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Disposing of Daily Life Resources by Active Modes



Analysis Based on Ergonomics of Access Applied to the Eurometropole de Strasbourg

Maxime Hachette, Eliane Propeck-Zimmermann, and Alain L'Hostis

Abstract Today, many cities are promoting sustainable mobility. Their policies have already reduced the car's place, developed pedestrian and bicycle facilities, or renewed public transport. This raises the question of the effects of these policies on the conditions of access to everyday resources. Are the facilities for sustainable mobility configured in such a way as to enable the population's needs to be met? Globally or selectively? Do active modes (walking and cycling) offer a credible alternative to the car in order to effectively provide the resources necessary for daily life throughout the urban agglomeration?

To answer these questions, this chapter presents a geographical analysis approach based on the concept of spatial ergonomics. The application to 12 test areas, using a geographic information system, has revealed cleavage situations within the Eurométropole de Strasbourg, to study finely differentiated situations and to put them in perspective with socio-demographic profiles to analyze socio-spatial disparities.

The various levels of information shed light on leeway available to inhabitants, wherever they are located, to change their mode of travel. The method makes it possible to produce territorial diagnoses and to help local authorities to promote effective sustainable development policies.

Keywords Spatial ergonomics · Access ergonomics · Sustainable mobility · Active modes · Daily resources · Socio-spatial disparities

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1 Introduction

In urban planning, the slogan “always faster, always further” is now outdated (Papon, 2003; Piombini, 2006; Saint-Gérard et al., 2019). As far as public policy is concerned, the car is no longer the symbol of progress and modernity that it once was. Indeed, in addition to being one of the largest CO₂ emitters on an international scale, the automobile has various negative externalities, especially in cities: noise pollution, congestion, massive use of space, accidents, etc. The time has come for peaceful and virtuous mobility on an ecological level.

Within the framework of sustainable development, particularly in urban areas, one of the objectives is to slow down the automobile system to make way for more sustainable mobility in accordance with the aims of the ecological and energy transition. Such a policy is now announced at all levels: local, national, and international. Limiting the damaging impact of cars appears to be a main guideline in all policies.

This priority has been reflected not only in a set of regulatory and normative measures (vehicle emissions, speed, etc.) but above all in urban planning in favor of sustainable modes of transport. Public transport, led by the tramway, and active modes, such as walking and cycling, are the main beneficiaries of these developments. Currently, many cities have developed facilities for pedestrians and cyclists (pedestrian zones, meeting areas, street furniture, play areas, cycle lanes, bicycle racks, etc.), they also shared vehicles (scooters, bicycles, or electric or nonelectric cars), carpooling, intermodality, multimodality, etc. Many measures in favor of sustainable mobility are combined with restrictive measures for private cars (regulated or paid parking, traffic restrictions, urban tolls, etc.). These sustainable mobility policies have already led to or accompanied a reduction in the use of cars in most major cities.

Trips are necessary for each person for different reasons (professional, leisure, and other activities). From this perspective, we may be curious if the various forms of mobility, especially active mobility, can meet their needs. Our interest in this research has focused on access to current resources (shops, education, health, public services, and leisure). Although policies recommend sustainable mobility over the whole territory, they seem to focus on strategic areas of cities (urban centers, eco-neighborhoods, upper tertiary centers, etc.) at the risk of increasing socio-spatial inequalities.

Under what conditions can inhabitants access daily resources through active modes?

Are the measures in favor of sustainable mobility configured in such a way as to meet the needs of the population? Globally or more narrowly focused?

Do sustainable modes, and in particular active modes, offer a reliable alternative to cars as a means of disposing effectively of the resources of everyday life? For all and wherever they are?

To tackle these questions, this research is based on the operational concept of spatial ergonomics in the sense of a conceptual approach that can be modeled in

spatial analysis methodology. Spatial ergonomics is defined as “the ability of a territory to provide its population with the socioeconomic resources they need at the lowest cost/effort/risk” (Saint-Gérard, 2002). The basic hypothesis is that “the suitability of a space for the life of its population depends largely on the ease it offers to the inhabitants to appropriate the resources they need, according to their specificities and where they are located” (Saint-Gérard et al., 2021).

Within the framework of this research, we developed the first exploration of spatial ergonomics through mobility and the appropriation of everyday resources by populations using active modes. We have called it “access ergonomics.” It adopts an approach that focuses particularly on the fulfillment of needs and on conditions of access to resources. Spatial ergonomics and access ergonomics undeniably play a role in the smart city (as presented by Cerema), related to the first component of collective intelligence but not so much to the technological part (Brussels Smart City, 2022; Cerema, 2020; CNIL, 2022).

The objective of this research is to develop an approach to analyze and evaluate the “ergonomics of access” to everyday life resources at each point in space, in a reasonable time, according to different modes of travel (on foot, by bicycle, and by car), and to analyze spatial disparities. On the one hand, the approach takes into consideration the overall functioning of the territory through the availability and distribution of the potential resources and, on the other hand, a panel of criteria characterizing their access conditions (service conditions, safety, comfort, monetary cost).

First, the chapter focuses on the theoretical framework of the concept of “spatial ergonomics” to distinguish it from related concepts such as accessibility. To ensure the reproducibility of the results, the method used for the calculation of each indicator will be detailed. Finally, the application focuses on 13 test areas within the Eurométropole de Strasbourg, which has a very proactive policy in favor of active mobility. It is based on a geographic information system (GIS) and an associated database. The calculation of a synthetic score, which is then declined by mode of travel, by time step, and according to different criteria, aims to characterize differentiated situations within the urban space. In fine, putting the indicators into perspective with the socio-urban environment allows revealing socio-spatial disparities.

2 Theoretical Approach

2.1 The Concept of Ergonomics in Geography as a Result of Conceptual Transfers

Ergonomics was originally and is currently practiced in workshops, factories, and companies. It aims to adjust the workspace, equipment, and process to the physical and behavioral capabilities of the workers to improve efficiency. The International Ergonomics Association defines ergonomics as follows:

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance. [...]. [Ergonomics] is a multidisciplinary, user-centric integrating science. The issues [ergonomics] addresses are typically systemic in nature; thus [ergonomics] uses a holistic, systems approach to apply theory, principles, and data from many relevant disciplines to the design and evaluation of tasks, jobs, products, environments, and systems. [Ergonomics] takes into account physical, cognitive, sociotechnical, organizational, environmental and other relevant factors as well as the complex interactions between the human and other humans, the environment, tools, products, equipment, and technology. (International Ergonomics Association, 2022)

Ergonomics aims to optimize the well-being of the person and the overall performance of a system. It therefore adopts a systemic approach to analyze the interactions between humans and other system components (configuration of workshops, materials, handling process, rhythm) to obtain the best individual work efficiency for lower overall cost (energy, time, money, effort, stress, exposure to danger) (Fleury, 2009). The analysis is thus based on economic and cost/performance type models.

A systemic approach must also take into account the complexity of the regulations that take place at two levels:

- at the level of the individual who regulates his activity, according to his external environment and his internal state (tiredness, for example),
- at the level of the company, which reviews the configuration of the workshops, the material equipment, the handling processes, and the rhythms for greater efficiency at the lowest cost.

Gradually, ergonomics began to be applied to different processes that can be assimilated into work. Conceptual transfers have led to their application to different fields, particularly in geography.

As in geography, ergonomics thus attaches great importance to planning, i.e., to spatial configuration (understood as a reasoned arrangement aiming at a general quality of connectivity). By considering the city as a man-machine system (De Montmollin, 1967), it seems to be able to fit into the field of study of ergonomics, and its methods could contribute to a reflection on its planning in connection with the activities and characteristics of the users of the territory.

Several researchers have been investigating the application of ergonomics to cities. Different concepts have thus appeared, such as “spatial ergonomics” (Saint-Gérard, 2002), “urban ergonomics” (Antoni, 2014), “ergonomics of daily mobility” (Lanteri & Ignazi, 2005), “ergonomics at the service of public space” (Bouché, 2014), and “ergonomics of the city” (Lejeune, 2004).

J-P. Antoni presents “urban ergonomics” as “the design of a given space in compatibility with the various characteristics of activities or users in order to achieve greater comfort or efficiency” (Antoni, 2014). Ergonomics reviews the way in which individuals “move” to perform a job or task. It is more specifically interested in accessibility through the study of distances, urban landscapes, and risks in the city. The aim of this type of ergonomics is to maximize proximity to improve

comfort and reduce effort. The author proposes a theoretical reflection on three-dimensional mobility in urban space, referring in particular to the work of (Reymond, 1998) on the “tridiastatic city” and the research of (Frankhauser, 1994) on fractal urban planning.

From a more practical point of view, the “ergonomics of the city” has been raised in the debates of the Centre d’Études sur les Réseaux, les Transports, l’Urbanisme et les Constructions Publiques (CERTU) to evaluate existing urban facilities or to pre-evaluate an urban project at the design stage (Lejeune, 2004). The CERTU bases its work on the postulate that the city, and in particular public space, is like a machine that city inhabitants used to achieve their goals. The objectives of city ergonomics include, among other things, improving accessibility, practices, and uses of urban space. This type of ergonomics emphasizes the human being as the main factor in the space and urban design with which he interacts.

In the same approach, other authors or professionals, such as G. Bouché, a consultant in ergonomics and architectural project management, focus on the psychological dimension of urban space, life scenarios, the study of people’s real expectations, and the quality of urban furniture (Bouché, 2014).

Therefore, there are different notions of ergonomics in geography. These are generally the result of conceptual transfers from the notion of ergonomics in its original meaning. The common objective between the different notions of ergonomics in geography is to take into consideration the human scale, the human becoming therefore an element among the major elements of urban conception. The main goals are then to reduce the costs and efforts of citizens in the accomplishment of their daily tasks. Ergonomics is multiscalar and can study different processes for the realization of a task in the city while focusing on the interactions of citizens with their environment (physical, psychological, etc.).

Many authors have made connections between ergonomics and geography, but T. Saint-Gérard was the first author to establish the concept of “spatial ergonomics” in the most holistic and systemic way. This research mobilizes this overall concept.

2.2 Spatial Ergonomics as a Founding Concept and Operating Model

Ergonomics of access to the resources of daily life by the population, developed in this research project, is based on the broader concept of spatial ergonomics introduced by T. Saint-Gérard in 2002. For this author, “spatial ergonomics is the expression of the adequacy of space to its occupants, which translates into the ease with which the territory offers its occupants access to the resources they need at the lowest cost/effort/risk” (Saint-Gérard, 2002). “Cost” is considered in a broad sense and covers all the constraints associated with the mobilization of resources: distance, time, money, security, and comfort.

Spatial ergonomics uses reasoning based on classical ergonomics applied to geographical space.

A semantic translation and a change in conceptual scale were proposed by this author. The work action is assimilated to a daily life action, the worker to the population, the workshop to the daily living area, the materials to the resources, the tools to the equipment, the process to the socio-spatial behavior, and the efficiency to the adequacy to the urban needs (Fig. 1) (Hached, 2019; Hached & Propeck-Zimmermann, 2020; Saint-G rand, 2002).

The main idea of spatial ergonomics, as mentioned above, is the adequacy of the territory/space to the life of its population. The hypothesis stated is that this adequacy depends to a large extent on the ease with which the territory offers all the territorial users to obtain the resources they need and to carry out all their activities. It must take into account spatial constraints, social constraints, the availability of resources, and their access at the lowest cost/effort. All these elements dynamically interact and form a complex system (Saint-G rand et al., 2021).

The analysis of the ergonomics of a territory therefore refers to a systemic approach, which takes into account the overall functioning of the territory with the interactions and regulations that take place, at different scales, between different elements of the urban system. The population, the socioeconomic resources, and the space of the community form a triad of objects that are to be integrated into a data structure aimed at modeling geographical phenomena from an ergonomic perspective (Fig. 2):



Fig. 1 From ergonomics to spatial ergonomics, according to (Saint-G rand, 2002)

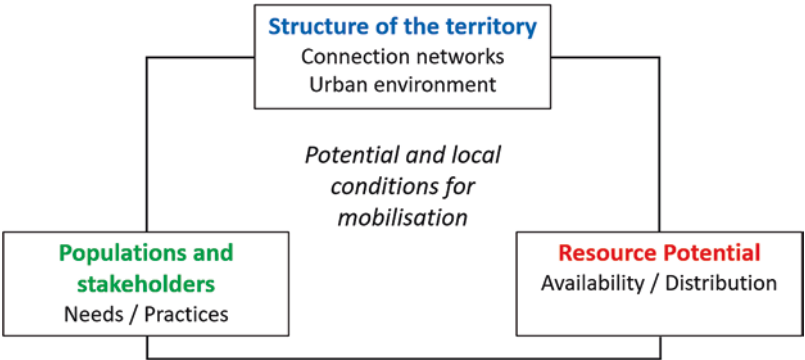


Fig. 2 General model of access ergonomics. (Source: authors)

- Populations (individuals, households, or other actors) have mobility needs and regulate their activities and practices, depending on their own characteristics, the availability and distribution of resources, and their environment, which is more or less suitable for travel by different modes.
- The availability and distribution of socioeconomic resources generate trips, allow the optimization of activity programs, or depending on the economic model (in particular with the help of digital technology), can be conveyed in part to consumers.
- The structure of the territory (the space of the community) is configured by the spatial distribution of populations, resources, functional mix, connection networks, urban environment, etc., which influences the conditions of access to local resources. It also determines the alternatives of resources and access that the territory can offer to users according to their socioeconomic profiles and the constraints of the moment. All the criteria linked to the territory's layout interfere with the demands/needs of the populations (all the territorial actors) and the potential of the territorial resources to form the potential and the local conditions of mobilization.

Every territory has a level of ergonomics due to the way it is structured at a given time. An ergonomic territory can then be understood as a territory designed and developed to provide the society that inhabits it (individuals, households, companies, or other territorial actors) with the resources it needs at the lowest cost/effort/risk of mobilization. (Saint-Gérard et al., 2021)

Spatial ergonomics has connections with other concepts such as accessibility, capability, motility, walkability, etc. Their similarities and differences are explained in the following section.

2.3 Spatial Ergonomics, Accessibility, Capability: Close Links But Different Objectives

The investigation of spatial ergonomics raises the question of its links with notions such as accessibility, capability, motility, walkability, etc. While the data and methods used may have similarities, their purposes differ.

2.3.1 Spatial Ergonomics and Accessibility

Accessibility is a widely used concept, especially in the fields of transport, urban planning, and geography. It seems simple until one tries to define or measure it. To exist formally, in geography, “accessibility only requires a topographic space” (Dumolard, 1999), and it is a measure of spacing that determines the distances between different entities in space. Accessibility can be established as “the possibility, the capacity of a place or anything else to be accessible to an individual; that is,

that one is able to reach, use, understand...” (Richer & Palmier, 2011) or as “the greater or lesser ease with which this place [can] be reached from one or more other places, by one or more individuals likely to travel using all or part of the existing means of transport” (Chapelon, 2004). It is therefore a broad concept that implies the accessibility of something or somewhere.

While ergonomics stems from the fields of improving working conditions and work efficacy, accessibility comes from the intersection of geography and spatial economics. While ergonomics focuses on the adequacy of peoples and territories, accessibility more broadly encompasses the spatial potential for developing existing or new activities from or at the destination of given places.

The investigation of accessibility makes it possible to evaluate the capacity of the urban environment, with its various components and infrastructure, to “reach a place in order to carry out an activity” (Richer & Palmier, 2011) or to fulfill a need.

We have referred to accessibility as the characteristic of a place that an individual can reach. However, for a place to be considered effectively accessible, several conditions must be met. These conditions can then be studied to evaluate the accessibility of places, especially in an urban space.

2.3.1.1 Connection Between Two Points

First, there must be a point of departure and a point of arrival, the latter corresponding to the destination or resource that the individual wishes to reach.

For the individual to get from their departure point to their destination, a link must exist that ensures “a spatial crossing between two points that respond to the person’s reason for traveling” (Cerema, 2015). The path from the point of departure to the point of arrival may, however, be faced with impassable obstacles: rivers without bridges, no crossing of a railway line, or a major road. Nonmotorized soft modes are the most sensitive to the effects of barriers. Cyclists and “pedestrians as a whole appear to be the first victims of the effects of the barrier. As they are not very mobile, they are forced to make deviations or cross sloping passages” (Héran, 2011).

2.3.1.2 Means of Transport Adapted to the User

To get to their destination, individuals must also be able to move around by means that are adapted both to themselves and to the environment in which they are located: walking, cycling, public transport, cars, etc. This condition then depends on various parameters, such as the existence and quality of transport infrastructure (frequency of transit, safety, operating hours, etc.) and their match with the user’s capacities in terms of time, distance, cost, quality, facilities for people with impaired mobility, physical capacities (age, disability, etc.) and financial means. Thus, “Accessibility can be measured by evaluating the area individuals can potentially reach within their time and mobility limits, or their (PPA) Potential Path Area” (Weber & Kwan,

2003). The “quality of service of the transport offer and the understanding of the complete travel chain of user” (Baptiste, 2003) are an essential part of the accessibility evaluation. This evaluation “also reflects the difficulty of the journey, the difficulty of connecting, which is most often measured by spatial and temporal constraints” (Chapelon, 2004).

2.3.1.3 Taking into Account the User Constraints

Finally, the accessibility of a location depends on the user’s ability to withstand the constraints of the journeys offered by urban networks (physical capacity, effort needed, distance, duration, etc.) and his or her ability “to reach the goods, services and activities desired by an individual” (Cerema, 2015).

Considering all these elements, we can therefore notice that accessibility can vary in a given location. Indeed, it depends, first of all, on the individual, on his or her requirements, on his or her own constraints (in terms of physical and intellectual capacities and his or her schedule) which may not correspond or not be compatible with the targeted resource (e.g., its opening hours), thus resulting in a loss of accessibility.

In addition, a temporal component should be integrated in the interpretation of accessibility, since it is influenced by the opening times that govern access to goods and services at different time periods of the day, by the amount of time that individuals allocate to these activities and by the quality of the transport system according to the different periods of the day (peak period, off-peak period, evening...). (Cerema, 2015)

Furthermore, accessibility also depends on variations in the connecting infrastructure system (closed tunnel or bridge, lack of lighting at night for a pedestrian, etc.) and the constraints caused by the means of transport used (public transport timetables, lack of parking facilities, etc.).

There is particularization because instead of being an eternally true measure (the Euclidean distance between a and b will always be the same), accessibility results from the conjunction of elements that can be modified in time and space. It implies a travel operator (characterized by speed and energy consumption); a travel infrastructure (sophisticated infrastructure or simple paths); knowledge of the place to be reached and the path to do so. Each mode of travel has its own properties (an operator, a graph, a speed, a cost). Its accessibility can therefore be modified by changing the operator or the network or the time of travel. (Dumolard, 1999)

Accessibility is a huge field. There is a large body of literature providing a comprehensive approach to the history, definitions, measures of accessibility, and practical applications. However, four categories of accessibility measures have been identified (Geurs & van Wee, 2004; Salze et al., 2011):

Infrastructure-based measures: This type of measure is mainly used for the planning of transport networks. Its aim is to assess the efficiency of transport networks through simulations or observations. For this purpose, studies often take into account indicators such as “degree of congestion” and “average speed on the network.”

Location-based measures: These measures are often used in the fields of urban planning and geography. They take into account the availability and spatial distribution of amenities in a given area, such as the number of bakeries accessible within 20 minutes. Other more complicated parameters can also be taken into account, such as the characteristics of the activities provided by the amenities or the consideration of competition between different resources.

Person-based measures: Often used in space-time geography, this is concerned with the assessment of space-time accessibility at the individual level, such as “the activities that an individual can participate in at a given time.” This type of measure is based on the work of Hägerstrand (1970). They assess the limits of an individual’s freedom of action according to, for example, his or her location, the duration of the activity to be performed, the travel-time budget, and the speed allowed by the existing transport system.

Utility-based measures: often used in economic studies, this measure assesses the ability of an individual or group of individuals to carry out a maximum number of activities in a given program. It also analyzes the (economic) benefits that individuals gain by accessing the activities distributed in the territory.

Depending on its goal, each of the four categories of accessibility measures focuses on well-defined components of accessibility but ignores others. K. Geurs and B. Van Wee propose a comparative table between the different categories of accessibility measures according to the indicators they take into account (Table 1):

Table 1 Perspectives on accessibility and components

Measures related to:	Transport element	Land-use element	Temporal element	Individual element
Infrastructure	Speed; time spent in traffic congestion		Peak period duration per day	Stratification by travel, such as home-to-work, commercial, etc.
Location	Time and costs of commuting to and from activities	Quantity and distribution of supply and demand of facilities	Journey duration as well as costs could fluctuate, from time of day, weekday, or season	Population fragmentation (e.g., according to household income, educational level)
Person	Journey duration to and from the locations of the activities	Quantity and distribution of facilities provided	Time-related limitations for activities and time to perform activities	The issue of accessibility is addressed at the individual level
Utility	Costs of commuting to and from the activity locations	Quantity and distribution of provided facilities	The duration and cost of journeys may vary, in particular from one hour of the day to another, from one day to another in the same week, or from one season to another	Benefits are considered at the individual level or at the level of a uniform population cluster

Adapted from Geurs and van Wee (2004)

To summarize, the concept of spatial ergonomics and the concept of accessibility have links and similarities. Accessibility in its broadest sense considers the greater or lesser ease for the inhabitants of a territory to carry out activities (Conesa & L'Hostis, 2010; Huriot & Perreur, 1994). However, despite probable similarities in the methods and data used, the objectives of ergonomics and accessibility differ. On the one hand, ergonomics seeks to understand the overall functioning of the territory and its capacity to meet needs through different elements, in particular the arrangement of its resource potential and its ability to respond to disturbances, whereas accessibility focuses on a very specific aspect of the functioning of the territory, that of travel and transport. While elements such as individual time use (Fosset et al., 2016) or accident risks (Cui & Levinson, 2018) can be taken into account in accessibility studies, the full systemic implications at the scale of the territory are generally not considered.

2.3.2 Spatial Ergonomics and Capability

Concepts such as capability, motility, walkability, and cyclability also have connections with ergonomics. Capability (in geography) is seen in this context as the ability (in the broadest sense: physical, psychological, cognitive, cultural, etc.) of an individual or a group of individuals to access a place that matches their needs. Indeed, an individual may dispose of resources (cinema, theatre, etc.), but he does not take advantage of them because these resources do not meet his needs, or they do not take into account his capacities (e.g., for a wheelchair user, a shop that is not adapted to welcome people with impaired mobility). Vincent Kaufmann considers that “Each individual has potential for mobility, the premises of movement, which he or she may or may not transform into movement according to desires and circumstances. This potential may not be strongly linked to mobility...” He then introduces the concept of motility, which he defines as “the capacity of a person or a group to be mobile, spatially and virtually” (Kaufmann, 2007). Walkability and cyclability are the pedestrian/cycling potential of an area. They reflect the capacity of a place to facilitate access on foot or by bicycle. The concept of walkability emerged in the early 2000s when American researchers began to focus on what they called the walkability of cities, their pedestrian potential. [...]. In Northern Europe, where cycling is widespread, research has been carried out on cyclability (Misery, 2013). The pedestrian (or cycling) potential of a place is determined by five main elements: housing density, diversity of activities, good location of activities, urban design, and location of public transport (VIVRE EN VILLE, 2016). It can be assessed at different scales: the parcel, the street or neighborhood unit, and the district.

Like accessibility, the concepts of capability, motility, walkability, or cyclability are concerned with a particular aspect of the functioning of the territory or its inhabitants. Ergonomics seeks to cover the different factors to characterize the ability of the territory to facilitate the real appropriation of the range of resources by the user in demand.

2.4 *Territorial Modeling of the Ergonomics of Access to Daily Life Resources*

Spatial ergonomics, as described above, integrates the potential of the territory in terms of availability of resources and conditions of appropriation by the population. It aims to build a global logic of description of the territory (physical characteristics of the territory, distribution of resources, practicability, alternatives, etc.) to establish multicriterion measures of the space in terms of provision of resources. In the framework of this research, the question raised is that of the conditions of access to the resources of daily life in active modes. Do active modes (walking, cycling) offer a credible alternative to cars for accessing the resources necessary for daily life?

To respond to this issue, the accessibility approach and related concepts (capability, walkability, etc.) have their limits. We propose a more global approach based on ergonomics.

The ergonomics of access to resources is the first step in the implementation of the global concept of spatial ergonomics. It focuses on the distribution of resources in the city and the conditions for accessing them in a reasonable time at the lowest cost/effort/risk. It underlines the importance of a quality urban space for access to resources and in this sense reminds us of the HQE (High Environmental Quality)¹ approach in architecture, which aims to improve the comfort and health of the users of a building while limiting its impact on the environment.

The ergonomics of access to resources cannot exist without the condition of accessibility being validated. In this study, accessibility is understood as the potential for travel, i.e., the greater or lesser ease with which a place can be reached from one or more other places, using all or part of the existing means of transport (Bavoux et al., 2005; Huriot & Perreur, 1994). However, ergonomics goes beyond accessibility criteria. Its evaluation is not limited to the capacity to reach a type of resource but includes a set of conditions of access to the resources that the population needs, according to different modes of travel and according to the offer of local resources, such as alternatives offered by the territory (Eliane Propeck-Zimmermann et al., 2018a, b). An ergonomically accessible resource must correspond to the needs of the citizen, be located at the shortest distance, offer an efficient connection, at the lowest cost, in comfortable conditions, and a quality environment.

The ergonomics of access to resources focuses as much on the material and physical conditions of the mobility system (infrastructure, resources, distances, etc.) as on the more immaterial variables of the urban space (landscape, safety, environment, “pleasant” quality of an urban space, etc.), accidents and monetary costs.

Within the framework of sustainable mobility policies, spatial ergonomics can contribute to the production of diagnostic tools to improve knowledge of the functional morphologies of the urban environment, of socio-spatial inequalities,

¹This approach includes 14 targets relating to eco-construction, eco-management, comfort, and health. The targets include, for example, hygrothermal comfort, acoustic comfort, visual comfort, olfactory comfort, air quality, water quality, and quality of spaces.

and, in fine, to help define operations and developments adapted to a local level. The objective of this research work is to develop a method for evaluating the ergonomics of access to the resources of daily life by the population at each point in the territory and to analyze the socio-spatial disparities potentially induced by sustainable mobility policies.

3 Development and Implementation of an Evaluation Approach of the Ergonomics of Access to Resources

The development of a method for analyzing and evaluating the ergonomics of access to everyday resources is an exploratory and experimental approach that opens up a way of understanding the complexity that prevails in the field in the practice of everyday life. However, the study conducted initially required making fundamental choices to simplify the approach, choices that will obviously have to be taken into consideration when evaluating these first results.

3.1 Methodological Approach and Hypotheses

Geographic location is clearly a key factor in conditioning access to resources for any population. Ergonomics therefore considers the conditions of access to resources at the lowest cost/effort that a territory provides to its occupants in the location where they live (Eliane Propeck-Zimmermann et al., 2018a, b).

Access ergonomic level for everyday resources can be assessed on the basis of two sets of complementary criteria (Fig. 3):

1. The spatial distribution of resources and the conditions of access to proximate resources. In the common sense that proximity evokes neighborhood, contiguity, and short distance (Huriet & Perreur, 1998). Access ergonomics is conditioned by the spatial distribution of resources and by the means of accessing them and therefore by the structure of the territory.
2. Resources and access alternatives within an acceptable range. This means a potential choice of alternative resources and access modes considered as “close substitutes, i.e., which are capable of satisfying the same need” (Huriet & Perreur, 1998). The ergonomic of access is conditioned here by the notion of ductility/plasticity of space, or “plastic space” (Wood, 1978).

The resources of everyday life are targeted by this study by considering that they respond to a universal need. Ergonomics of access is then analyzed to evaluate the access of citizens to shops, schools, leisure activities, health services, and public services.

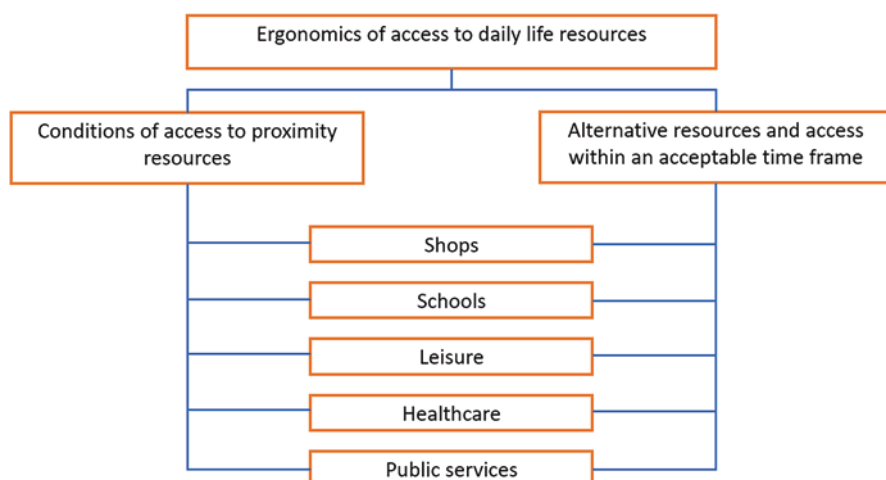


Fig. 3 Synthetic indicator of access ergonomics (Hached, 2019, 2020)

The social characteristics of the populations must be integrated into the model, and they also play an important role in assessing the needs (or demands) and the capacity of individuals to access and appropriate these resources according to their situation (average age, lifestyle, income, etc.). The characteristics of the population are taken into account in the second step.

The access ergonomics level assesses the more or less capacity to minimize the costs (in the broad sense) of appropriating the resources that the population needs in daily life.

Although access to resources may concern different categories of actors (individuals, workers, companies, managers, etc.), we were only interested in the access of inhabitants to the resources they need on a daily basis.

Currently, thanks to the development of the Internet, there are offers to deliver resources (services, goods, etc.) to the inhabitant or to a collection point. This type of offer, which is increasing but still little explored, although it can meet certain daily needs, has not been taken into account. Furthermore, only a standard range of equipment and services have been considered. For example, clothing and aesthetic shops have not been taken into account.

Different populations, from different social or professional categories, may have different needs or demands for resources. In addition, the level of demand (daily, weekly, etc.) may vary significantly from one category to another. The selection of daily life resources in this study ignores these differences, as it is supposed to match most inhabitants of the territory. However, a person's age, health condition, or disabilities have an impact on their ability to travel in daily life. This is particularly true for journeys made by soft modes: the speeds of trips made by these modes can vary, particularly according to age, while accessibility can be compromised in the case of disability and the absence of adapted

facilities. We therefore assume—temporarily—in this research that the individuals considered are adults, in good health and without disabilities. The specificities of the older age groups, which will become increasingly numerous, will be introduced later.

We assume that the resources considered are available and therefore take into account travel during the daytime and on a working day.

We also assume that urban inhabitants make a trip from a starting point (home) to reach one resource at a time. Activity programs that combine several resources at once, although often part of the daily routine of households, have not been taken into account for the moment. They would require the development of a displacement model beyond the time constraints of this research. However, an indicator of resource dispersion was taken into account to partially remedy this limitation, reflecting the fact that the most grouped resources improve the ergonomics of access and that the most dispersed resources deteriorate it.

We also assume that the trips of the inhabitants of the city are made in a logical, thoughtful, and least effort manner (Lynch, 1960). The routes studied are then the shortest paths to the nearest resources (Zipf, 1949). These routes are studied to find the resources from the points of departure, assuming that the return path is identical to that of the original path.

The modes of travel studied are active modes, such as walking and cycling. They have benefited from specific facilities in the cities. Other light individual modes exist, such as scooters, rollerblades, and electric bikes. Scooters and electrically assisted bicycles can have an impact on access ergonomics, particularly on access times. Despite the fact that their use is growing rapidly today, this work does not take them into account. The method developed here could nevertheless be easily adapted to these other modes of travel by adapting, among other things, to the travel speeds.

3.2 Synthetic Indicator of the Ergonomics of Access to Resources and Its Variation in Different Levels of Information

Considering the predefined framework of the study, the approach consists of calculating a synthetic indicator at each point of the territory, according to different modes (walking and cycling compared to the car), based on criteria applied to the two sets above (proximity and alternatives). The synthetic indicator puts into perspective the sustainable mobility facilities and the types of socio-spatial environments and allows to evaluate the impact of the sustainable mobility policy on the potentialities of access to resources and characterizing the socio-spatial disparities.

3.2.1 Implementation of Two Joined-Up Approaches

To study the ergonomics of access, two different but complementary approaches were developed in parallel:

1. The first approach is global and aims to establish an overall diagnosis and a vision at the scale of the Eurometropole de Strasbourg of the ergonomics of access to current resources. It was developed within the framework of the National Research Agency (ANR) project on Emerging Risks of Sustainable Mobility (RED) (Saint-Gérard et al., 2021).
2. The second method developed in this chapter is more detailed. It is route-based and takes into account more criteria but on a limited number of test areas (Hached, 2019, 2020; Hached et al., 2018; Hached & Propeck-Zimmermann, 2020).

In this chapter, we will focus only on the second method.

3.2.1.1 Local Detailed Approach

This approach consists of refining the analysis of the ergonomics of access at a more local scale. It analyzes the distribution and conditions of access to resources and puts them into perspective with socio-urban environments to analyze the social disparities within the territory.

The territory is divided into 200 m × 200 m grids, which represent the most detailed INSEE grid for French socio-spatial data. From a starting point (centroids of an inhabited mesh), the overall approach involves four stages:

The first step consists of calculating the shortest path to the nearest resources in the chosen panel of resources. The calculation is performed for each transport mode (walking, cycling, cars) and for different time steps (5, 10, and 20 minutes). The closest resources for each type, with a defined time step, form a proximity zone. The “5, 10, and 20 minutes” travel times were defined on the basis of the relevance of the travel modes, the physical capacity of citizens, the travel-time budget, and the number of trips in the study area from the 2009 household travel survey.

The second step is the computation of the area of alternatives representing the whole space accessible by the networks, from the starting point, in a given time (5-minute, 10-minute, and 20-minute isochrones) and where additional resources are likely to be found, beyond the closest ones (Fig. 4).

Different criteria are then calculated, which refer, for a given time step, to

- The amount and diversity of resources in the catchment area
- The conditions of access to local resources on the paths (distribution of resources, safety, comfort, and monetary cost)
- The amount and diversity of alternative resources

Access alternatives to the resources (different paths, different modes of transport, especially public transport, or multimodality) can be integrated at a later stage.



Fig. 4 Calculation of the proximity zone and the zone of alternatives within a 5-minute walking distance (the resources studied are common to both approaches, by isochrone and by path). (Source: Author, Hached, 2020). (a) Territory divided into cells of 200 m × 200 m. (b) Calculation of the centroid of an inhabited cell to constitute the departure point. (c) Calculating the shortest path to each of the resources. (d) Calculation of the proximity polygon formed by the closest resources. (e) Calculation of the alternatives polygon formed by the isochrone corresponding to the accessible area for the chosen time interval. (f) Search for alternative resources in the alternatives polygon

In the last phase, a normalized score between 0 and 100 is attributed to each criterion calculated previously, with 100 representing, for a given criterion, the highest result of all the meshes of the study territory. For example, the score for the “number of resources in the proximity zone” will be equal to 100 for the grid cell from which the highest number of resources in the study area can be accessed and 0 for the mesh from which no resources can be accessed. The average of the scores of all the criteria (as presented below) provides the synthetic indicator of usability at each point of the territory.

The approach required reflection on the indicators and the development of a large localized database including the distribution of resources, infrastructure, roads, urban environment, etc., and its exploitation using the functionalities of a GIS.

3.3 Implementation of the Approach Within a GIS

Implementing the approach to assessing the ergonomics of access to everyday life resources by itinerary explained in the previous sections requires several steps:

- Selection of daily life resources.
- Calculation of itineraries based on the principle of the shortest paths.
- The selection and calculation of numerous indicators contributing to the ergonomics of access.
- The elaboration of a synthetic indicator translated into scores.
- To do this, an extensive localized database had to be created.

3.3.1 Selecting Everyday Life Resources

Work-related trips represent 26% of all trips in the Eurometropole de Strasbourg, according to the 2009 Household Travel Survey (ADEUS, 2010). Despite the significant proportion that this represents for daily travel, access to employment is not taken into account at this stage but should be integrated into future research. Daily life resources are the main concern of this study. They are defined as the resources, other than work, that people may need in their daily lives. They are intended to correspond to a universal need, without distinction as to social or professional categories. The chosen resources are then classified according to a typology that aims to group them by category and/or class.

Different typologies exist (Boudouda, 2019). The INSEE typology distinguishes, for all municipalities or *irises*,² ten main categories, classified according to their frequency of establishment (local, intermediate, higher-level equipment):

- Commercial
- Services to individuals
- Social action service
- Medical and paramedical functions
- Health services
- Primary education
- Second-level education
- Higher education, training, and education services

²Iris is a geospatial subdivision used for socioeconomic data in France.

- Transport, tourism
- Sports, leisure, and culture

The Institut d'aménagement et d'urbanisme Île-de-France lists five main categories (education, care and health, sport, market services, leisure), each of which contains several types of resources that we will not detail here (Mangeney et al., 2014).

Finally, the choice and classification of resources were the object of in-depth reflection and numerous debates, notably within the framework of the ANR RED project. The selection of everyday resources from the 2015 SIREN data was based on several parameters. First, we want to consider the resources that city dwellers frequently use in their daily lives on a daily, weekly, or monthly basis. In addition, there are other resources that are perhaps less frequently used, but their presence near the household is a desirable asset. Examples include public services (municipality, job center, etc.) and health services (hospital activity, dentistry, etc.). Consequently, resources that are occasionally required or are not necessary for everyday life have not been taken into account (clothing, cosmetics, etc.). Future developments could include attributing weight to resources according to their probability of a visit. It would have been interesting to include other resources related to sociability, such as children's playgrounds, green spaces, associations or cash dispensers, banks, relay points, etc. However, various practical difficulties were encountered: nongeographical referencing, classification confused with other resources, difficult data verification, etc., which led to their exclusion. The access ergonomics to everyday resources is then investigated to evaluate the accessibility of city inhabitants to the following five categories of resources: shops, schools, public services, health services, and leisure. Classes (subcategories from A to O) are defined for each category, taking into account more precisely the nature of the activities, the surface area of the activity, the number of employees, and the levels of demand by the population (Tannier, 2014; Tannier et al., 2014). These classes are useful for calculating the diversity indicator.

The list of everyday resources selected for this study (Table 2) can be expanded according to needs and data availability.

3.3.2 Creation of a Geographical Information System (GIS)

Analyzing the ergonomics of access to resources requires investigating the movement of a population with its own demographic, professional and income characteristics, mobility habits, etc., in a chosen territory that itself has intrinsic properties at both the administrative (boundaries, public policies, etc.) and geographical (relief, land use, etc.) levels. This territory is distinguished by its urban organization, whether it is built up or not. Travel to access resources is carried out using specific means of transport and networks adapted to the needs of the population and the characteristics of the area. The daily travel of the population in the territory creates traffic and flows while generating various accidents. The state and local authorities

Table 2 Daily life resources (Hached, 2019, 2020; Hached & Propeck-Zimmermann, 2020)

Categories	Class	Daily life resources
Commercial	A	Bakery and patisserie
		Patisserie
		General food trade
		Retail sale of fruit and vegetables in specialized shops
		Retail sale of meat and meat products in specialized shops
	B	Mini-market
		Supermarket
	C	Hypermarket
	D	Retail sale of tobacco products in specialized shops
		Retail sale of newspapers and stationery in specialized shops
Schools	E	Retail sale of pharmaceutical products in specialized shops
	F	Marché
	G	Preprimary education
		Primary education
	H	General secondary education
Healthcare	I	Hospital activities
		Surgical activities
	J	Activities of family doctors
		Activities of nurses and midwives
	K	Diagnostic and radiotherapy activities
		Dental practice
Public services	L	Medical analysis laboratories
		Municipal office
		Police station—Gendarmerie
		Medico-social centers
Leisure	M	Pôle Emploi (Job Centre)
		Cinema
		Museum
	N	Performance hall
		Library—Media library
	O	Activities of sports clubs
		Sports infrastructure

act on the whole system of territorial mobility through public policies applied to the territory, thus causing social, economic, and other changes.

The synthetic structure of this data model is composed of five families of data (hyperclasses): resources, territorial actors, territories (specific features of the territories and land use), infrastructure and facilities, and finally access costs. The elaborated database then includes the different elements necessary for the

evaluation of the ergonomics of access in the area under study, taking into account the analysis method. The data used for this study concern the year 2015 and come mainly from INSEE or the Eurometropole de Strasbourg. Collecting and organizing this information into a structured database required several months:

- The data related to the population are provided by INSEE
- The data related to the territory and the network (boundaries, roads, etc.) were obtained from Eurometropole de Strasbourg.
- Some resources were georeferenced manually (markets), but most of them were extracted from the SIRENE file of INSEE.
- The accident data come from the BAAC file administered by ONISR and supplied by the SIRAC of Eurometropole de Strasbourg.

3.3.3 Itinerary Calculation

The application of the method of assessing the ergonomics of access to resources required the use of ESRI's "ArcGis 10.6" GIS software, and more specifically the "Network Analyst" module, which specializes in the calculation of itineraries. The starting points and resources were linked to the nearest roads within a 300 m radius. The following criteria were used to calculate the itineraries:

- The trips made are considered door-to-door, from the point of departure to the resource, as if the chosen mode of travel is immediately available. However, parking is included in the criteria for assessing the ergonomics of access. For car drivers, the journey to the nearest parking space on foot was taken into account.
- For cars and bicycles, it was necessary to respect the direction of circulation.
- Speeds were chosen by mode. Indeed, the speed adopted for walking is 4 km/h, for cycling 15 km/h, and for driving 30 km/h in the extended city center and regulatory speed elsewhere.
- The possibility of turning at junctions (intersections) was taken into account.
- The hierarchy of lanes has been ignored.
- The impedance chosen for the calculation of the shortest path is time. The calculated itineraries are the shortest in terms of time-distance (Hached, 2019).

3.3.4 Indicators for Evaluating the Ergonomics of Access to Resources

Many criteria are used to evaluate the ergonomics of access to resources. The diagram in Fig. 5 summarizes the indicators taken into account and explains how they are prioritized in order to obtain a synthetic indicator of the ergonomics of access. In practice, the indicators were chosen for their divisive nature in the study area (e.g., slope was not taken into account in the Eurometropole de Strasbourg, as our itineraries are all located in a flat zone). They are also adapted to the mode studied (e.g., parking is not considered for pedestrians).

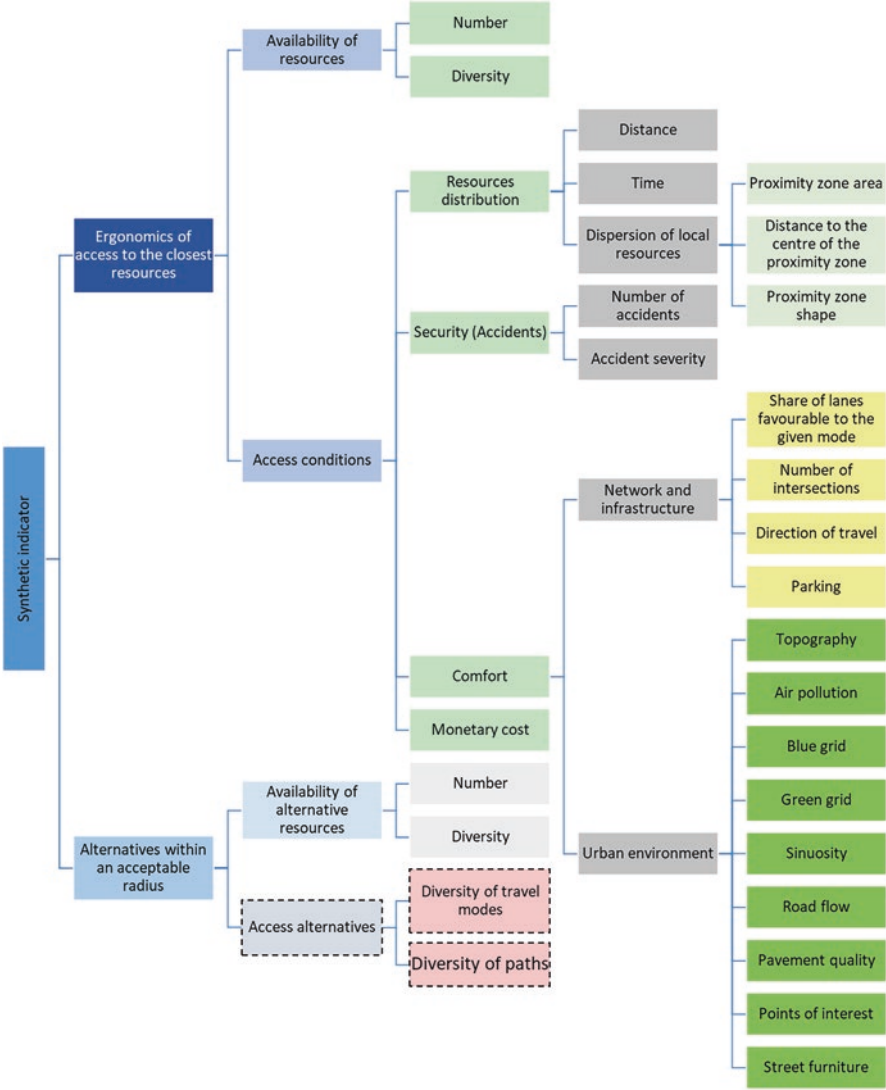


Fig. 5 Indicators of ergonomics of access to resources (Hached, 2019, 2020; Hached & Propeck-Zimmermann, 2020; Saint-Gérard et al., 2021)

The synthetic indicator of ergonomics of access depends on the combination of two indicators:

1. The first is related to the ergonomics of access to the nearest resources.
2. The second is related to the alternatives within a given radius (5, 10, or 20 minutes).

These are the result of the combination of the lower levels (Hached, 2019):

1. **The indicator of the ergonomics of access to the nearest resources.** It depends on two criteria. The availability of resources in the proximity area and the conditions of access to these resources.
 - 1.1. ***The availability of resources in the proximity area*** is defined by:
 - 1.1.1. ***The number of resources available*** from the panel of 32 everyday resources
 - 1.1.2. ***The diversity of these resources.*** The latter takes into account the number of accessible classes in relation to the total number of classes (15 classes of resources from A to O).
 - 1.2. ***The conditions of access to the nearest resources*** through 4 variables: distribution of resources, security, comfort, and monetary cost:
 - 1.2.1. ***The resource distribution indicator*** aims to investigate the distribution of resources in relation to the selected study points. It takes into account:
 - 1.2.1.1. ***The total distance*** to reach all accessible resources in a given time interval (5, 10, and 20 minutes). The further the resources are located, the more effort it takes to access them.
 - 1.2.1.2. ***The total time*** to access all resources as quickly as possible. The access time is proportional to the distance on foot and by bicycle but can vary considerably with the speed for cars.
 - 1.2.1.3. ***The dispersion*** of resources within the proximity polygon. If the resources are clustered together, it is easier to establish a program of activities.
 - 1.2.1.3.1. ***The dispersion of resources*** then investigates the area of the proximity zone. The wider the area, the further away the proximity resources are from the starting point and the greater the distances they have to travel to reach them.
 - 1.2.1.3.2. ***The distance to the center of gravity*** of the proximity zone informs about the location of the greatest concentration of resources in relation to the starting point. Thus, if the center of gravity of the proximity resources is located at a short distance from the starting point, this implies mostly short-distance daily trips.
 - 1.2.1.3.3. ***The shape of the proximity zone*** reflects the homogeneity of the distribution of resources around the study point. A circular shape means that resources are distributed in a homogeneous way around the starting point, indicating that the

inhabitants have a higher probability of finding resources, regardless of the direction of their journey. A more elliptical shape shows that resources are concentrated in a main direction, which must be taken to access the majority of resources.

1.2.2. ***The safety indicator*** takes into account accidents involving the mode under study on access routes to local resources. Accidents are evaluated for each study point for each mode (walking, cycling, or driving) with regard to the following:

- 1.2.2.1. ***Their number***. The accidents taken into account are those involving at least one user of the investigated mode,
- 1.2.2.2. ***The accident rate*** (number of accidents per kilometer)
- 1.2.2.3. ***Their severity***, which takes into account accidents resulting in serious injury or death.

In addition to accidents, the safety indicator can have broader dimensions by taking into account other parameters such as incivilities (assaults, thefts, damage to bicycles, etc.), but these data were not available in our study area.

1.2.3. ***The comfort indicator*** evaluates, on the one hand, the comfort linked to networks and infrastructure and, on the other hand, the quality of the urban environment.

1.2.3.1. ***Comfort*** linked to networks and infrastructure includes 6 variables defining the ease of traveling by a mode:

1.2.3.1.1. *The proportion of facilities dedicated to each mode*, i.e., those designed specifically for a particular mode: bus lanes for buses, cycle facilities for bicycles (cycle tracks, cycle lanes, etc.), pedestrian streets for pedestrians and roads for cars (motorways and roads where the speed is generally higher than 70 km/h). These facilities attempt to reduce conflicts between different modes with different vulnerabilities and to improve the performance, including speed, of each mode by giving it more space in public areas. From a political point of view, this would ensure equitable sharing of the street between the different users.

1.2.3.1.2. *The proportion of lanes favorable to a given mode*. These are the lanes that allow one mode to be favored over another. For soft modes, in addition to dedicated facilities, favorable lanes are

those that have been the subject of policies to reduce the dominance of cars. Thus, all lanes with a reduced speed of 30 km/h or less (30 km/h zones, meeting zones, pedestrian zones) are favorable to soft modes (walking and cycling), and all lanes with a speed of more than 30 km/h are considered favorable to cars.

- 1.2.3.1.3. *The proportion of physically practicable lanes* that enable a flow of traffic that meets the current normative requirements in terms of width or number of lanes. For infrastructure (roadway, pavement, etc.) to be considered practicable, it must have a width greater than or equal to 1.4 m for pavements (Legifrance, 2007; Bruyere, 2014), 1.5 m for bicycle facilities (Bruyere, 2014; Fédération française de cyclotourisme, 2019) and 3.5 m for a car lane (Grandlyon, 2010).
- 1.2.3.1.4. *The number of intersections.* A high number of intersections, although contributing to the porosity of the urban space and offering users opportunities to change routes, is considered negative. Indeed, this study is based on the shortest paths (in terms of distance-time), and each intersection represents a slowing down and an additional effort of attention, in a way similar to the “space syntax” approach (Hillier & Hanson, 1984), as well as a higher risk of accident.
- 1.2.3.1.5. *The direction of traffic* was taken into account for both bikes and cars. For example, a two-way cycle facility is favorable to cyclists, as it provides extra width to facilitate overtaking. On the other hand, a one-way system is favorable to cars because of the absence of crossing with cars in the opposite direction.
- 1.2.3.1.6. *Parking* is a parameter for bikes and especially for cars. Users often try to park as close to resources as possible. The number of bicycle racks within 50 m of the resources was taken into account. For cars, the number of on-street parking spaces, the number of car parks within 50 m of the resource, and, inversely, the number of resources located in a tariff zone (where parking is charged) were taken into consideration.

1.2.3.2. Comfort related to the urban environment. The notion of adherence to the territory refers to the idea that interaction with the urban environment increases with the decrease in user speeds (Appleyard, 1980; Conesa, 2010). In this sense, soft modes would be the most sensitive to the quality of their immediate environment (weighting could be introduced in the analysis):

1.2.3.2.1. *Natural elements:* The green and blue grids bring nature into the city and partially hide some nuisances. For example, trees provide shade for walkers and cyclists (in summer, on sunny days). They reduce the perception of noise (psycho-acoustics) by partially hiding the sources of noise pollution. In addition, trees planted between the pavement or cycle path and the roadway provide a feeling of safety by forming a barrier that protects soft modes from motorized modes. Watercourses, often lined with greenery, contribute to the animation of the urban space (swans, ducks, etc.). For example, water partially masks traffic noise. The green and blue framework is also important for motorists. They provide landmarks as well as a pleasant, nonmonotonous landscape. Air quality is an important element, even if it is more difficult to perceive, except for people with respiratory problems. Pedestrians and cyclists are more exposed to pollutants because their physical activity requires deeper breathing. Car drivers are less sensitive to air pollution because the car is typically a closed capsule with filtered air entering the cabin. The topography of the terrain can make mobility difficult. Cyclists and pedestrians are much more sensitive to slopes than motorists. The sharper and longer they are, the more physical effort they require.

1.2.3.2.2. *Sinuosity* is the ratio of the actual length of routes relative to the straight-line distance from the starting point to the resources. The more sinuous the routes, the longer they are and therefore the less efficient they are in providing connections between the starting point and the resources. Furthermore, the more sinuous the paths, the

more difficult it is for the urban user to locate himself in space.

- 1.2.3.2.3. *Flow* is a data item that is often available for cars but rare for soft modes. It can be investigated in two ways. The flow of the same mode as the one studied, crossed with the number of traffic lanes, reflects the degree of congestion. The flow of modes other than the one studied reflects the inconvenience/risk experienced. For the purposes of this study, only car flow data were available for the entire study area. The higher the car flow, the more it was considered to be negative for car drivers (traffic jams, risk of accident, etc.) and for soft modes (noise, air pollution, risk of accident, etc.), consistent with Appleyard observations (Appleyard, 1980).
- 1.2.3.2.4. *The quality of pavements* has an impact on travel comfort but also on safety. For example, a good-quality surface reduces the risk of falling for pedestrians and slipping or loss of control for bicycles and allows better braking for cars.
- 1.2.3.2.5. *Landmarks* such as monuments, sculptures, and historical buildings contribute to the aesthetics of the urban space and form landmarks for moving around the city (Hillier & Hanson, 1984).
- 1.2.3.2.6. *Street furniture* has also been taken into consideration in terms of number and diversity. This equipment ensures the comfort of those who use soft mobility. Indeed, public seats allow people to take a break, to sit down, to put down their shopping, etc., fresh water fountains allow people to hydrate and refresh themselves in hot weather, while dustbins and public toilets (rare) provide appreciable comfort.
- 1.2.3.3. The monetary cost is a difficult indicator to assess. It is estimated according to the distance traveled, with a cost per kilometer per mode. It is strongly correlated with the distribution of resources. Furthermore, it is mainly of interest in the comparison between modes. This cost is difficult to evaluate. On the basis of scientific literature and local studies (Beauvais, 2012; Papon, 2002; SMTc, 2008; STIF, 2005) and excluding clothing costs for pedestrians and cyclists, an average price has been adopted for the different modes: on foot 0 euro/km, bicycles: 0.036 euro/km, and

cars: 0.41 euro/km. This average price is subject to discussion. Indeed, walking is not free, but clothing costs (for pedestrians and cyclists) are difficult to assess. Moreover, whatever the mode, the figures may vary according to the studies carried out in different contexts. The main point here is to put the prices of the different modes into perspective for comparison.

2. The indicator of alternatives within an acceptable radius. It takes into account two parameters:

- 2.1. **The availability** (number and diversity) of alternative resources, i.e., all resources accessible within a given time interval (zone defined by a network distance of 5, 10, or 20 minutes)
- 2.2. **Alternative accesses** have not been developed in this research project, but they should take into account the diversity of travel modes (presence of public transport, multimodality, etc.) and the diversity of itineraries (choice of possible itineraries between the starting point and the studied resource in a given time interval).

3.3.5 Scores and Synthetic Indicator of Access Ergonomics

A score between 0 and 100 is attributed to each criterion calculated previously, where 100 represents, for a given criterion, the highest (i.e., favorable) result of all the meshes of the study area. For example, the score for the “number of resources in the proximity zone” will be equal to 100 for the mesh from which one has access to the highest number of resources in the territory studied and 0 for the mesh from which one has access to no resources. In contrast, for negative criteria such as accidents, a score of 100 is assigned to the grid cell with the fewest accidents and a score of 0 to the grid cell with the highest number of accidents. The average of the criteria scores (as presented below) provides the synthetic ergonomics indicator at every single location in the zone (Hached, 2019, 2020; Hached & Propeck-Zimmermann, 2020; Saint-Gérard et al., 2021).

The diagram in Fig. 6 summarizes all the criteria taken into account and explains how they are combined to produce a synthetic indicator of ergonomics of access. The latter represents the average of the scores of the indicator “Ergonomics of access to proximate resources” (EAPR) and the indicator “Alternatives within an acceptable radius” (AAR).

The scores for the overall indicators (EAPR and AAR) are obtained by the nested averages of the scores for the lower-level criteria. For example, the score for “Ergonomics of Access to Proximate Resources (EAPR)” is the average of the scores for “Resource Availability” (defined as the average of the scores for Number and Diversity) and the scores for “Access Conditions.” The latter is defined by the average of the scores for four criteria: resource distribution, safety, comfort, and monetary cost.

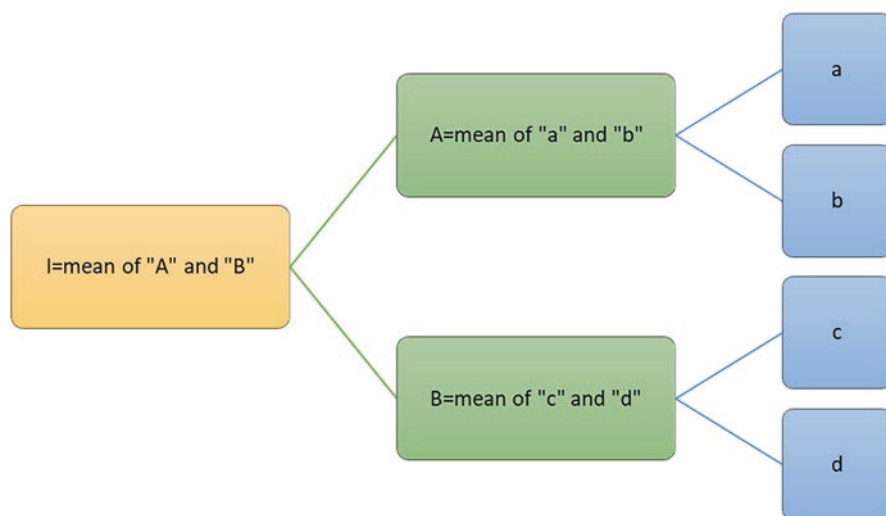


Fig. 6 Method of calculating nested indicators (Hached & Propeck-Zimmermann, 2020)

The “alternatives within acceptable radius” score is the average of the “availability of alternative resources” scores (the “access alternatives” are not taken into account in this study).

Access alternatives, requiring additional data and a specific and heavy processing chain, will be the object of further research. In fact, to not give too much weight to the availability of alternative resources, weighting was adopted: a factor of “2” for the indicator “Ergonomics of access to proximity resources” (EAPR) and a factor of “1” for the indicator “Alternatives within an acceptable radius” (AAR).

Finally, the synthetic indicator, calculated for each mesh on a scale of 0–100, allows the analysis of spatial disparities in terms of ergonomics of access to resources, all modes combined, and according to different modes or different time steps. In a second step, an in-depth study allows us to understand the combinations of criteria leading to a particular level and thus to provide information on the contribution of each criterion to the overall level. Putting the levels of ergonomics into perspective with a typology of socio-urban environments ultimately allows us to study the socio-spatial disparities in access to resources within the territory.

To summarize, spatial ergonomics, and more particularly access to resources in this context, is a geographical concept with an operational purpose. This means that the global and complex vision of territories, which is the basis of this concept, makes it suitable for experiments in spatial analysis that can be applied to several scales of territory and issues. In the subfield studied here, which focuses on the local conditions of appropriation of everyday resources using active modes, its assessment required the development of a methodology based on a GIS. This method consists of the following:

- First, define the resources that fit the needs (resources of daily life in this case study).
- Second, calculate the access itineraries from the starting points distributed over the whole territory (e.g., mesh centroids) to the closest selected resources, according to the shortest paths in terms of distance-time.
- Then define a proximity zone formed by the closest resources.
- Calculate the access itinerary to all alternative resources.
- Calculate the alternative paths of access.
- Select discriminating indicators adapted to the study area and allowing the comparison of the different zones. These indicators are applied to proximity resources, itineraries, proximity zones, and alternatives.
- Assigning scores to each indicator from 0 to 100, with 100 representing the best score, to finally calculate a synthetic score.

4 Application to the Eurometropole de Strasbourg

The implementation focused on the Eurometropole de Strasbourg. The territory has 2645 inhabited meshes of 200 m × 200 m. To test the developed method, 12 study areas were selected (Fig. 7). The choice of the test areas is crucial for making comparisons within the territory and revealing socio-spatial disparities. Two selection criteria were used: on the one hand, the geographical distribution throughout the Eurometropole, taking into consideration the urban morphology structuring the territory (center, planned center, first and second peri-urban ring), and on the other hand, the socio-environmental characteristics of the different neighborhoods resulting from a typology based on population data (age, household size, socio-professional categories, etc.) in their respective urban environments (land use, blue grid, green grid, etc.). The typology (carried out within the framework of ANR RED) distinguishes 8 classes represented on map 2. All the test areas were validated by urban planning experts at the Eurometropole de Strasbourg.

5 Results

The method of assessing the ergonomics of access (detailed and on a local scale) to the resources of daily life by active mobility was applied to the selection of selected study points distributed in the Eurometropole de Strasbourg, presented above. The assessment considered 5-, 10- or 20-minute walking and cycling trips and 5- and 10-minute car trips (Hached, 2019, 2020; Hached & Propeck-Zimmermann, 2020). For each location, a synthetic indicator of access ergonomics is obtained in the shape of a score between 0 and 100. This synthetic indicator can be analyzed and developed according to all the lower-level criteria that make it possible.

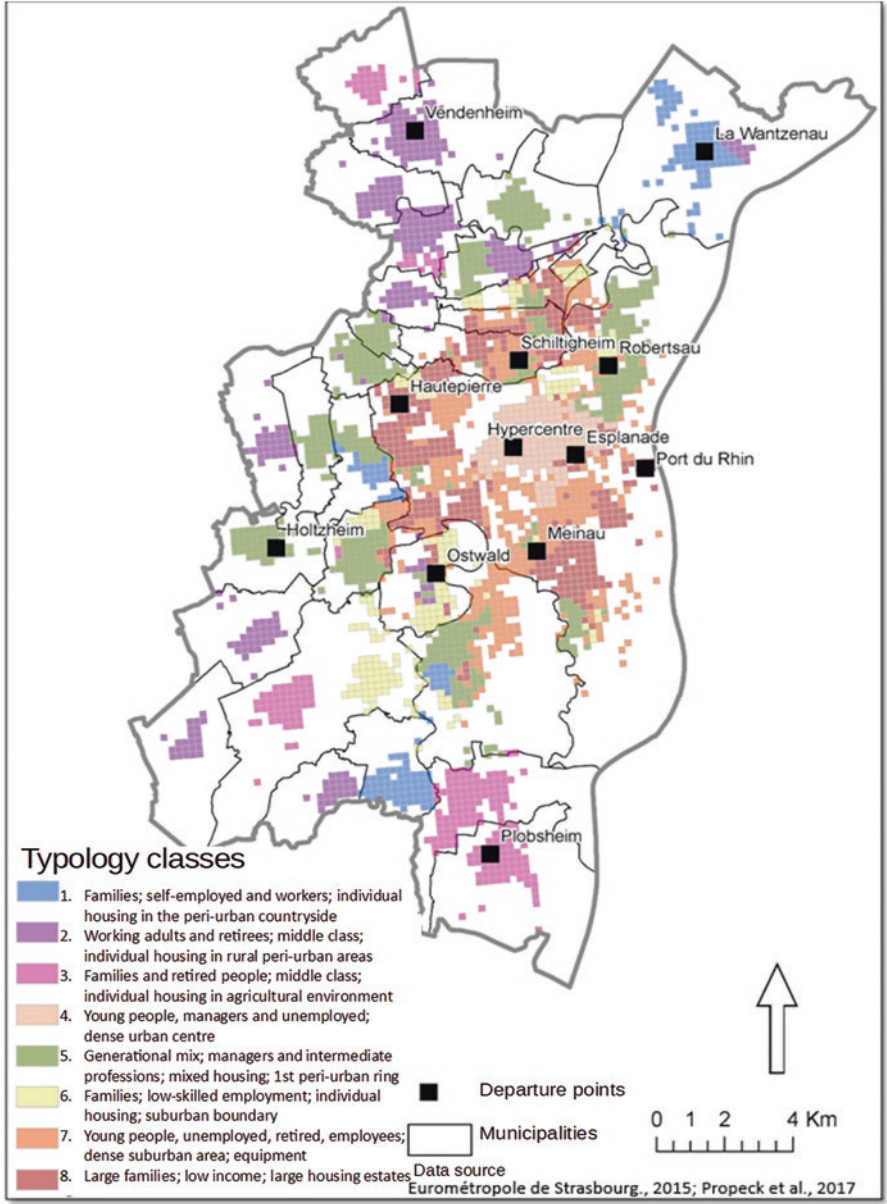


Fig. 7 Typology and investigation areas in the Eurometropole de Strasbourg (Hached, 2019; Propeck-Zimmermann et al., 2018a, b)

The results can be presented in two forms. The first, synthetic, allows a comparison of the level of access ergonomics between the different modes studied (walking, cycling, and cars) for each time step. The second, analytical, allows the analysis and comparison of the ergonomics profiles, i.e., the combinations of the different criteria leading to a given level of ergonomics (Hached, 2019, 2020; Hached & Propeck-Zimmermann, 2020).

The application to the 12 test areas shows disparities at the level of the Eurometropole de Strasbourg. Indeed, the synthetic indicator, for a time step of 10 minutes, varies from 41.0 to 86.2 for the bicycle and from 38.9 to 76.9 for the car (Table 3 and Fig. 8).

By bicycle, the highest ergonomics score (86.2) is located in the hypercenter of Strasbourg. This can be explained by long-standing developments in favor of soft modes (large pedestrian area, numerous cycle facilities), a high number and diversity of resources, and favorable access conditions with regard to the criteria selected. Conversely, travel by car has the lowest ergonomic score (38.9) due to facilities that discourage the use of this mode (study point located in the pedestrianized hypercenter).

Ergonomics by bicycle are lower in the inner ring and even lower in the outer ring. By car, the level of ergonomics is relatively homogeneous. Map 3 and Table 3 therefore show a center-periphery gradient, but this gradient is not perfect, and some places have very distinct characteristics.

The Robertsau, to the northeast of the city center, is less ergonomic to cycle than other points located at an equivalent distance. It is an affluent neighborhood with a generational mix where managers and middle occupations are overrepresented. The resources grouped together in the center of the district are numerous and diversified, but the potential resources accessible by bicycle within 10 minutes are generally lower due to a low-density urban environment that is relatively far from the other districts. The proportion of lanes dedicated to cycling is low, but conditions are favorable to the car.

Table 3 Scores of ergonomics of access to daily life resources in 10 minutes by bicycle and cars (Hached & Propeck-Zimmermann, 2020)

Point of departure	Ergonomics of access to resources by bicycle	Ergonomics of access to resources by car	Distance to city center in km
Hypercenter	86.2	38.9	0.0
Esplanade	73.6	76.3	1.8
Schiltigheim	69.4	76.9	2.6
Meinau	65.2	71.6	3.2
Hautepierre	63.9	69.6	3.6
Robertsau	61.4	66.8	3.7
Port du Rhin	41.0	44.6	3.9
Ostwald	54.1	63.4	4.4
Holtzheim	43.1	62.9	7.6
Vendenheim	49.9	57.2	10.0
La Wantzenau	60.6	64.1	10.6
Plobsheim	57.6	59.8	12.3

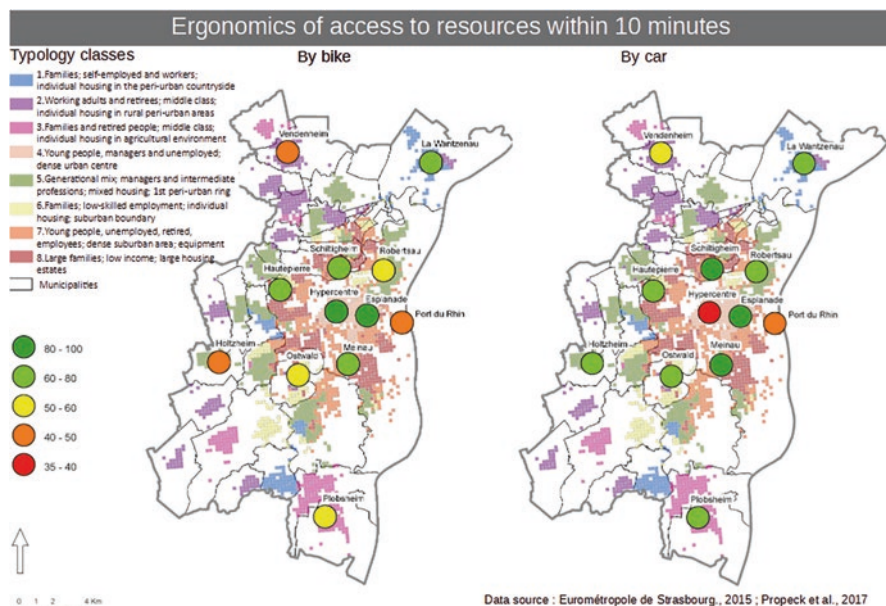


Fig. 8 Ergonomics of access to everyday resources within 10 minutes by bike and car (Hached, 2019, 2020)

The Port du Rhin (red dot in the east) also presents an atypical situation in the first suburban ring. It is a popular neighborhood with large families, low incomes, and large housing estates, with the lowest ergonomics by bicycle and one of the lowest scores by car. Resources are very limited, and alternatives are almost nonexistent due to the isolation of the area between an industrial zone and Germany. However, the result in this respect should be treated with caution due to the lack of data on the German side, which does, however, offer local resources (particularly by bicycle since the creation of a new bridge over the Rhine to the city of Kehl).

In the most densely populated peri-urban districts and suburban areas, the bicycle seems to be an alternative to the car for accessing everyday resources (numerous accessible resources with networks favorable to the use of the bicycle, bicycle racks, and urban furniture, especially in Esplanade, Schiltigheim, and Hautepierre). However, the ergonomic scores by car are still slightly higher.

The communes of the second ring are favorable to the use of bicycles thanks to the relative safety of travel and low exposure to road traffic.

In the second ring, the situation is more heterogeneous between municipalities of comparable size. In some cases, the overall score is relatively good, the resources are numerous and well distributed in the center of the town, and the urban environment is of good quality (La Wantzenau, Plobsheim). In others, the resources are more fragmented between retail outlets and large shopping centers, the network is more complex, and the number of serious accidents is higher (Vendenheim). Finally, in some communes characterized by a certain isolation from Strasbourg (such as

Holtzheim in the west), resources are limited and dispersed, although their ergonomics improve rapidly by car because of their integration into the network of surrounding communes.

The examples presented above show that although the synthetic indicator gives an overall level of usability that reveals disparities on the scale of the Eurometropolis, it is necessary to use combinations of criteria to explain these disparities. Moreover, the same score can correspond to very different ergonomic profiles.

5.1 *From the Synthetic Indicator to the Exploration of Combinations of Criteria*

Consider an example to illustrate spatially variable situations leading to similar ergonomic scores but with different profiles. These profiles can be related to the socio-urban characteristics of the neighborhoods.

Two dense suburban areas, La Meinau in blue and Schiltigheim in orange, are located approximately 3 km from the city center. They are both inhabited by managers and intermediate professions with a generational mix in mixed housing areas. Their scores, for 10 minutes by bicycle, are relatively close (65.2 and 69.4, respectively) but hide contrasting ergonomic profiles (Fig. 9). While the availability of

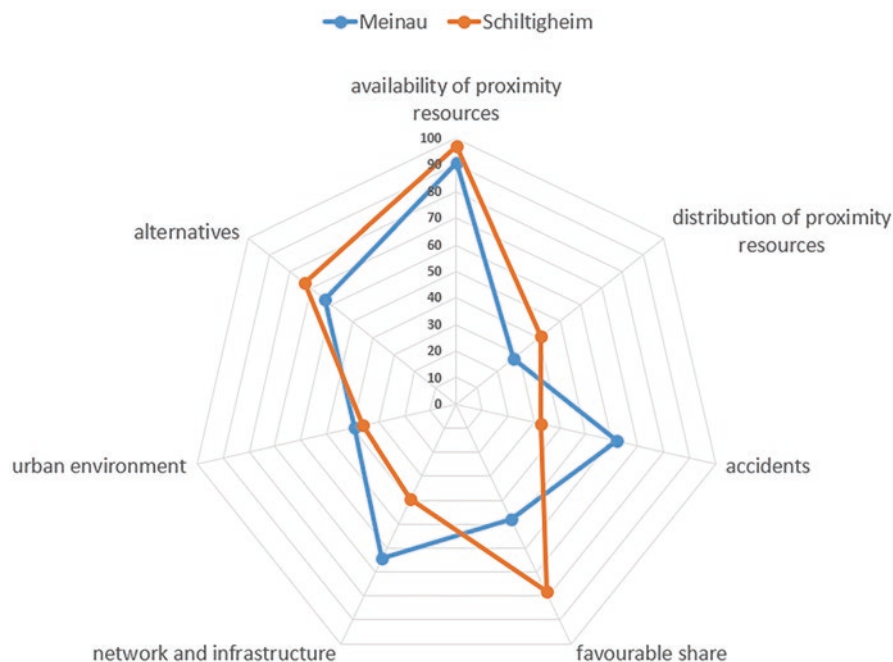


Fig. 9 Comparison of the ergonomics of 10-minute bicycle access at two study points with similar profiles but different scores (Hached, 2019; Hached & Propeck-Zimmermann, 2020)

resources appears to be equivalent, the two neighborhoods differ greatly in terms of networks and safety. Schiltigheim has more facilities for cycling but is included in a denser traffic network (in terms of road flow, intersections, share of two-way road network), and the number of accidents is higher. Conversely, in Meinau, the proportion of facilities in favor of cycling is lower, and there are fewer accidents in an environment marked by many one-way roads. This analysis needs to be completed, in particular by looking at the flow of bicycle traffic. It should also be borne in mind that even if particular care was taken in selecting the study points, the scores for the various criteria could vary significantly over short distances.

6 Conclusion

The research presented in this chapter is part of the contemporary issue of urban policies for sustainable mobility, particularly active modes. It questions the effectiveness of these policies in terms of access to the daily resources that people need. In this context, spatial ergonomics seems to be a relevant operational concept to reveal in a global and detailed way the situations favorable and unfavorable to these modes and to investigate the socio-spatial disparities induced by sustainable mobility policies.

On the one hand, a global approach to evaluate the level of ergonomics of access to current resources has been elaborated, taking into account the general functioning of the territory through the availability and distribution of resources and, on the other hand, a panel of criteria characterizing their access conditions.

Compared to accessibility approaches, our own contribution, based on spatial ergonomics, shares many criteria and methods related to the efficiency of the mobility system but places more emphasis on several criteria related to user welfare, in particular road safety and comfort. Resource accessibility criteria (number and diversity of resources accessible in a given time) reflect the effectiveness of a spatial configuration in optimizing travel and meeting the mobility needs of populations. Comfort can be included in accessibility approaches in the way that it contributes to influencing itinerary choices, but in ergonomics approaches, its justification is different: comfort will be considered part of the urban design, with the intention of favoring sustainable and active modes (share of lanes dedicated to soft modes, continuity of infrastructure, parking facilities, etc.). Road safety plays a role in the choice of the mode, but it also reveals problems of incoherence in the design of urban and peri-urban spaces, a dysfunction of a territory linked to the choices of development and urban organization. The criteria of alternatives/choice in terms of resources (number and diversity) and modes of access (in particular public transport to be integrated into the study) are intended to reveal the possibilities that the territory provides to respond to the constraints of the moment or to the differentiated needs of a population with different socioeconomic profiles (range of goods and services).

The application of the approach to 13 test areas, with the help of a GIS and an adapted database, has made it possible to detect disparities within the Eurometropole de Strasbourg to analyze the differentiated situations in detail, and to put them into perspective with the sociodemographic profiles. The different levels of information (maps that can be presented by mode of transport, by time step, and criteria by criteria) show how certain sectors allow easier adoption of active modes, point out locally the barriers to be removed to adapt the facilities and the urban environment to the mobility needs of the inhabitants, and provide information on the scope of residents to modify their mode of transport. The results clearly show, as expected, that the ergonomics are more favorable to walking and cycling than to the car in the hypercenter and that there are very different degrees of ergonomics for cycling in suburban areas. It is worth mentioning that the city's policy priority area has higher-than-average scores. More unexpected is the fact that active mode access can correspond to car access in peri-urban contexts, where urban developments have been closely associated with cars.

Implementation throughout Eurometropole has been initiated on the basis of certain key indicators (distribution of local resources, share of roads favorable to active modes, number of accidents, etc.). Many developments are still necessary to get closer to the real complexity on the ground. In particular, it seems crucial to include the issue of access to employment in the analysis. In the context of a sustainable mobility policy, it is also essential to take into account the public transport offer to evaluate the possibilities of intermodality with soft modes. Household travel surveys provide information on mobility practices, but they must be supplemented by field surveys to identify specific needs and practices and to assess the adequacy of urban planning to the needs and practices of people in their daily lives. These developments are envisaged within the framework of a research program of the A.N.R. URFé.

The ergonomics approach implemented therefore makes it possible to carry out territorial diagnoses to help local authorities develop effective sustainable mobility policies that meet the needs and expectations of users. However, beyond mobility, ergonomics aims to take into account more globally the issue of territorial ecology through a reflection on resources and alternative practices (e.g., short circuits, digital place in the process of supply of resources) at the heart of actual developments.

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