interesting case study for testing the 15-minute city approach for a couple of reasons.

First, the city is highly car-dependent. It has hosted the headquarters and the manufacturing plants of the car company FIAT (which merged with Chrysler into FCA in 2014 and recently with PSA into Stellantis) since its foundation in 1899, and this strongly determined the social identity and the urban rhythm of the city during the 20th century (Vanolo, 2008). The legacy of the dominant role of this automotive company can still be acknowledged in the present mobility patterns: Turin has one of the highest rates of car ownership in Europe (over 650 cars/1000 inhabitants), and the modal share of private motorized mobility reaches 39% at the city level and 62% at the metropolitan level (only 4 out of the 29 cities monitored by the European Metropolitan Transport Authorities have a higher rate; EMTA, 2020). Car circulation is poorly moderated; only one restricted traffic zone, covering 2% of the municipal areas, and few small 30 km/h zones are in operation. Public transport (one metro, 8 streetcars, and about 90 bus lines) and the bicycle network (nearly 200 km of bicycle lanes and paths) are underused; their respective modal shares are 24.3% and 3%. Because of this unbalanced modal share, Turin has one of the worst levels of air pollution in Europe, in particular in terms of NO_2 and $PM_{2,5}$ concentrations (which are respectively due to traffic emissions for 60% and 84%)

Secondly, the urban fabric of the city can be roughly articulated according to three main phases of development: a historical central part, developed around the original Roman core and completed in the 19th century; a first ring around this core, built in the first 40 years of the 20th century; and a second outer ring, developed after the Second World War, mainly in the 1950s and 1960s. As a result, 88% of the city's residential buildings were built before 1971 (Fig. 1): this means that most of the city was developed before the adoption in 1968 of the national law n. 1444, which established for the first time in Italy a minimum amount of local public services (green areas, schools etc.) that have to be provided in new built urban areas.

Fig. 2. Census tracts in Turin.

In other words, a city like Turin can be a significative "stress test" for the 15-minute city strategy, both because of the significant role that automobility keeps playing in the daily lives of its residents compared to active mobility, and because of the historical growth of its urban fabric which was poorly coordinated with the spatial distribution of local services.

3.3. Methodology

The proposed methodology is articulated in 4 steps.

3.3.1. Defining a partition of the city, whose zones are the origins of the trips that citizens make to access a service

In this case, the origins of these trips are assumed to be the residential houses. Data on residents are not available for individual addresses, but only at the level of census tracts, which were therefore chosen as the more appropriate partition. The municipality of Turin is divided into 3851 census tracts (Fig. 2), most of which correspond to the – more or less large – blocks of the city. Some tracts (434) host no residents, as they are industrial areas, parks, cemeteries, rivers etc.; excluding these, the average number of residents in each tract is 253, ranging from 4 to 2,049. The tracts have an average area of 33,766 sqm; their extension increases progressively (from a minimum of 693 sqm to a maximum of 1,771,415 sqm) moving from the historic centre and the urban districts built around it between 1900 and 1940, to the outer edges of the city and its Eastern hillside. The average residential density of the inhabited tracts is 18.8 residents per 1,000 sqm.

3.3.2. Identifying the locations of services for which accessibility is to be calculated

Twenty types of services have been taken into account. They belong to three main categories:

- *Education*: nurseries, kindergartens, elementary schools, middle schools, secondary schools;
- *Health and social services*: neighbourhood health centres, counselling centres, social care services, registry offices, post offices, police stations, churches, open-air markets;

Table 1
Number of locations for each of the twenty services considered.

Education	Locations	*Health and social services*	Locations	*Entertainment*	Locations
Nurseries	120	Neighbourhood health centres	12	Green areas	234
Kindergartens	218	Counselling centres	37	Playgrounds	285
Elementary schools	144	Social care services	151	Playrooms	30
Middle schools	87	Registry offices	15	Sports facilities	451
Secondary schools	162	Post offices	78	Libraries	20
		Police stations	25	Theatres	28
		Churches	174	Cinemas	26
		Open air markets	42		

- *Entertainment*: green areas, playgrounds, playrooms, sports facilities (swimming pools, tennis courts etc.), libraries, theatres, cinemas.

The selection of these services was based on a thorough review of the services that were generally taken into analysis in the literature about the 15-minute city (in particular, Abdelfattah et al., 2022; Balletto et al., 2021; Calafiore et al., 2022; Capasso Da Silva et al., 2020; Caselli et al., 2022; Ferrer-Ortiz et al., 2022; Gaglione et al., 2022; Gower & Grodach, 2022; Moreno et al., 2021; Pozoukidou & Chatziyiannaki, 2021; Stanley et al., 2015; Weng et al., 2019; Whitzman et al., 2013; Zhou, 2019). In this overall list of potential services for the 15-minute city, the twenty services considered in this article were selected according to two main criteria. First, they were supposed to be available at the neighbourhood level; therefore, services such as universities or hospitals were excluded, as they are provided at the scale of the city, rather than the neighbourhood. Secondly, georeferenced data about their spatial locations were available (mainly through AperTo – http://aperto.comune.torino.it –, the open database of the city).

As regards commercial services, only open-air markets (which are widely used at the neighbourhood level in Italy) will be examined in the next sections. Initially, single food shops, restaurants and cafés were taken into account, but the analysis showed that their spatial distribution is so widespread that 95% of Turin inhabitants can access them by a 5 minutes' walk; due to this high accessibility by proximity, they were not considered worthy of further attention in this work.

As shown in Table 1, the number of locations of the twenty services considered varies significantly, from 12 in the case of neighbourhood health centres to 451 in the case of sports facilities.

Each location was georeferenced as a point at the service entrance address. Only open-air markets and green areas were georeferenced as polygons maintaining their actual extension, since they do not have limited entry points; in fact, in Turin they are generally not fenced and can be entered from any point on their perimeter.

3.3.3. Drawing the 5-, 10- and 15-minute isochrones from the census tracts

For each census tract, the geometric barycentre was identified[1]. Then, for each barycentre three isochrones were identified, representing the parts of the city that could be reached by the residents of the tract via a 5, 10 and 15 minutes' walk from the barycentre (Figs. 3,4 and 5). The selection of these three time thresholds could not be based on surveys on the current and desired travel times to access the twenty kinds of services examined, as these surveys were not available in the case of Turin. The 15-minute threshold was adopted as it is the one at the base of the 15-minute city concept; the 10 and 5-minute thresholds were chosen as the high density and walkability levels in Turin allowed to suppose that certain services could be accessible by foot in less than 15 minutes.

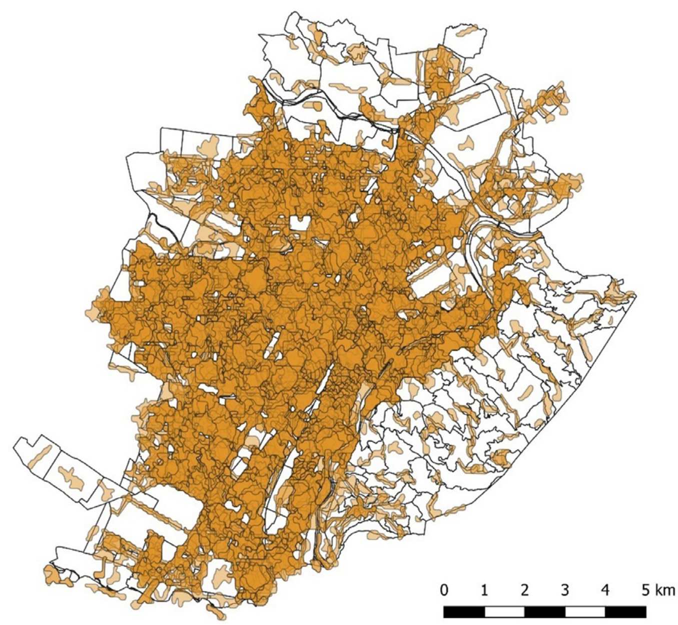

Fig. 3. The 5-minute isochrones.

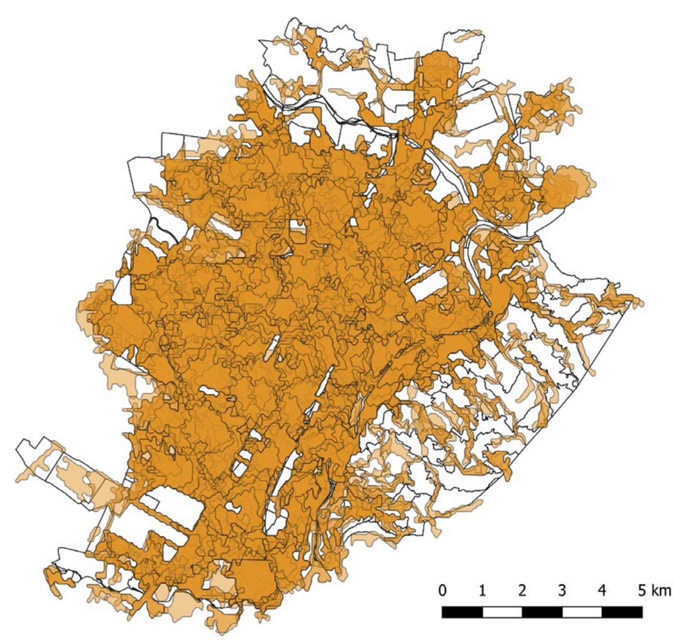

Fig. 4. The 10-minute isochrones.

[1] In the cases where data about land use inside each census tract are available, these data can be used as a weighting factor to influence the position of the barycentre. For Turin these data were not available, so the mere geometric barycentre was identified.

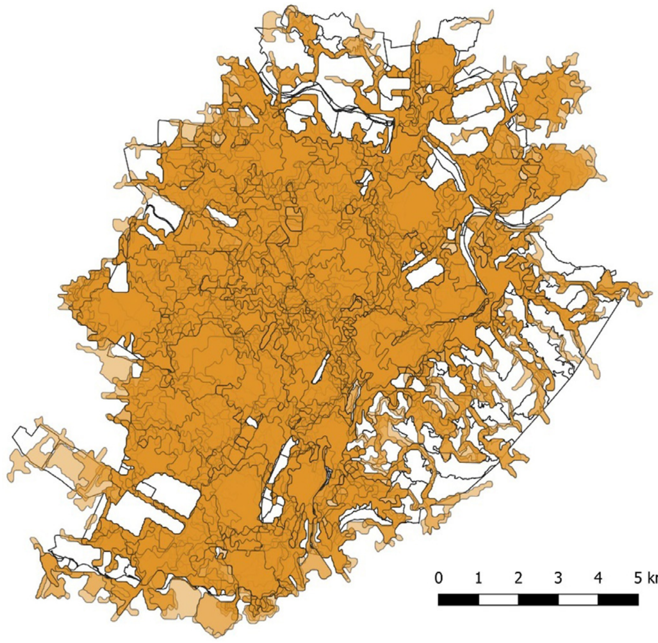

Fig. 5. The 15-minute isochrones.

Fig. 6. Census tracts (in grey) that have access to one or more library locations (orange dots) by a 15 minutes' walk.

The isochrones were drawn using the free HQgis Python plugin for QGis, developed on the HERE Routing API (https://developer.here.com/products/routing), which calculates them using an average walking speed of 4,8 km/h (similar, for example, to the one used by Google Maps, and consistent with common definitions used in walkability studies which equate a 5-minute walk to 400 m; Barton et al., 2002; Thornton et al., 2022) along the sidewalks of the street network. To verify the accuracy of the isochrones, the author compared 10 of them with the corresponding ones obtained by walking personally for 5, 10 and 15 minutes and found a good overlapping.

The average area of the 5-, 10- and 15-minute isochrones turned out to be 0.24, 0.95 and 2.15 square kilometres respectively. This means that the three isochrones calculated along the street network cover 47-48% of perfectly isotropic circles having the same radius of 5, 10 and 15 minutes (i.e., 400m, 800m and 1,200m, due to the considered average walking speed of 4,8 km/h). Doubling the time threshold from 5 to 10 minutes, the average area of the isochrones increases by 290%; the same 5-minute increment from 10 to 15 minutes results in a rather smaller growth of the isochrone area, equal to 127%[2].

3.3.4. *Assessing accessibility to services from census tracts*

For each of the 20 services and for each census tract, it was calculated (using the QGis "Select by position" function) how many locations of that service were included in the isochrone from that census tract for the three walking thresholds (5, 10 and 15 minutes). In this way, for each kind of service, it was possible to verify whether or not the residents in each census tract had access to at least one location of that service (in the census tract where they live or in another one) within the three time thresholds (see Fig. 6 for an example). By summing up the number of residents of all the tracts having access to at least one location of a service, the percentage of Turin's population that had access to that service within a certain time was calculated.

[2] This is remarkably in line with the geometric progression of the circle's areas: increasing the radius from 400m (i.e., a 5 minutes' walk) to 800m, the area raises by 300%; if the radius increases from 800m to 1200 m, the area grows by 125%.

4. Results

This section does not aim to present systematically and in detail all results for each service and each of the three time thresholds. Rather, it will show the main general findings, which will then be discussed in Section 5.

4.1. *Population having access to each service*

First of all, it was calculated how many Turin's residents could access one or more locations of each service (Table 2). As can be seen, this percentage varies greatly from service to service. For example, only 2.8% of residents can walk to a neighbourhood health centre in 5 minutes, but 66.4% of them can reach a green area in the same time.

Overall, the average percentage of inhabitants who have a 5-minute accessibility to services is 29.2%; it rises to 61.8% for the 10-minute threshold and to 77.7% for the 15-minute one. In other words, while raising the time threshold from 5 to 10 increases the "served" population by 32.6%, the same increase of 5 minutes from 10 to 15 minutes only allows an additional 16% of inhabitants to access services.

As regards the three categories of services taken into account, education is the most accessible: at least one quarter of the population can access one location for each of the five school degrees in 5 minutes, nearly two thirds in 10 minutes and nearly 90% in 15 minutes. Among health and social services, less than 40% of the population can access a neighbourhood health centre in 15 minutes; post offices and churches are widely accessible in 10 minutes; social care services and open-air markets are available to about 90% of the residents through a 15 minutes' walk. Concerning entertainment, green areas, playgrounds and sports facilities are accessible to over 50% of residents in 5 minutes and nearly 100% in 15 minutes; in contrast, cultural services such as libraries, theatres and cinemas are only available to about 50% of the population even in 15 minutes.

4.2. *Accessibility to multiple locations*

A second research question was related to the share of Turin's citizens that could access more than one location for each service whiting a given time threshold. As Table 2 shows, for most ser-

Table 2
Percentages of Turin's inhabitants having access to one or more locations of a service within 5, 10 or 15 minutes walking distance.

	5 m			10 m			15 m			Δ% 5-10 m	Δ% 10-15 m
Accessible locations	1	>1	≥1	1	>1	≥1	1	>1	≥1	≥1	≥1
Education											
Nurseries	25.5	9.5	35.0	29.8	48.8	78.6	11.2	81.4	92.6	43.6	14.0
Kindergartens	35.6	22.0	57.6	12.5	81.3	93.8	2.2	96.7	98.9	36.2	5.1
Elementary schools	39.6	8.8	48.4	25.2	66.5	91.8	6.6	91.8	98.4	43.4	6.6
Middle schools	30.8	3.0	33.9	38.0	43.6	81.6	14.8	81.1	95.8	47.8	14.2
Secondary schools	10.0	15.4	25.5	14.4	51.1	65.4	8.9	79.8	88.8	40.0	23.3
Health and social services											
Neighbourhood health centres	2.8	0.5	3.3	15.8	1.4	17.1	34.1	3.9	38.0	13.9	20.8
Counselling centres	4.2	4.5	8.7	14.6	20.3	34.9	17.8	44.8	62.7	26.1	27.8
Social care services	14.2	13.1	27.4	23.4	47.3	70.7	8.6	79.8	88.4	43.3	17.7
Registry offices	5.8	0.0	5.8	22.4	1.1	23.5	39.9	5.7	45.6	17.7	22.1
Post offices	29.9	2.2	32.1	47.5	33.3	80.8	19.8	75.2	95.1	48.6	14.3
Police stations	5.2	5.1	10.3	14.9	20.5	35.4	19.9	42.9	62.9	25.1	27.5
Churches	37.2	9.4	46.6	32.0	60.8	92.8	7.8	91.0	98.8	46.3	6.0
Open air markets			33.2			73.7			90.7	40.5	17.0
Entertainment											
Green areas			66.4			95.8			99.1	29.4	3.3
Playgrounds	37.5	24.9	62.5	11.9	83.4	95.2	3.2	95.9	99.1	32.8	3.8
Playrooms	6.7	2.2	8.8	16.3	11.1	27.5	21.8	26.2	48.0	18.6	20.5
Sports facilities	23.5	28.6	52.1	10.9	80.8	91.7	2.1	96.1	98.3	39.6	6.6
Libraries	6.4	0.1	6.4	26.3	1.1	27.4	41.9	8.9	50.8	21.0	23.4
Theatres	9.7	0.6	10.3	22.8	6.7	29.5	35.0	19.9	54.8	19.2	25.3
Cinemas	7.9	1.6	9.5	22.5	5.2	27.7	33.9	14.0	47.8	18.2	20.1
Mean value	21.6	8.4	29.2	28.5	36.9	61.8	26.0	57.5	77.7	32.6	16.0

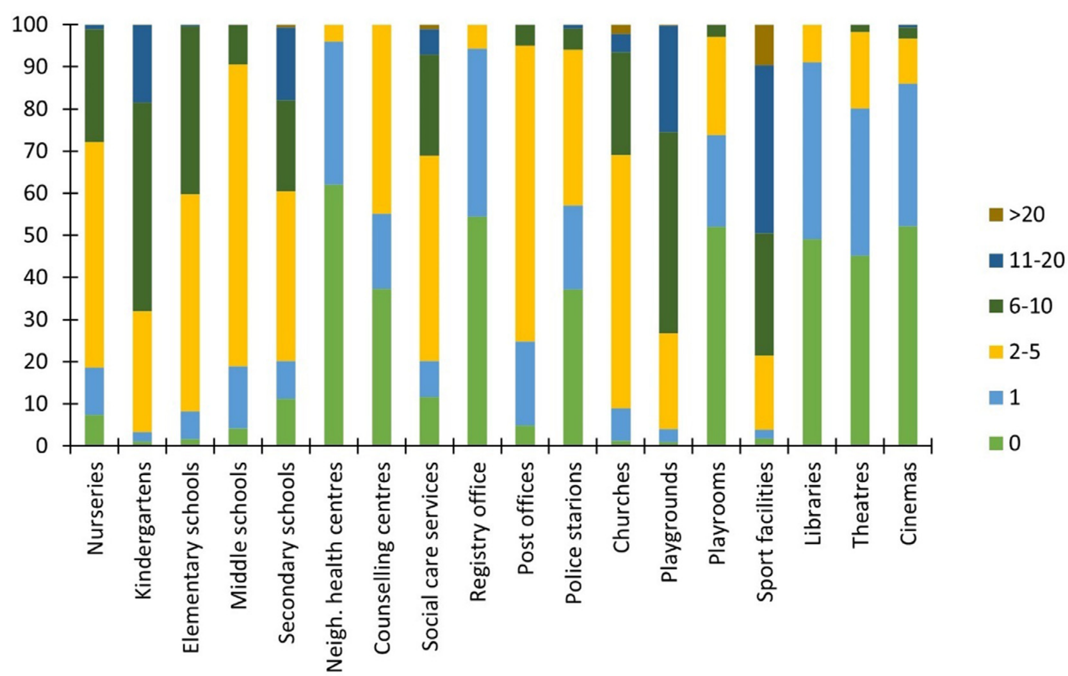

Fig. 7. Percentage of population that can access by foot a certain number of locations for each service within 15 minutes.

vices the inhabitants can reach more than one location. Just to provide some examples (Fig. 7): half of the residents can choose among over 10 sports facilities through a 15 minutes' walk from home; 27.8% can reach more than 5 different nurseries; 31.15% more than 5 social care services Conversely, only 8.7% can access in 15 minutes more than one library, 13,9% more than one cinema (but 0.2% up to 12 cinemas), 19.9% more than one theatre (0.16% up to 10 theatres).

4.3. Relationship between number of locations and served population

Is there a relationship between the number of locations for a given service and the percentage of the population served by this service? Fig. 8 shows a positive trend– as expected –, since the percentage of the population served tends to increase with the number of locations. At the same time, some discontinuities can be pointed out. First, 40 locations seem to be the threshold beyond which it becomes possible – in Turin – to ensure 10-minute accessibility to a given service for about two thirds of the population, and 15-minutes accessibility for over 80% of the population. Conversely, over 450 locations of sport facilities are just sufficient to ensure 5-minute accessibility to half of Turin's population. Secondly, opportunities for rationalising the spatial distribution of locations emerge. For example, 151 locations of social care services are accessible in 10 minutes for 70.7% of the inhabitants, a percentage which is lower than the 80.8% ensured by only 78 post offices. Similarly, 218 kindergartens are sufficient to ensure for all the three time

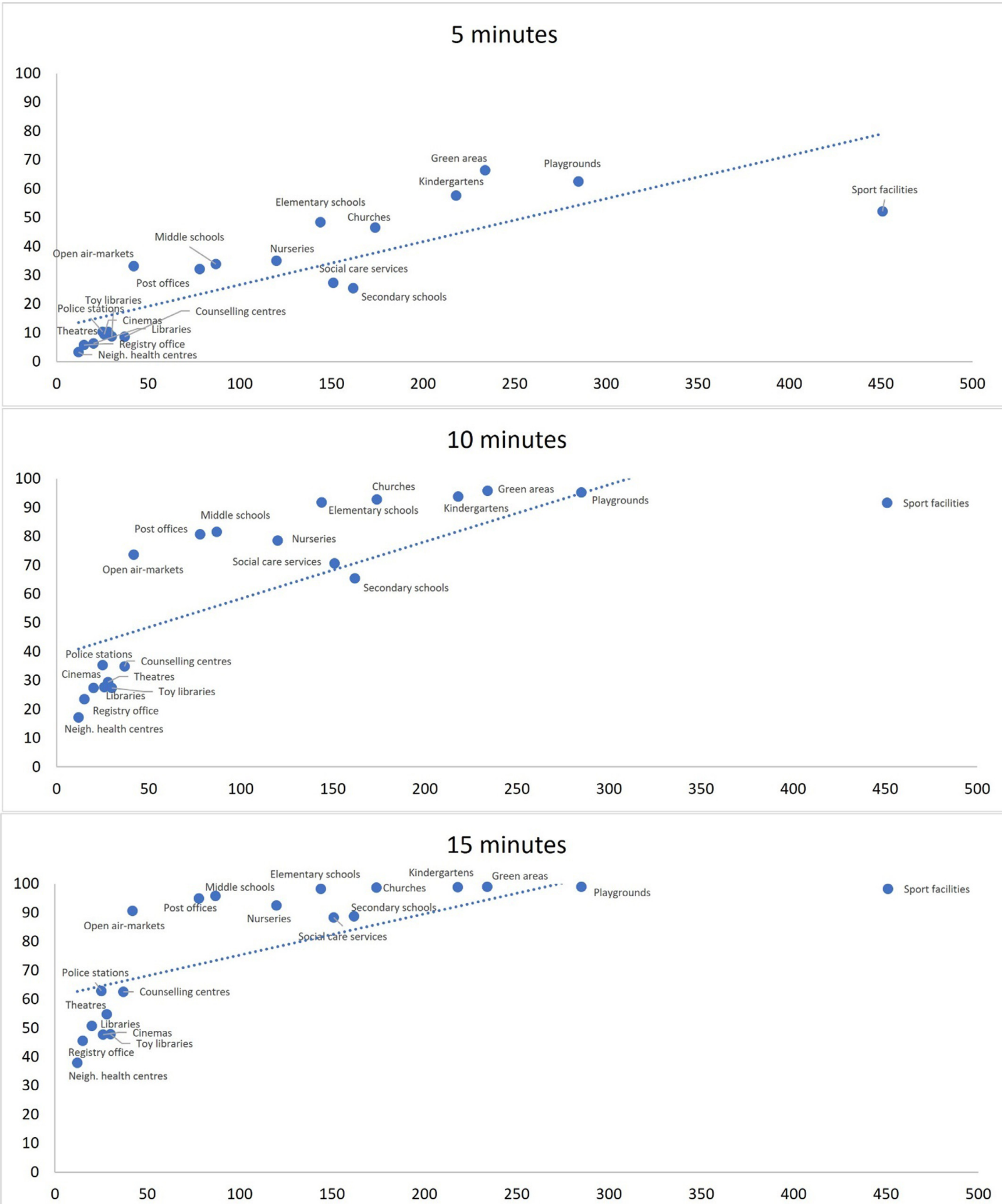

Fig. 8. - Relationship between the number of locations of each service (*x-axis*) and the percentage of the population served by this service (*y-axis*) within a 5, 10 and 15-minute walk.

thresholds greater accessibility than twice the number of locations of sports facilities (451).

4.4. Multi-service analysis

A further elaboration was aimed at calculating how many different services (among the twenty that were considered) could be reached in 5, 10 or 15 minutes from each census tract. Figure 9 shows these results for the three time thresholds. Instead, Figure 10 shows the cumulative percentage of the population of the whole city that can reach at least a certain number of different services within the three time threshold.

From a spatial point of view, it is possible to recognise that most of the least served census tracts are located in the outer part of the city (in particular in the eastern hilly area), where the service locations are less widespread, the road network is less dense and the census tracts are wider. In the inner part of the city, differences among census tracts are more pronounced for the 5-minute threshold, while they become more homogeneous for the 15-minute threshold. In general, anyway, no evident gradient emerges from the centre of the city toward its outer areas; tracts seem to have greater accessibility to multiple kinds of services in the part of Turin built before 1945 (see Fig. 1), where the road network is substantially dense, but in particular for the 5-minute threshold this is not so regular.

Considering the whole city, Fig. 10 shows that a 5 minutes' walk allows to access a maximum of 14 types of services, and this is possible only for 0.1% of the residents. Within this time, 9.5% of the population can access at least 10 different services, 63.9% can reach 5 services, 97% at least 1 service; this leaves 3% of the inhabitants who cannot access any service at all. Increasing the time threshold to 10 or 15 minutes drastically modifies the level of service. In 10 minutes, 84.6% of the population can access 10 services (95.9% in 15 minutes), 25.5% can reach 15 services (71.4% in 15 minutes); 0.3% can access a maximum of 19 services, while in 15 minutes 0.4% of the inhabitants has access to all twenty services.

4.5. Sensitivity analysis on time thresholds

Finally, a rapid sensitivity analysis was carried out to verify how a slight change (±1 minute) in the 15-minute threshold modifies the percentage of the population that can access a given service. Figure 11 shows how much the percentage of the population that can access a given service in 15 minutes (represented on the *x-axis*) decreases or increases (in terms of percentage points, on the *y-axis*) if a 14-minute or 16-minute threshold is adopted respectively[3]. As can be seen, the positive change due to one more minute and the negative one due to one less minute are nearly symmetrical. Moreover, the change is more significant the lower the 15-minute percentage is. Up to a 15-minute percentage of 63%, a ±1 minute variation increases/reduces this percentage by about 4-5 points; between 65% and 95%, this change decreases progressively in absolute terms; over 95%, the same ±1 minute variation modifies the percentage by less than 1 point.

5. Discussion

The analysis of the city of Turin described in Sections 4 and 5 can be used to assess whether or not Turin conforms to the model of the 15-minute city. Given that more than 70% of its inhabitants can walk to 15 out of the 20 considered kinds of services within this time threshold, one

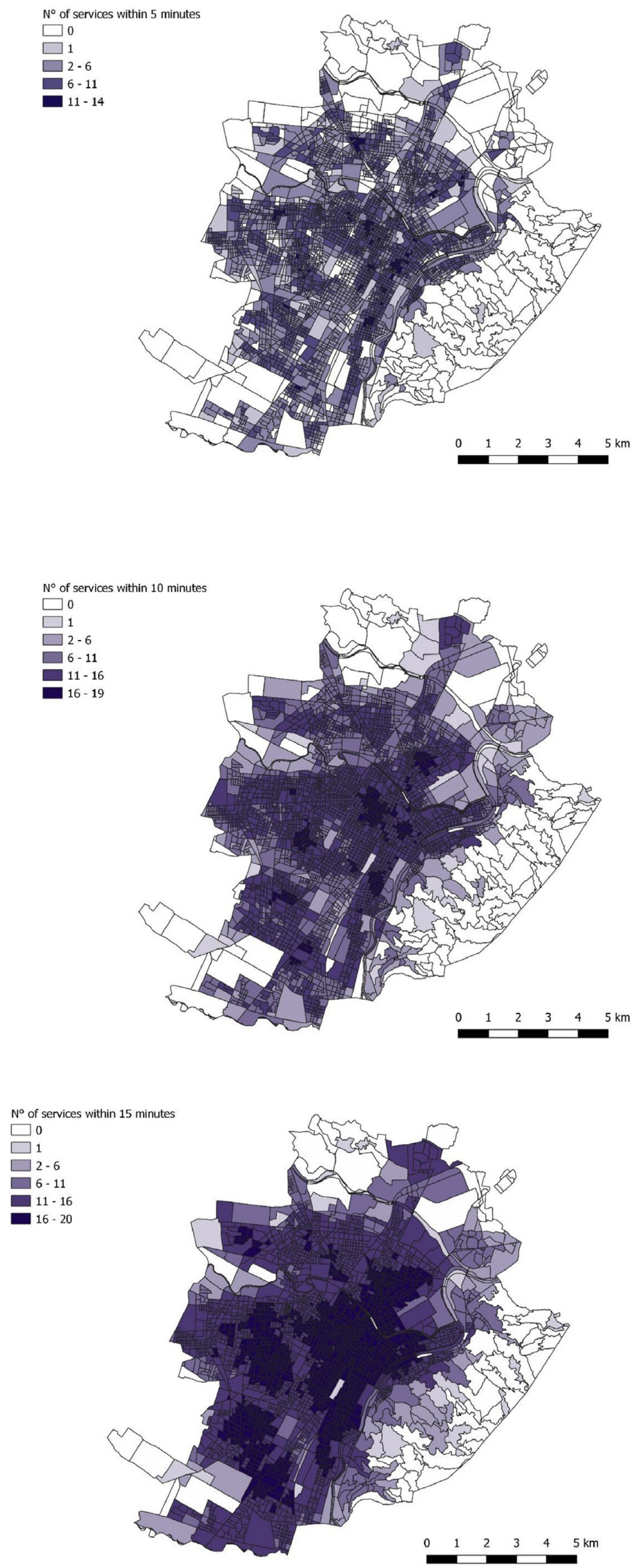

Fig. 9. Number of different services that are accessible from each census tract through a 5, 10 or 15 minutes' walk.

[3] This sensitivity analysis is very time consuming, because it requires repeating the application of the entire methodology for each new time threshold taken into account. This is why we considered only ±1 minute with respect to the 15-minute threshold. In any case, it might be interesting to evaluate further variations (e.g., ±2 or ±3 minute) for each threshold considered.

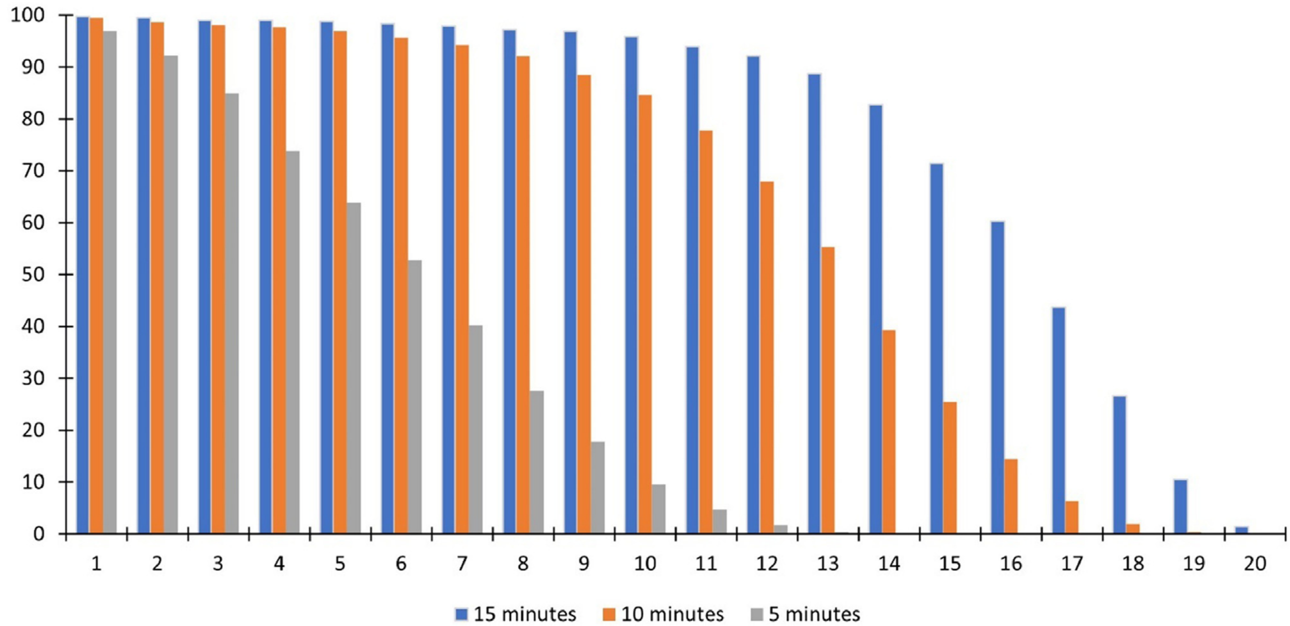

Fig. 10. Percentage of Turin's population (*y-axis*) that can access at least a certain number of different services (*x-axis*) through a 5, 10 or 15 minutes' walk.

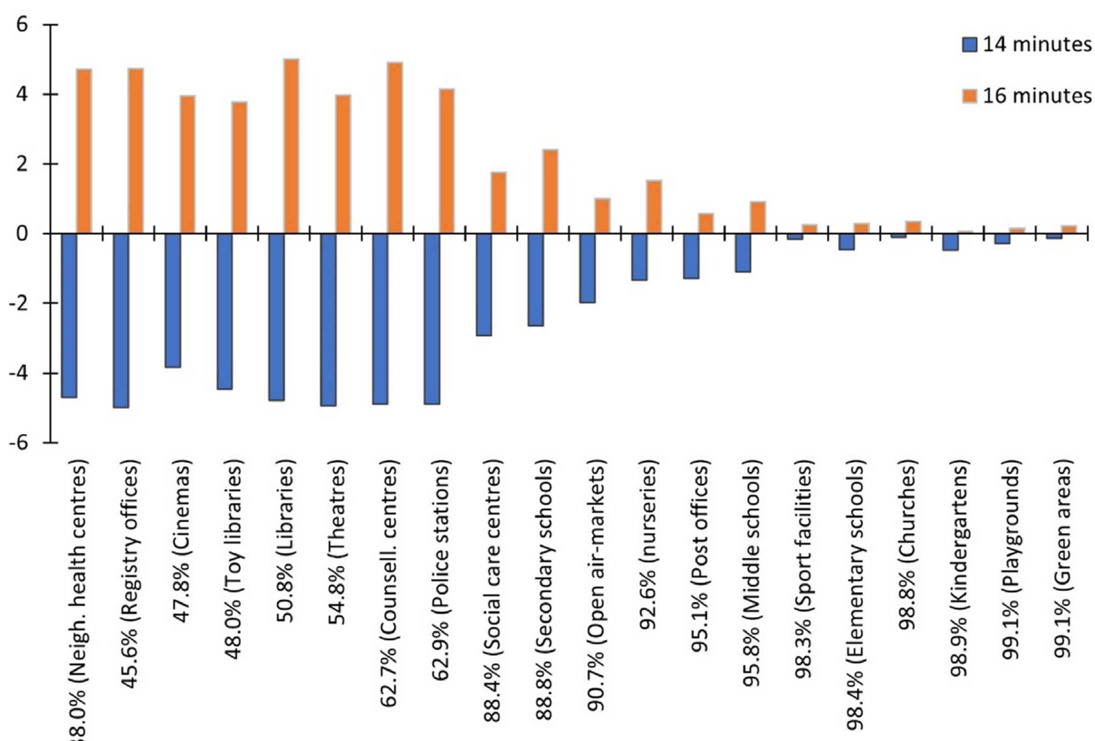

Fig. 11. Change of the percentage of the population that can access a given service in 15 minutes if a 14-minute or 16-minute threshold is adopted.

could imagine that it does[4]. But the answer probably cannot be binarily unambiguous.

Firstly, the percentage of the population that can access at least one location of a given service varies greatly from service to service, as well as depending on the time threshold. Currently, about 9 out of 10 Turin's inhabitants can reach schools of all levels, post offices, churches, green areas, playgrounds, sport facilities by a 15 minutes' walk; some of these services are already accessible by over 90% of residents in just 10 minutes. Then, the 20-minute threshold, often proposed as the target for low-density neighbourhoods, seems poorly appropriate for dense cities like Turin, at most, it could be set for services such as neighbourhood health centres, registry offices, playrooms and cinemas, as these are currently accessible in 15 minutes only to less than 50% residents. In contrast, the 5-minute threshold is probably excessively ambitious for most

[4] Despite most of the city was built before 1971, as anticipated in section 3.2, the current spatial distribution of the services covers most of the residential areas of the city, also thanks to the reuse from the 1990s of a great amount of abandoned industrial areas, which were mostly converted to residences and services.

services, even though some of them (kindergartens, green areas, playgrounds and sports facilities) are at present accessible by a 5 minutes' walk for over 50% of Turin's residents.

In this sense, it is questionable whether a unique time threshold is appropriate, or whether it would be more useful to adopt different target thresholds for different services (for example, 10 minutes for green areas and 15 minutes for cinemas). This would probably weaken one of the key factors for the success of this planning concept, i.e. its extreme simplicity; on the other hand, it would allow identifying different "desired" accessibility time thresholds through surveys, interviews etc., which can be carried out to co-define with residents which services are essential at the neighbourhood level and the maximum time citizens would accept to take to walk to a location of these services. As stated by Capasso Da Silva et al. (2020), "accessibility is a metric, but what are acceptable parameters of what is considered accessible must be set through policies" (p. 1). For example, a survey carried out in Guangzhou (Zhou, 2019) showed that elderly people over 70 were very time-sensitive to the trip distance to public facilities and considered a 15 minutes' walk unsuitable for their age. The normative adoption of the desired thresholds could allow identifying which actions – e.g., walkability improvement or spatial re-distribution of service locations – are primary in the different parts of the city.

Anyway, the identification of the most appropriate time threshold for accessing services cannot be based only on the demand side, but should take also into account the supply side. As a matter of fact, there is a trade-off between these two points of view: on the demand side, a high number of locations of a service would reduce the time threshold to access them, as shown in Section 4.3 (but at risk of worsening the cost efficiency of the service provision); on the supply side, a limited number of locations would allow some economies of scale (in terms of cost reduction for example for water provision, garbage collection, heating etc.; see Gómez-Reino et al., 2021), but at risk of worsening the spatial accessibility of these locations for users.

Accessibility indicators can help to find the balance between these two sides. Since its original definition by Hansen (1959), accessibility links land use (i.e. the location and attractiveness of an opportunity, for example a certain service) and transport variables (i.e. the generalised cost of travelling to reach that opportunity from a certain origin). As anticipated in section 2, in most cases, current approaches to putting the 15-minute city concept into practice focus on the transport variables, i.e. improving accessibility to services by increasing the speed of the trip to these services (through widened pavements, new pedestrian streets and cycle lanes etc.); less attention is paid to land use variables, i.e. the number and size of the service locations which are the destination of the trip. Actually, as seen in Section 4.3, the number of these locations is crucial in determining the percentage of the population which can access a service within a given time threshold. Moreover, these locations are not all the same. They may differ in terms of "attractiveness": for example, the number of screens and seats in a cinema, the number of plays in a playground, the number of stalls in an open-air market, the number of books in a library etc. On the demand side, this might make a location of a certain service more interesting for residents – even if farther away – than another. On the supply side, this attractiveness size can require a minimum number of users/customers that a service location has to attract in order to compensate for its operating costs. In other words, neglecting the different sizes of the locations can alter the cost efficiency of the number and spatial distribution of these locations (which is a key issue in public service provision nowadays, due to the shrinking financial resources of public administrations).

In order to take this dimension into account, cumulative opportunities indicators (which simply sum up the number of locations inside an isochrone, as it has been done in this paper; see also Cervero et al., 1999; Koenig, 1980) could be integrated with classical gravitational indicators. In this approach, for each census tract only service locations accessible within a certain time threshold (for example 15 minutes) would continue to be counted, but each of them would be "weighted" according to both its attractiveness and the generalized cost of accessing it (which includes not only time costs, but also qualitative issues: the same 15 minutes' walk can be much more pleasant if done under the shadow of a row of trees along the road, where car speed is moderated etc.). Accessibility indicators of this kind were proposed, for example, by Black & Conroy (1977) and Breheny (1978).

More complex indicators of accessibility were elaborated by Botham (1980), Fotheringham (1986), Shen (1998), van Wee et al. (2001) and Weibull (1976), in order to weight the attractiveness of service locations in relation not only to their size, but also to the number of their potential users. These indicators can be useful in identifying the optimal balance between the number, size and spatial distribution of service locations (given the spatial distribution of users). In a case like Turin (see Section 4.5), some services are overconcentrated in parts of the city (from which residents can access more than one of their locations within the considered time threshold), while scarce or absent in other parts. Most of the twenty considered services are public (except for cinemas, theatres and private nurseries) and could probably be re-distributed to other abandoned areas to serve the residents of the city more homogeneously and evenly. Balletto et al. (2021), for example, explain how to exploit disused public properties from the perspective of the 15-minute city.

As anticipated in Section 3.1, in this paper the attention has been focused on the diagnostic application of the methodology; however, in the planning phase it can be easily used to simulate how adding a new location of a given service in a certain (currently poorly served) part of the city, or modifying the spatial distribution of a few locations, could increase (or not) the percentage of Turin's population that can access the service, so increasing the spatial equity of accessibility.

6. Conclusions

This paper has tried to develop a methodological framework to analyse the levels of walking accessibility to services throughout a typical dense and walkable European city such as Turin. Most issues of the 15-minute city can be traced back to more or less past planning ideas such as the garden city, the neighbourhood unit, the superblock etc., which were generally conceived for designing new districts or urban areas, rather than being applied to existing cities. In the latter, the distribution of services is much more scattered and less homogeneous between one neighbourhood and another, so it can be more appropriate to address the issue throughout the whole city, and not at the level of the single neighbourhood.

The analysis of the city of Turin carried out in this paper has been aimed at identifying the level of walking accessibility to twenty kinds of local services from each census tract of the city. As just one case study has been considered, any claim of exhaustiveness and systematicity must be excluded; moreover, the analysis could be further articulated by including other transport means (e.g., cycling), more kinds of services, more disaggregated service users (children, elderly etc.). Nevertheless, some general conclusions can be drawn.

Firstly, the results show that, at least in dense and walkable European cities such as Turin, the 15-minute threshold cannot be always assumed as the necessarily most appropriate target, as many services can already be reached by foot within this time, or even in 10 minutes, by the majority of the population. Different thresholds could have to be set in different cities, or even in the same city for different services. In this sense, involvement of urban actors can be desirable to identify which local services are considered essential, which different time thresholds are acceptable to reach each of them and so on.

Secondly, it is true that in European cities such as Turin, probably more than in many Australian or American cities, walkability is often already widely assured throughout the city, as nearly all streets have pavements and spaces reserved for pedestrians. Although there is often ample room for further improvement in this walkability, the current levels of accessibility to services are significantly determined by another factor, namely the number and spatial distribution of the locations of these services. As anticipated in Section 2, this variable is currently given little consideration in the narrative, literature and practices of the 15-minute city. In this sense, it could be useful to recover some tools and approaches to complexify the operationalisation of the 15-minute city and plan it with reference not only to the demand side, but also to the efficiency of the spatial distribution of services and opportunities.

Finally, in the last two decades, the concept of accessibility has received renewed attention also in theoretical terms, by researchers who outlined how accessibility cannot be reduced only to the two dimensions of land use and transport; conversely, it is entrenched with spatial, economic, social, and personal factors, which influence the affordability of services and opportunities (Handy, 2020; Lucas et al., 2019; Silva et al., 2019). These factors are often neglected in the 15-minute city approach; however, they are crucial in order to design this city first of all for the most vulnerable citizens such as children, the elderly, the disabled etc., precisely those who often cannot use the car to access essential services (Calafiore et al., 2022; Guzman et al., 2021; Weng et al., 2019).

In conclusion, a major challenge for future academic research on the 15-minute city seems to be finding a set of accessibility indicators to operationalise the concept in all its complexity, without losing the simplicity and communicability of its narrative.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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