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Changing perspectives in times of crisis. The impact of COVID-19 on territorial accessibility

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ABSTRACT

The link between transport and land use in urban areas has always been characterized by a slow evolution process. COVID-19 brought, suddenly and unexpectedly, severe changes to the trip structure within urban areas, as several restrictions were combined with individual health fears. This study addresses the impact of the COVID-19 pandemic in the territory of Porto Greater Urban Area, in Portugal, measured under a structural accessibility approach. This was evaluated through a simulation model, combining different destination restrictions in three alternative scenarios during the pandemic and post-COVID, as well as the definition of four different personas, with distinct risk aversion to infections and telecommuting patterns. The results, presented as the spatial configuration of different mobility environments, foster a critical reflection on their implication for future transportation and land use policies.

This pandemic has shown that the territory behaves differently under a critical lockdown scenario, where active modes gain predominance to satisfy most travel needs, signalling a potential ability to enforce more sustainable mobility habits. Still, as the territorial configuration tends to the previous state of equilibrium as restrictions are lifted, particularly for non-telecommuters, the need for acting quickly is reinforced. While the growth of telecommuting can induce additional challenges to the management of urban mobility systems, most policy recommendations that were valid in the past will maintain its relevance, as non telecommuters will retain previous travel habits.

1. Introduction

The COVID-19 pandemic has dramatically distorted the mobility status quo. Suddenly, usual, and repetitive travel needs were severed by emergency states and ‘stay at home’ appeals. Living rooms and home offices became the destination of what was once a tedious commute, and e-commerce and online streaming services replaced the trips to local shops, shopping centres and most leisure destinations. At a time when concepts such as the ‘15-minute city’, inspired by the urban design principles of ‘New Urbanism’, were gaining traction, the need to study this new reality into the future of urban living is reinforced.

The three core elements of density, diversity and design (Cervero and Kockelman, 1997), that for long have guided the understanding of urban mobility became irresponsible to these abrupt changes. While essential activities remained open, commuting, being a significant portion of daily travel, became for many a mere vision of the past. Urban mobility faced a dramatic shift that decades of

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scientific research, activism and policies were not able to fully leverage.

Active transport modes, namely walking and cycling, suddenly became more attractive. To seize this mobility momentum, numerous cities invested in temporary cycling infrastructure and jumpstarted a long sought-after increase in bicycle use, with inherent environmental benefits. In addition, as those who cannot afford a car experienced improved mobility conditions, this trend reinforced the need to think on the equity of urban areas through a search for greater mobility justice (Sheller, 2018). However, the situation induced by the COVID pandemic came as a double-edged sword. Growing fears of crowding also increased the risk perception of using public transport (Cho and Park, 2021; Kim and Kang, 2021), reinforcing the car’s role as a ‘safe haven’ to satisfy mobility needs, which could revert the benefits of other efforts targeting more sustainable mobility habits.

In fact, COVID-19 has highlighted the complex nature of territorial planning by exposing how the social sphere can imply massive repercussions on the accessibility of multiple activities (Beck and Hensher, 2020; Zecca et al., 2020). As a consequence, it is a unique opportunity to rethink the organization of urban activities and the transport system, following the growing trend from “planning for mobility” to “planning for accessibility” (Banister, 2008; Silva and Pinho, 2010).

This paper evaluates the impact of the disruptions caused by the COVID-19 pandemic on the territory, under a structural accessibility approach (Silva and Pinho, 2010). It does so by considering the accessibility to different daily activities and under various transport modes, overlaid with the restrictions imposed during the COVID-19 pandemic. As individual perceptions are an important part of the decision to travel, a layer of behavioural perceptions, using the concept of personas (Cooper, 1999), is used to model different interpretations of risk and commuting needs.

This analysis connects the characteristics of the transport infrastructure, the location of activities, with imposed restrictions, and individual perceptions, simulating different typologies of travel patterns, before, during and after the COVID-19 pandemic. This combination, in turn, defines a typology of mobility environments (Bertolini and Dijst, 2003) for the territory. These characterize an homogenous geographical unit by the diversity and/or the number of activities accessible by a particular combination of transport modes. The Porto Greater Urban Area, in Portugal, was used as a case study. The objective of this paper is, first, to simulate the changes, for different moments in the pandemic, on the relationship between the land use and transport system layers in this territory. Second, through a critical analysis of these results, evaluate the adequacy of different mobility management measures, aiming at more sustainable mobility habits.

Following this introduction, this article is divided in five additional sections. The first introduces the concepts utilized in this study. The second and third, respectively, present the adopted methodology and the case study. The two last sections discuss the main findings and present the conclusions and future steps to deepen this research.

2. The determinants of travel choice

2.1. Accessibility as an aggregating concept

The diversity of activities surrounding each one’s home has a major impact on the number of trips taken daily and the transport modes compatible with said trips. While self-selection plays an important part in selecting the place of residence, following individual preferences, attitudes and economic factors, the built environment is crucially influential (Chen and McKnight, 2007; Mokhtarian and Cao, 2008).

The concept of accessibility is known to provide a useful framework for evaluating the territory and the designing of integrated land-use and transport policies (Bertolini et al., 2005; Halden, 2002; Handy, 1996; Silva and Pinho, 2010), aiming to redistribute the demand for travel (Banister, 2008). Since Hansen’s (1959) definition of being the “potential of destinations for interaction”, the concept has evolved into more comprehensive forms. The gradual inclusion of components, particularly those focused on the individual level, has shifted the concept’s meaning to the “ability of people to access destinations” (Curl et al., 2011), which is suited to the purpose of this exercise.

Recent studies have addressed the characterization of the territory and its population either by evaluating accessibility to a wide range of destinations (Soria-Lara et al., 2015), or by taking a more sectorial approach, by exploring solely retail (Arranz-López et al., 2017) or green spaces (Jalkanen et al., 2020), to name a few. Some determine accessibility through catchment areas of certain mobility types, which in turn are identified through travel surveys and georeferenced data (Ellder et al., 2020; Jalkanen et al., 2020; Shin, 2020; Zecca et al., 2020). These are based on current or past travel patterns, with some providing a comparison between both (Zecca et al., 2020). Yet, Liu et al. (2020) provide a different approach by predicting future accessibility through population growth projections, points of interest and surveys on their perception of crowding to collect their discomfort levels. This final point touches on important issues for accessibility analysis in the COVID-19 era, as public’s perception of safety in travel and destinations shifts.

This study resorted to the concept of structural accessibility, as defined by Silva and Pinho (2010). It is based on the general formulation of the concept of accessibility, yet instead of focusing on a single type of activity, it considers key daily activities, such as workplaces, schools, and shopping locations, to other less used facilities hosting leisure and cultural activities, while combining different travel modes (Silva and Pinho, 2010). By considering a wide range of possible urban destinations and mobility options from a given origin, structural accessibility reveals to which extent the urban structure constrains travel choices. It does not measure mobility by itself, but rather the potential for it, which is useful for evaluating the impact of changes in the distribution of land uses or improvements in infrastructure (Albacete et al., 2017; Da Silva et al., 2020; Hernandez, 2018; Silva and Pinho, 2010).

While accessibility can be defined and operationalized in different forms, as a result of its inherent complexity (Batty, 2009), it is generally understood that it comprises four independent components: land use, transport, time, and individual (Geurs and van Wee, 2004; Iacono et al., 2010; Silva and Pinho, 2010). The first evaluates the structure of the territory, measuring the opportunities
(demand) for travel, and the second characterizes the capacity of the transport infrastructure (supply), often measured by travel time and/or cost. The two additional components are extra layers that reflect the complexity of urban living. While the time component digs into existing temporal constraints that prevent certain activities at a given period, the individual component looks at the influence of needs, abilities, and opportunities. However, accessibility evaluation approaches often explore only a subset of these dimensions, depending on the perspective taken.

2.2. Addressing the impact of COVID-19

In the context of COVID-19, the infrastructure system, apart for some temporary limitations, kept offering similar levels of service, housing occupied the same physical location, but new restrictions were imposed on the use of certain activities. These restrictions, explaining a significant part of mobility reductions (Beck and Hensher, 2020; Mendolia et al., 2021), were combined with strong individual concerns on health and safety (Vallet et al., 2020; Wang and Thiel, 2014), creating a stronger aversion for social encounters (Lapatinas, 2020), crowded places (Cori et al., 2020; Kim and Kang, 2021), or public transport (Shelat et al., 2021). Combined, these have been found to decrease the number of daily trips from 15% (Mendolia et al., 2021) up to 80% (Cronin and Evans, 2020), depending on the context. These policy restrictions and behavioural adjustments can therefore simulate the use of time or individual accessibility components, which are more complex to consider (Geurs and van Wee, 2004). However, as no two persons are alike, the consideration of all different possibilities that influence individual behaviour is a difficult task.

Given the scarcity of detailed data on individual perceptions, in this study the concept of personas is used to exemplify different mobility tendencies of the population that have emerged from the pandemic. Born within the field of marketing (Cooper, 1999), personas define fictional characters representing user typologies. These characters provide a base for decisions and have been used within the transportation domain to develop user-targeted solutions (De Clerck et al., 2018; Mayas et al., 2014; Vallet et al., 2020).

To merge these lenses of analysis into a cohesive characterization of the urban environment, this study adopted the concept of mobility environment (ME), as defined by Bertolini and Dijst (2003). By aggregating the territory under similar mobility profiles, a given portion of the territory, for example, can host a multimodal mobility environment if possessing high levels of accessibility to most activities via different transport modes. On the other end of the sustainability scale, an area can be home to a ‘car-centric’ mobility environment, if such mode is the only alternative. The definition of this abstract identity of a certain location is no more than a measure of its performance within the land use – transport interaction (Zandvliet et al., 2008).

Characterizing the territory in such a manner allows identifying where certain modes and/or activities take precedence and how shifts in the spatial configuration of these mobility environments can be used to guide the definition of consistent and comprehensive policy actions. In this study, these actions will be based on Transportation Demand Management (TDM) which, in its essence, blend measures that encourage sustainable modes of transport while reducing the attractiveness of the car (Banister, 2008; Bond and Steiner, 2006; May 2016). These combinations offer the ability to form synergetic relations, improving the overall outcome of the TDM strategy (Eriksson et al., 2010) and generating a more equitable mobility system.

3. Methodological approach

Mobility patterns in urban areas are the result of the complexity of the urban structure, with non-work trips often exceeding the frequency of traditional commutes. To account not only for the diversity in activities, but also for its relevance for mobility patterns, this study uses a Comparative Accessibility (CA) Index. It consists on a contour measure that counts the number of reachable activity types within a predefined time limit based on the dissimilarity index of Cervero and Kockelman (1997), hence being a type of structural accessibility.

![Fig. 1. Contour factor schematic representation.](image-url)
with \( y = \text{activity type}, \ CF_y = \text{contour factor of } y, \) and \( f_y = \text{potential use frequency of } y. \)

This comparative accessibility index introduces a fuzzy contour factor (CF), that attempts to introduce the complexity of the gamut of destinations. For all activity types this factor assumes a value between 0 and 1 (from null to full accessibility). For a certain set of opportunities, the CF adopts a ‘binary’ nature and is defined by a rectangular function, i.e., it can only assume the values of 0 or 1. For example, if one post office is accessible, accessibility to that activity type is satisfied, since all post offices provide the same service. For others, diversity is important. For instance, while being able to access a single restaurant might not be enough to satisfy one’s needs, after a given amount an increase in the number within reach is subject to diminishing returns. In these situations, identified as ‘gradual’, a linear function is used, and the contour factor results from the ratio between the number of accessible activities and a cut-off value (Fig. 1). This cut-off value, representing the previously mentioned target amount, is calibrated according to each context under analysis. Above this value, the CF assumes a unitary value, meaning that accessibility needs for such destination type are satisfied. As not all destinations are equally relevant within the pool of daily trips, potential use frequencies represent the percentage of trips to each activity type on the overall set of potential daily trips and are calibrated to match likely urban travel patterns.

While contour accessibility measures are less accurate than gravity-based ones, which consider a distance or time decay effect (Geurs and Van Eck, 2001), they also imply considerable increases in computation time, especially in large catchment areas and an extensive dataset of destinations. This method also reduces a possible distortion on accessibility values caused by the concentration of

Fig. 2. Study Area.
certain activities types within a small area (Geurs and Van Eck, 2001), while being sensitive to the lack of variety offered in peripheral urban territories. At the same time, it maintains a responsiveness to changes on the availability and willingness to travel to such activities, which is exactly in line with the dynamics brought by the pandemic. In this study, activities are also classified according to the nature of trips, defining a floating catchment area. Some, such as primary schools, parks and supermarkets tend to adopt a local nature, meaning that users tend to use those in close vicinity and, hence, be reluctant to take longer trips. For trips to activities such as universities, hospitals or even work, classified as non-local, these limitations tend to be less severe and longer trips are tolerable.

The fuzzy contour factor and the floating catchment area introduced in this study introduce competition effects, consider the nature of activities, and avoid the need to calculate several additional indicators to fully characterize accessibility (Apparicio et al., 2007), optimizing the calculation procedure.

| Date       | Event Description                                                                 |
|------------|-----------------------------------------------------------------------------------|
| March 12th | Suspension of schools                                                             |
| March 15th | Closing of all cultural and leisure facilities                                     |
|            | Prohibition of all events with over 100 participants                                |
| March 18th | Mandatory lockdown - closing of all non essential services*                        |
|            | Implementation of work from home regime                                           |
|            | 1/3 occupancy limit on public transport                                           |
| May 4th    | Reopening of public services and shops <200m²                                      |
|            | Lifting of restrictions for events <10 participants and practice of individual open air sports |
|            | 2/3 occupancy limit on public transport                                           |
| May 18th   | Reopening of shops <400m² restaurants and cafés                                   |
|            | Reopening of kindergartens and schools for the 11th and 12th grades                |
| June 1st   | Reopening of all stores, shopping centres, cinemas and theatres                    |
|            | Partial work from home regime                                                     |
| September 15th | Beginning of school year                               |
|            | End of work from home regime                                                      |
| October 14th | Prohibition of all events with over 50 participants                                |
| November 9th | Mandatory lockdown after 23:00 during weekdays and 13:00 during weekends          |
|            | Closing of all non-essential services* during that period                          |

* Essential services: supermarkets, food retail, newsstands, pharmacies, home appliances and electronics, hardware stores, repair services, drycleaners, restaurants (take-away only), drugstores, gas stations, opticians, banking and insurance, health services

Fig. 3. Summary of the evolution of restrictions and mobility patterns during 2020.
This method, however, cannot address a sequence of chained trips. While trip chaining is a natural component of urban mobility, possible by the concentration of activities (Adler and Ben-Akiva, 1979; Shiftan, 1998), the results of its application do not show significant differences to individual trip-based accessibility models (Dong et al., 2006). For example, it is expected that with insufficient CA values for walking or public transport, meaning that only some of daily travel needs can be satisfied by such travel modes, the car appears as the only alternative for making more complex trip chains. This is line with the literature stating a positive influence of polycentric urban structure on the reduction of car use (Casello, 2007; Schwanen et al., 2001). As such, in this study, trips starting from the place of residence act as proxies to characterize territorial performance.

The CA index is responsive to local conditions, and thus require a context-specific calibration. This encompasses the definition of activity types, cut-off values for the gradual contour factors and the distribution per trip purpose (\( \xi \)). The definition of travel time cut-off values for each of the transport modes under analysis is also context dependent, providing a better fit to the real travel patterns of the population. While there is hardly an agreement on the most appropriate assumptions and methods in accessibility measurement (Vale et al., 2016), it is important to stress that this calibration is associated with some subjectivity and interpretation from the evaluator, which is an undeniable part of the modelling process. A visual summary of this methodological approach can be found in Appendix C.

4. Case study

4.1. The context of Porto Metropolitan area

The Metropolitan Area of Porto is Portugal’s second largest urban area, with an estimated population of roughly 1.7 million over an area of 2 000 km\(^2\). The selected case study, known as the Greater Porto Urban Area, comprises the six core municipalities of this territory, hosting roughly 1.1 million residents within 562 km\(^2\). Despite the presence of an extensive public transport network, a similarly comprehensive high-capacity road network increases the attractiveness of the car (Fig. 2). The results from the 2017 Mobility Survey (INE, 2018) demonstrate the establishment of a strong car dependency, with a modal share of 66%. Approximately 19% of all trips were made by foot and only 15% by public transport. The bicycle had a residual modal share of 0.4%. With roughly 2,7 trips/day, common travel patterns extended beyond the usual binomial work-home or school-home trips. These results are in line with a previous exercise performed in the year 2000 for the region, which demonstrates a relative stability in mobility patterns under normal conditions (INE, 2000).

Lower densities at suburban areas, discouraging walking and cycling, combined with an apparent disconnection of public transport coverage to the travel needs of residents (Silva and Pinho, 2010) and the cultural association of the car as a status symbol (Beirão and Sarsfield Cabral, 2007) are the strongest determinants of this region’s modal share distribution. As a profound reconfiguration of the territorial structure is difficult to enforce, at least within a reasonable time frame, changes in regular mobility habits can provide the necessary push for meaningful change.

The COVID-19 pandemic brought severe disruptions to the mobility habits within this region. The timeline of events shows, within the period of one week, the suspension of activity at schools followed by the leisure and culture sectors, quickly extended to a mandatory lockdown on March 18th, 2020 (Fig. 3). At the beginning of May, restrictions were gradually lifted and by early June nearly all activities were operational. Closer to the end of year, a second wave of the pandemic forced the government to impose additional restrictions, albeit less restrictive than before.

Google Mobility reports (Google, 2020), which compile anonymized location data from user’s mobile devices, were used to analyse the evolution of mobility patterns. Fig. 3 represents average weekly use patterns of five different activity types, compared with a baseline period of January 3rd to February 6th, 2020. During the critical lockdown period (mid-March to early May) reductions are noticeable (~80%) in trips to retail and recreation, parks, and workplaces, both during weekdays and weekends. Grocery and pharmacy was the least affected category, as virtually no restrictions were enforced. Despite a 50% reduction in access to parks during April, the variation after the lockdown period is mostly influenced by the more inviting summer weather. The increase in December, especially for retail and grocery, demonstrates the impact of the Christmas shopping season. Access to workplaces also shows an interesting trend. During weekdays, a strong reduction in the months of April and May (~60%) is followed by a steady increase until November (~20% from baseline), notwithstanding a dip in August as result of summer vacation. This indicates that telecommuting became the ‘new normal’ for roughly 20% of the workforce. A similar analysis on weekends and holidays indicates a weaker impact of these restrictions as those mostly refer to workers of essential services, retail, and restaurants, who cannot telecommute.

Public transport data is another relevant indicator for gauging the impacts of the pandemic. Analysing monthly metro ridership and supply data (Metro do Porto, 2021), from March 18th to May 4th access to the metro system was made free, as all ticket vending machines and validators were put offline for sanitary reasons. This explains, in part, the sudden observable dip in demand in March and impedes the analysis in April. Nevertheless, as total supply experienced a significant decrease (roughly ~33%), it is safe to assume that demand fell to dramatically low values. And while the metro operator quickly added capacity to the system (roughly 15% above average supply), user’s trust in public transport was never fully restored, with ridership peaking in October and December at around two thirds of the average demand.

Road traffic data was also analysed, considering monthly traffic reports from the Portuguese National Institute for Mobility and Transports (IMT, 2021). Measured at five of Porto’s main highway entrances, results indicate a similar trend, with a critical reduction between March and May (peaking at ~60%). And while during summer and fall months traffic volumes were restored to previous averages, November and December showed the impact of a new wave of restrictions.
4.2. Calibration of activity types and contour accessibility parameters

In this study, accessibility measurement relies on twenty activity types, encompassing work, school, shopping, health, and leisure activities, but also other destinations to fulfill personal needs (Table 1). This was determined by the need to include diversity in possible destinations but also the discrepancy in access restrictions during the lockdown stage of the pandemic.

The definition of cut-off values for the gradual contour factors follows a sensitivity approach, fine-tuned to the particularities of the study area. These represent 5% of the total set of opportunities for higher education facilities, public administration, and employment, 10% for culture and leisure, 1% for retail, and 2% for the remaining activity types. These values are defined considering the existing variety within each activity type, and were calibrated following consultation with experts on the field. As an example, being able to access thirty different restaurants, for a particular transport mode, signifies full accessibility to activity type 12.

The CA index is calculated via the shortest network time, using ArcGIS, for four transport modes: pedestrian (PED), bicycle (BIKE), car (CAR) and public transport (PT). Time is considered as the only cost variable, with values for each mode calibrated from the Regional Travel Survey. Starting from average travel times of 15, 28, 19 and 32 min for walking, bicycle, car, and public transport, respectively, these set the basis to calibrate cut-off values for local and non-local activities (Table 2). The exception was for the bicycle, as the values are matched to the car to demonstrate the potential of a modal transfer. Following consultation with experts, travel cut-off times for non-local activities were defined as being twice the value of local ones, for all transport modes.

A calibration of the transport infrastructure was required prior to the calculation of CA value. For the pedestrian and bicycle mode, travel speed was calibrated from each segment’s slope (Silva et al., 2018; Tobler, 1993). Pedestrian speeds varied between 1 and 5 km/h while cycling speeds ranged from 4 to 21 km/h. Car travel speeds were adjusted based on road hierarchy and average congestion, varying from 30 to 80 km/h for the highway network and 15 to 40 km/h for the remaining infrastructure. The time spent looking for parking was defined according to parking pressure on the road network, imposing a time penalty ranging between 1 and 10 min (Vasconcelos and Farias, 2017).

For public transport total travel time was composed of three distinct steps: walking from origin to the first stop, travel within the transport network, including any possible interchanges, and walking from the last stop to the destination. This imposes limits over which users will not walk to and from a stop nor wait for the next vehicle. Considering the generally used catchment area of public transport stops of 400 m, it is reasonable to consider walking time to be around 5 min, with an average speed of 5 km/h. Similarly, a 5 min walk limit was imposed after the exit from the final vehicle. This means that trips that incurred in a walking time of more than 10 min were excluded. For non-local activity types, a longer walk time of 15 min was considered, according to users’ willingness to make longer trips. Waiting time was calibrated as half the value between headways and no limit was imposed on the number of interchanges, as long as total travel time stayed below the predefined cut-off limit.

While only six municipalities are addressed in this study (Gondomar, Maia, Matosinhos, Porto, Valongo, and Vila Nova de Gaia), the activities database encompass a wider urban territory, eliminating the underestimation of accessibility closer to the edges of the study area. The results are calculated for the census tract, the smallest unit of spatial disaggregation.

4.3. Calibration of trips motives

The last step in the calibration procedure consists of the definition of potential use frequencies (f_p) for each activity type (Table 3). The baseline scenario (S0) corresponds to a situation before COVID-19 restrictions were put in place, and to which reliable information

| Activity type                          | Type | Contour (cut-off value) |
|----------------------------------------|------|------------------------|
| 1 Nursery and kindergarten             | L    | G (5)                  |
| 2 Primary school                       | L    | B                      |
| 3 Elementary school                    | NL   | B                      |
| 4 High School                          | NL   | B                      |
| 5 Higher Education                     | NL   | G (3)                  |
| 6 Parks and Gardens                    | L    | B                      |
| 7 Culture and Leisure                  | NL   | G (15)                 |
| 8 Supermarket                          | L    | B                      |
| 9 Proximity Retail                     | L    | G (20)                 |
| 10 Non-proximity retail                | NL   | G (100)                |
| 11 Pharmacy                            | L    | B                      |
| 12 Restaurants                         | NL   | G (30)                 |
| 13 Hospital                            | NL   | B                      |
| 14 Health Centre                       | L    | B                      |
| 15 Private Health                      | NL   | G (30)                 |
| 16 Post Office                         | L    | B                      |
| 17 Banks                               | L    | G (10)                 |
| 18 Public administration               | NL   | G (10)                 |
| 19 Other services                      | NL   | G (70)                 |
| 20 Employment                          | NL   | G (30 000)             |

L Local NL Non-local B Binary G Gradual.
on the disaggregation of trip motives exists. The Regional Travel survey’s microdata for the Porto Metropolitan Area was truncated to account for only the trips performed by adults (25–64 years), initiated at the six municipalities under assessment and excluded return to work trips, increasing the fidelity of the distribution of travel reasons. Only adults are considered in this study as these host more complex travel patterns than the remaining age groups. On average, adults have more responsibilities, from work, accompanying children to school or elderly family members, to shopping and household and personal errands. This multiplicity of activities results in more dynamic mobility patterns, which would also be more impacted by the imposed restrictions and thus provide a more comprehensive scope of the changes in accessibility. A sample of approximately 18 000 trips was hence used to calibrate the distribution of travel needs of an adult.

Trip reasons from the Travel Survey are then distributed between the 20 activity types. As the number of trip reasons is smaller than the number of activity types, these are distributed following a sensitivity approach on the expected frequency of trips (for more information see Appendix A). Regarding trips to school (adults accompanying students and encompassing activity types 1 to 5), trip frequency distribution took into consideration the current demographic distribution by age group.

Three scenarios are designed, reflecting the impact of access restrictions: SL (lockdown), SA (alleviation of restrictions), SF (possible future). In addition, four personas are created, simulating different levels of awareness to risk and travel needs: CA-T (COVID aware and telecommuter), CA-NT (COVID aware and non-telecommuter), CF-T (COVID fearless and telecommuter) and CF-NT (COVID fearless and non-telecommuter). It is important to stress that these represent purely simulation exercises and exist to test the sensitivity of the model in capturing differences in territorial performance, according to shifting individual travel needs.

The lockdown scenario (SL) corresponds to the quarantine period when restrictions were more severe. Activities that were forcefully shutdown, as is the case with schools, imply a null \( f_y \) value. For the remaining categories, the results from Google Mobility Reports are used to calibrate the distribution by activity categories (see Appendix B). As this dataset lacked the necessary discrimination in terms of the activity types considered, generalized tendencies of evolution from the baseline scenario were modelled (maintain, half and double the number of trips). The number of trips to work (5 trips per week represented 44% of all weekly trips) was used to calibrate the number of weekly trips for the remaining activity types. Under this scenario, those more aware to the risks of

| Table 2 | Travel time cut-off values. |
|---------|-----------------------------|
| Activity type | PED cut-off time (min) | BIKE | CAR | PT |
| Local | 10 | 15 | 15 | 25(a) |
| Non-local | 20 | 30 | 30 | 50(b) |

(a) incl. max. 10 min. walking time.
(b) incl. max. 15 min. walking time.

| Table 3 | Modelling of potential trip frequencies for the different scenarios and personas. |
|---------|--------------------------------------------------------------------------------------------------|
| Activity types | Potential trip frequencies per adult \( (f_y) \) - % | S0 | SL | SA | SF |
| Nursery and kindergarten | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 |
| Primary school | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 |
| Elementary school | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 |
| High School | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 |
| Higher Education | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 |
| Parks and Gardens | 6 | 10 | 9 | 35 | 24 | 9 | 8 | 24 | 18 | 6 | 14 |
| Culture and Leisure | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 5 |
| Supermarket | 4 | 7 | 6 | 24 | 16 | 6 | 5 | 16 | 12 | 4 | 5 |
| Proximity Retail | 4 | 7 | 6 | 24 | 16 | 6 | 5 | 16 | 12 | 4 | 5 |
| Non-proximity retail | 2 | 0 | 1 | 0 | 4 | 1 | 3 | 4 | 6 | 1 | 1 |
| Pharmacy | 1 | 2 | 1 | 6 | 4 | 1 | 1 | 4 | 3 | 1 | 1 |
| Restaurants | 5 | 0 | 4 | 0 | 10 | 4 | 6 | 10 | 15 | 5 | 12 |
| Hospital | 1 | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 |
| Health Centre | 1 | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 |
| Private Health | 1 | 2 | 1 | 6 | 4 | 1 | 1 | 4 | 3 | 1 | 1 |
| Post Office | 2 | 0 | 1 | 0 | 4 | 1 | 3 | 4 | 6 | 1 | 1 |
| Banks | 2 | 0 | 1 | 0 | 4 | 1 | 3 | 4 | 6 | 1 | 1 |
| Public administration | 2 | 0 | 1 | 0 | 4 | 1 | 3 | 4 | 6 | 1 | 1 |
| Other services | 2 | 0 | 1 | 0 | 4 | 1 | 3 | 4 | 6 | 1 | 1 |
| Employment | 44 | 72 | 64 | 0 | 0 | 64 | 57 | 0 | 0 | 46 | 26 |

S0 – Base scenario SL – lockdown scenario SA – alleviation scenario SF – future scenario.
CA – COVID aware CF – COVID fearless NT – non-telecommuter T – telecommuter.
COVID (CA) reduce their trips to the bare minimum (primarily focused on parks and gardens, supermarkets, proximity retail and health). Those with a COVID fearless (CF) personality tend to make trips and access other activities such as restaurants, non-proximity retail and other services, despite less often than on the baseline scenario due to restrictions on opening schedule and number of visitors allowed per m². Those who telecommute (T) have a null \( f \) value to activity type 20 (employment).

Scenario SA reflects an alleviation in some of the restrictions previously in place. Its enforcement can adopt a cyclical nature, in the path to the full eradication of the pandemic. In this scenario, while schools remain physically closed, all commercial and most leisure activities are reopened. Those who can continue working from home avoid trips to workplaces, while those with a COVID aware personality continue making fewer trips, particularly to less essential services, non-proximity retail and restaurants, while avoiding enclosed culture and leisure activities. On the other hand, those without fear of the virus (CF) maintain most of their habits prior to the pandemic, with the exception being culture and leisure, due to less frequent events.

Scenario SF corresponds to a potential future, after the pandemic, meaning that fears of the virus are left behind. In this vision, changes in habits during COVID-19 restrictions generate new travel needs, namely a growth in online services and a corresponding decrease in the need to travel to work, shops (particularly non-proximity retail), and other services. This is line with studies that point working from home as one of most significant long term changes emerging post pandemic (Bojovic et al., 2020; Currie et al., 2020). For telecommuters (T) this scenario envisions a 50–50 distribution of presential and 'work from home'. Consequently, this requires a counterbalancing act to sustain the social nature of humans (Beck and Hensher, 2020). The reduction in commuting and subsequent increase in discretionary time could mean either added working hours or more time spent in recreational and social activities (Marcus and Pepper, 1995). This simulation adopted the second premise, to which there is evidence from before (Chakrabarti, 2018; Nayak and Pandit, 2021) and during the pandemic (Restrepo and Zeballos, 2020). Hence, telecommuters are attributed double the frequency of access (compared with the baseline scenario) for activity types 6, 7 and 12.

The following section compares the changes in accessibility throughout the different scenarios and personas to understand the shifts in territorial performance.

### Table 4
Distribution by accessibility intervals.

| Accessibility conditions | % of adult population within each accessibility interval |
|--------------------------|--------------------------------------------------------|
|                         | S0         | SL         | SA         | SF         |
|                         | CA NT | CF NT | CA T | CF T | CA NT | CF NT | CA T | CF T | NT | T |
| **Pedestrian**           |        |        |      |      |        |        |      |      |    |   |
| High                     | 5,6   | 18,4  | 23,6 | 48,7 | 57,0  | 4,4    | 6,5  | 30,1 | 42,2 | 4,5 | 11,2 |
| Medium                   | 28,8  | 0     | <0,1 | 0    | 0    | 19,2   | 23,4 | 26,9 | 20,9 | 26,1 | 32,8 |
| Low                      | 65,6  | 81,6  | 76,3 | 47,5 | 42,5  | 76,3   | 70,0 | 42,5 | 36,4 | 69,3 | 56,0 |
| No accessib.             | <0,1  | <0,1  | <0,1 | 3,8  | 0    | 0      | 0    | 0    | 0    | 0,0  | 0,0  |
| Average CA               | 0,33  | 0,26  | 0,28 | 0,44 | 0,42  | 0,28   | 0,30 | 0,42 | 0,41 | 0,33 | 0,37 |
| **Bicycle**              |        |        |      |      |        |        |      |      |    |   |
| High                     | 93,7  | 85,9  | 92,0 | 91,1 | 97,1  | 92,0   | 94,2 | 97,1 | 98,2 | 92,6 | 94,6 |
| Medium                   | 4,7   | 11,2  | 5,7  | 7,2  | 1,9   | 5,7    | 4,0  | 1,9  | 1,1  | 5,7  | 4,2  |
| Low                      | 1,6   | 2,9   | 2,3  | 1,7  | 1,1   | 2,3    | 1,8  | 1,1  | 0,7  | 1,7  | 1,2  |
| No accessib.             | 0     | 0     | 0    | <0,1 | <0,1  | <0,1   | <0,1 | <0,1 | <0,1 | 0,0  | 0,0  |
| Average CA               | 0,96  | 0,96  | 0,96 | 0,96 | 0,96  | 0,96   | 0,96 | 0,96 | 0,96 | 0,96 | 0,96 |
| **Public Transport**     |        |        |      |      |        |        |      |      |    |   |
| High                     | 64,6  | 54,0  | 63,6 | 54,4 | 64,4  | 63,6   | 69,7 | 64,4 | 71,9 | 61,7 | 64,4 |
| Medium                   | 16,0  | 24,2  | 15,8 | 12,9 | 9,1   | 15,8   | 11,4 | 9,1  | 13,6 | 18,2 | 17,2 |
| Low                      | 13,0  | 15,3  | 14,1 | 24,3 | 19,4  | 14,1   | 12,4 | 19,4 | 7,3  | 13,6 | 12,0 |
| No accessib.             | 6,5   | 6,5   | 6,5  | 8,5  | 7,2   | 6,5    | 6,5  | 7,2  | 7,2  | 6,5  | 6,5  |
| Average CA               | 0,76  | 0,77  | 0,76 | 0,66 | 0,69  | 0,76   | 0,76 | 0,69 | 0,72 | 0,76 | 0,74 |
| **Car**                  |        |        |      |      |        |        |      |      |    |   |
| High                     | 99,8  | 98,4  | 99,7 | 98,4 | 99,7  | 99,7   | 99,9 | 99,7 | 99,9 | 99,7 | 99,7 |
| Medium                   | 0,1   | 1,5   | 0,2  | 1,5  | 0,2   | 0,2    | <0,1 | 0,2  | <0,1 | 0,2  | 0,2  |
| Low                      | <0,1  | <0,1  | <0,1 | 0,1  | <0,1  | <0,1   | <0,1 | <0,1 | <0,1 | 0,1  | 0,0  |
| No accessib.             | 0     | 0     | 0    | <0,1 | <0,1  | <0,1   | <0,1 | <0,1 | <0,1 | 0,0  | 0,0  |
| Average CA               | 1,0   | 1,0   | 1,0  | 0,99 | 0,99  | 1,0    | 1,0  | 1,0  | 0,99 | 1,0  | 1,0  |
| High Accessibility threshold | 0,81 | 0,97  | 0,86 | 0,86 | 0,61  | 0,86   | 0,77 | 0,61 | 0,45 | 0,85 | 0,76 |

S0 – Base scenario SL – lockdown scenario SA – alleviation scenario SF – future scenario.
CA – COVID aware CF – COVID fearless NT – non-telecommuter T – telecommuter.
5. Results and discussion

5.1. Accessibility metrics

For the analysis of the aggregate score, accessibility conditions are divided in four intervals (Table 4) for each of the four considered transport modes. The high accessibility threshold is defined by the sum of the weights of a set of basic activities that are considered, by the authors, as being essential, regardless of the restrictions in place (education, employment, green spaces, supermarkets, proximity retail and pharmacies). Due to the different weighing system for each scenario, the threshold value fluctuates accordingly. The two following intervals (medium and low) are separated at half this value. A fourth and last interval indicates territories with no accessibility, which is particularly useful, for example, to identify situations with no access to public transport. This table also presents, for each transport mode, scenario and persona, a population weighted average CA value.

The results for the base scenario (S0) are clearly illustrative of the asymmetries between different transport modes. Walking does not get one so far when attempting to fulfil travel needs with only 6% being able to satisfy most of them, and 29% half of the possible destination types. This means that most of the population has low pedestrian accessibility, demonstrated by an average CA score of 0.33. While bicycle accessibility is particularly high (average CA of 0.96), it is not representative of its modal share. Therefore, these results should be interpreted as a latent potential, and its geographical analysis (particularly for the 94% of the population that have high accessibility) can be useful for targeting efforts towards bicycle promotion strategies. Public transport accessibility is relatively good (average CA score of 0.76), with more than two thirds of the population benefitting from high values. Still, 6.5% of the population has no public transport accessibility, meaning that roughly 70 000 residents must rely on alternative modes to satisfy their mobility needs. Car accessibility, on the other hand, is high for the overwhelming majority of the population. The average CA of 1.00 is a clear indicator of the car’s predominance in the modal share distribution.

The new daily mobility needs in the lockdown scenario (SL) imply a considerable shift in territorial performance. Those who can benefit from telecommuting (CA T and CF T) experience an increase in pedestrian accessibility. Nevertheless, in the case of COVID aware personas, it appears that nearly 4% of adults reside in areas without pedestrian access to basic amenities, even if other activities are accessible. For non-telecommuters (CA NT and CF NT), the increased weight of work trips within the average daily journey leads to an overall worse performance, with a similar tendency found when comparing awareness to risk.

Regarding accessibility by bicycle, there is generally a tendency for an increase of those with medium accessibility, at the expense of previous (S0) high accessibility levels, particularly for COVID aware personas. Instead, COVID fearless telecommuters are granted with better accessibility conditions, as more accessible destinations are available. In general, COVID aware non-telecommuters (CA NT) are those most penalized regarding accessibility by active modes, as trips to work (often longer) represent nearly three quarters of total trips. For the same reason, telecommuters tend to demonstrate higher accessibility levels.

For public transport users, COVID aware personas, and especially telecommuters, experience the most significant performance decrease. This is in line with the geographic nature of public transport coverage, which tends to favour high demand axes, connecting denser residential areas, large employment concentrations and high traffic generators. Simultaneously, these are the groups, in theory, more reluctant in using public transport. Across the different individual profiles, car accessibility experiences a residual decrease and still provide maximum performance to most residents, as average CA retains, for most, the unitary value.

Moving towards the scenario reflecting the alleviation of restrictions (SA), the primary change is an increase in the number of available activities. With most of them being, on average, located farther from home, pedestrian accessibility is worsened for all personas. Simultaneously, given the higher competitiveness of the bicycle and public transport for longer distances, the accessibility gap in this transport mode between commuters and those who can work from home, but also between different acceptance to risk, narrows.

Finally, under the theoretical characterization of future urban living described by scenario SF, telecommuters are those most benefitted, not only in comparison with regular commuters, but also with the baseline scenario. The need to travel less to work, and hence perform more trips to destinations often closer to home is, once again, the driver of these differences. This is also explained by a lower threshold defining high accessibility levels for telecommuters (0.76 vs 0.85). Differences in public transport accessibility are minimal for telecommuters, albeit more significant for regular commuters, due to the structure of current public transport networks, that cater for a particular type of trip structure, as previously explained. As expected, the variation in car accessibility is minimal, as coverage levels were already high across the different scenarios and personas.

Beyond the shifts in population coverage, the territorial distribution of accessibility, measured by the extent of mobility environments (ME), undergoes significant variations. Seven different ME result from the combination of high and non-high accessibility for each of the four transport modes:

- Multimodal: High accessibility in all modes;
- No public transport: High accessibility in all modes, except public transport;
- Pedestrian unfriendly: High accessibility in all modes, except pedestrian;
- Individual transport: High accessibility for the car and the bicycle;
- Motorized transport: High accessibility for the car and public transport;
- Car-centric: High accessibility only for the car;
- Disfavoured: Non-high accessibility values for all modes;

At stated previously, the high accessibility threshold varies according to scenario and persona, due to their different mobility
Fig. 4. Mobility environments for scenarios S0 and SL.
Fig. 5. Mobility environments for scenarios SA and SF.
patterns. Figs. 4 and 5 detail the geographic distribution of mobility environments and the corresponding population coverage is presented in Table 5.

For the baseline scenario, the ‘multimodal’ mobility environment (A) is located within the main centrality of this territory (hosting roughly 6% of the adult population). ‘Pedestrian unfriendly’ (C) and ‘Individual transport’ (D) ME are prevalent in a large share of the territory, presenting, in theory, a high potential to prevent car usage. In these, both car and bicycle accessibility are high, and they only differ in public transport accessibility. While car-centric environments (F) still comprise a considerable stake of the territory, they host<6% of the population. The eastern edge of the territory (<1% of residents) lacks high accessibility levels in any of the considered transport modes, and as such constitutes a ‘disfavoured’ environment (G).

The lockdown scenario causes dramatic shifts in the configuration of the territory, according to the perspective of each persona. COVID fearless non-telecommuters (CF NT) are those less influenced, with population coverage shifts between ME’s at around 1%. When awareness of the risks of the virus is introduced (CA NT), the territory becomes less adapted to the mobility needs of residents. Multimodal (A) ME areas are replaced by pedestrian unfriendly (C) and car-centric zones (F) double its population coverage (from 6 to 12%). On the contrary, many of those who can telecommute experience a new reality, where trips on foot enable the satisfaction of all trip motives, reflected on a shift from mobility environment C into A. These are visible across the numerous urban centralities of this territory. The reduction in public transport accessibility in some (very) limited areas leads to the appearance of a “No public transport” (B) ME. During this critical period, those more aware to risk (CA T), and hence with a smaller gamut of destinations, face a more favourable territorial configuration.

The alleviation of restrictions (scenario SA) leads to an increase in territorial performance across the perspective of all personas, visible through a noticeable spatial expansion of mobility environments A, C and D. This improvement applies particularly for those who can collect the benefits from working from home. When in combination with a COVID fearless persona (CF T), the multimodal (A) ME becomes the most representative. Despite representing a temporary condition, this scenario indicates the best outcome of the set of possibilities. In fact, most of recent efforts to improve the liveability of territories, by either implementing temporary measures or speeding the implementation of existing plans, are being performed under a variation of this scenario, therefore reinforcing the timely relevance of its execution.

Similarly to the previous analysis, telecommuters are the most benefitted when exploring the results of the future scenario (SF). The expansion of multimodal environments (A) comes at the expense of reduced pedestrian unfriendly zones (C), while some car-centric areas (F) are absorbed into car and bicycle friendly (D) environments. For non-telecommuters, the differences with the baseline scenario are less noticeable. However, there is a slight reduction in the representativeness of multimodal (A) and pedestrian unfriendly (C) environments, in line with the previously noticed reduction in pedestrian and bicycle accessibility. For both personas, the eastern portion of the territory retains the worst results (car only or low accessibility for all modes) even when pandemic concerns are no longer an issue, demonstrating its frailty to induce sustainable mobility habits.

5.2. Policy implications

What can these results imply for policy development? The apparent disconnection between accessibility conditions and population travel needs, particularly in the periphery, reinforces the need for improving coordination between mobility and land-use strategies. In fact, certain peripheral areas of this territory retain a car-centric nature across all scenarios and persona viewpoints. On the other hand, the baseline scenario also demonstrated that, despite most residents living in areas with one or more alternatives to the car (mobility environments A, C and D), only in one mobility environment (G) the car does not possess high accessibility levels. This is a strong evidence explaining the previous dominance of the car.

Under extreme conditions, such as a pandemic, the territorial configuration, measured through the distribution of different mobility environments, does indeed change dramatically. During the lockdown period, as less activities constitute the gamut of possible destinations, more sections of the territory enable the use of active modes to meet such needs. Under an alleviation of restrictions, as more activities restore its availability, public transport becomes a viable alternative as well. However, this condition is just temporary, and as restrictions and fears are fully eliminated from the travel equation, as defined in the future scenario, the territorial configuration of mobility environments will tend towards the initial state, particularly for those that will not benefit from telecommuting. As cultural changes are not directly enforceable by policy makers, the previous car dominance is prone to perpetuation...
without a radical shift in policies to deter car use, reinforce public transport attractiveness and improve conditions for the use of active modes.

One of the most interesting conclusions is the maintenance of high accessibility levels for the bicycle in all scenarios in a significant portion of the territory, despite the current lack of adoption by the population. In fact, the creation of pop-up cycling infrastructure in many cities worldwide is in line with the ‘hidden’ bicycle accessibility of the territories. Policy recommendations in this regard suggest additional investment in safe cycling infrastructure, and the creation of campaigns for its adoption in daily travel. Also, improving the conditions for using the bicycle in combination with public transport can be seen as an alternative for increasing the latter’s coverage at a reduced cost.

The expected rise in telecommuting, even if for only a portion of the population, will induce new challenges to policy making. An increased flexibility of travel patterns could also lead to a more even distribution of trips for personal reasons during the day. By travelling more outside congested rush hour periods, those users can see the car with an even stronger appeal. In addition, less congestion would mean higher car speeds, potentially increasing the risk of accidents between motorized vehicles, pedestrians, and cyclists. Investing in traffic calming solutions could be crucial to increase perceived safety and thus reinforce the promotion of active modes of transport.

Secondly, the challenges over the management of public transport systems would increase. At the short term, there is a need to act swiftly to restore the trust of PT users, otherwise ridership will take longer to return to previous levels. Most systems rely on a steady income stream from frequent travellers, mainly commuters. Those users, who tend to use monthly Travel Cards, often also resort to public transport for non work trips, in order to maximize their return on investment. While less commuting trips would equate less revenue, the implementation of solutions such Travel Cards valid for a fortnight instead of the common monthly subscriptions would better suit cyclical telecommuters, keeping them tethered to public transport for their commuting trips. Policies should also attempt to harvest the benefits from a reduced overcrowding condition to raise satisfaction levels, while demand based public transport services could fill the gap in more peripheral locations. As these policies are ineffective, per se, to restrain car accessibility, further measures will be necessary to reduce its attractiveness, either by enforcing stronger parking restrictions or implementing congestion charge zones.

On the land use side of policies, for a metropolitan region such as Porto’s, characterized by low densities on a significant part of its suburban areas the desire of providing access to a high range of activities within walking distance (20 min maximum) is in fact touching the realm of utopia. In fact, the fairly low levels of pedestrian accessibility, which only improves dramatically when the realm of accessible destinations shrinks, show that there is still room for improvement. The strategy should pass by stimulating the implementation of proximity activities and supplying a stronger network of neighbourhood public spaces, further reducing the incentive to use the car in all trips. Providing just and sustainable means of access to more destinations plays a crucial part in providing better urban living not just during a crisis but for generations to come.

6. Conclusions

COVID-19 has highlighted how quickly human preferences and needs can change and how these impact attitudes towards urban space. Structural accessibility, used to define the spatial configuration of different mobility environments, demonstrated how these changes dramatically impacted territorial performance. In addition, the concept of personas was added to simulate different perceptions to risk and commuting profiles that, for some extent, are outcomes of this pandemic event. This consideration of the human factor, along with reliable knowledge on the mobility infrastructure and the location of diverse activities, improves the level of understanding of the territory and of the factors that require change. These results suggest that most pre-existing policy recommendations towards the enforcement of more sustainable mobility habits will likely still be valid in a post COVID future, according to the simulated trip profiles for the different personas.

Public perceptions on the risk of infection will continue for the near future, particularly on those with less tolerance to risk, albeit with gradually less relevance as vaccination levels increase. Failing to address the opportunity for a paradigm shift will revive the outcomes from the oil crises of the 1970s, where the result was not a shift in mobility practices away from the private car but rather an industry move towards more fuel-efficient vehicles.

While in this research only the perspective of adults was considered, given the flexibility of the method further studies can explore other possibilities and compare them with the current paradigm. Different personas can also be tested for assessing the suitability of the territory for different age groups, but also for a wider gamut of new forms of urban living. Understanding the specificities of each group can contribute with a deeper field of knowledge to plan and implement more equitable urban spaces. Also, a similar approach in other cities, with differing urban structures, but subject to the same impacts of COVID-19, could assist in typifying certain fundamental guidelines to consider when planning during crises and pave the way for a better future.

CRediT authorship contribution statement

Miguel Lopes: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Supervision. Ana Mélice Dias: Investigation, Validation, Formal analysis, Investigation, Writing – review & editing.
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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Appendix A. Calibration of trip frequencies for Scenario S0

| Activity types          | Frequency of use | % of trips (INE, 2018) | fy (%) |
|-------------------------|------------------|------------------------|--------|
| 01 Nursery and kindergarten | Daily            | 22                     | 5      |
| 02 Primary school       | Daily            | 5                      |        |
| 03 Elementary school    | Daily            | 5                      |        |
| 04 High School          | Daily            | 4                      |        |
| 05 Higher Education     | Daily            | 3                      |        |
| 06 Parks and Gardens    | Weekly           | 8                      | 6      |
| 07 Culture and Leisure  | Sporadic         | 2                      |        |
| 08 Supermarket          | Weekly           | 11                     | 4      |
| 09 Proximity Retail     | Weekly           | 4                      |        |
| 10 Non-proximity retail | Sporadic         | 2                      |        |
| 11 Pharmacy             | Sporadic         | 1                      |        |
| 12 Restaurants          | Weekly           | 5                      |        |
| 13 Hospital             | Sporadic         | 2                      | 0.5    |
| 14 Health Centre        | Sporadic         | 1                      |        |
| 15 Private Health       | Sporadic         | 8                      | 2      |
| 16 Post Office          | Sporadic         | 2                      |        |
| 17 Banks                | Sporadic         | 1                      |        |
| 18 Public administration| Sporadic         | 2                      |        |
| 19 Other services       | Sporadic         | 2                      |        |
| 20 Employment           | Daily            | 44                     | 44     |

Appendix B. Trip distribution for the different scenarios

| Activity types          | Av. Weekly trips | Shift tendency in average weekly trips |
|-------------------------|------------------|---------------------------------------|
|                         | S0              | SL         | CA | CF | T | CA | CF | T | SF | NT | T |
| 01 Nursery & kind.      | 0.6             | X           | X  | X  | X  | X  | X  | X  | –  | –  | –  |
| 02 Primary school       | 0.6             | X           | X  | X  | X  | X  | X  | X  | –  | –  | –  |
| 03 Element. school      | 0.6             | X           | X  | X  | X  | X  | X  | X  | –  | –  | –  |
| 04 High School          | 0.5             | X           | X  | X  | X  | X  | X  | X  | –  | –  | –  |
| 05 Higher Educ.         | 0.3             | X           | X  | X  | X  | X  | X  | X  | –  | –  | –  |
| 06 Parks & Gard.        | 0.7             | –           | –  | –  | –  | –  | –  | –  | –  | –  | –  |
| 07 Culture & Leis.      | 0.2             | X           | X  | X  | X  | \  | X  | \  | –  | –  | –  |
| 08 Supermarket          | 0.5             | –           | –  | –  | –  | –  | –  | –  | –  | –  | –  |
| 09 Non-prox. retail     | 0.2             | X           | \  | X  | \  | \  | –  | \  | –  | –  | –  |
| 10 Pharmacy             | 0.1             | –           | –  | –  | –  | –  | –  | –  | –  | –  | –  |
| 11 Hospitals            | 0.6             | X           | \  | X  | \  | \  | –  | \  | –  | –  | \  |
| 12 Restaurants          | 0.1             | –           | –  | –  | –  | –  | –  | –  | –  | –  | –  |
| 13 Hospital             | 0.1             | –           | –  | –  | –  | –  | –  | –  | –  | –  | –  |
| 14 Health Centre        | 0.1             | –           | –  | –  | –  | –  | –  | –  | –  | –  | –  |
| 15 Private Health       | 0.1             | –           | –  | –  | –  | –  | –  | –  | –  | –  | –  |
| 16 Post Office          | 0.2             | X           | \  | X  | \  | \  | –  | \  | –  | –  | \  |
| 17 Banks                | 0.2             | X           | \  | X  | \  | \  | –  | \  | –  | –  | \  |
| 18 Public admin.        | 0.2             | X           | \  | X  | \  | \  | –  | \  | –  | –  | \  |
| 19 Other services       | 0.2             | X           | \  | X  | \  | \  | –  | \  | –  | –  | \  |
| 20 Employment           | 5               | X           | X  | X  | X  | X  | X  | X  | –  | –  | \  |
| Variation from scenario S0: | \               | –           | \  | \  | \  | \  | –  | \  | –  | –  | \  |

- (no trips performed)  \ (half the number of trips)
  \ (double the number of trips)
  - (maintain number of trips)

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Appendix C. Flowchart of the calculation procedure

![Flowchart of the calculation procedure](image-url)

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