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POLYTECHNIQUE MONTRÉAL

affiliée à l'Université de Montréal

Modélisation de l'accessibilité aux parcs : intégration des attributs des destinations et des perceptions, besoins et préférences des individus

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Mémoire présenté en vue de l'obtention du diplôme de *Maîtrise ès sciences appliquées*

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POLYTECHNIQUE MONTRÉAL

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Ce mémoire intitulé :

Modélisation de l'accessibilité aux parcs : intégration des attributs des destinations et des perceptions, besoins et préférences des individus

présenté par **Karl EL MURR**

en vue de l'obtention du diplôme de *Maîtrise ès sciences appliquées*

a été dûment accepté par le jury d'examen constitué de :

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Owen WAYGOOD, membre et codirecteur de recherche

Kevin MANAUGH, membre externe

DEDICACE

Pour un monde juste, libre, humain et équitable.

« Choisir le doute comme philosophie de vie c'est comme choisir l'immobilité comme mode de transport. »

- Yann Martel

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RÉSUMÉ

Au cours des dernières années, l’augmentation de la proportion de la population vivant dans des zones urbaines a mis en valeur l’objectif ainsi que le défi des autorités publiques de rendre les villes inclusives et durables. Plusieurs stratégies ont été développées pour atteindre cet objectif en se basant sur les domaines du transport et d’aménagement du territoire. Parmi ces stratégies, l'accessibilité aux destinations est de plus en plus considérée comme une alternative au paradigme de planification des transports axé sur la mobilité.

Les parcs et espaces verts sont des destinations d'intérêt en raison de leur contribution à la qualité de vie des individus en milieu urbain. Les parcs sont des lieux d'activités diverses ainsi que des espaces d'interactions sociales qui contribuent à l'amélioration de la santé mentale et physique. Les parcs présentent également de nombreux avantages sociaux, économiques et environnementaux. Afin que les bénéfices des parcs et espaces verts se matérialisent, la qualité des parcs ainsi que l’accessibilité aux parcs doivent être assurées.

C’est dans ce contexte que le mémoire vise à modéliser l’accessibilité aux parcs et espaces verts en considérant d’une part, les attributs des destinations et d’autre part, les perceptions, préférences et besoins des individus. En complément des attributs des parcs, il est essentiel de comprendre comment l’accessibilité concerne différents groupes de la population. Une méthode pour y parvenir consiste à comprendre comment les différents groupes de la population perçoivent leur accessibilité aux parcs. La revue de littérature a montré que peu d’études considèrent la qualité des parcs et les perceptions des individus lors de la modélisation de l’accessibilité aux parcs quoique leur importance ait été démontrée. La majorité des études modélisent l’accessibilité en utilisant des mesures simples telles que le nombre de parcs accessibles ou la surface des parcs accessibles.

Le projet se décline en trois objectifs spécifiques. Le premier était de mesurer l’accessibilité calculée aux parcs et espaces verts de la ville de Montréal en considérant le nombre de parcs, la surface et les types d’activités présentes dans les parcs. Trois mesures d’accessibilité calculée ont été générées par la méthode d’opportunité cumulative pour une distance de 1000 mètres à pied à partir des lots résidentiels en utilisant les données géospatiales de la Ville de Montréal. La première mesure compte simplement le nombre de parcs accessibles. La seconde mesure additionne la

surface des parcs accessibles. La dernière mesure compte le nombre d'activités accessibles pour cinq types d'activités.

Le second objectif était de développer une méthode qui considère les différents attributs et la qualité des parcs dans les mesures d'accessibilité. La mesure d'accessibilité développée pour cet objectif a été inspirée d'un indice déjà développé qui mesure la qualité d'un seul parc à partir de données géospatiales. La méthode proposée dans cet objectif visait premièrement à adapter l'indice en fonction du contexte et des données disponibles. Ensuite, la méthode requérait l'adaptation de l'indice déjà développé pour qu'il s'applique à un groupe de parcs. Cette adaptation a été réalisée en changeant l'approche de notation pour chaque variable dépendamment des résultats d'accessibilité obtenus pour chaque variable. La méthode de mesure d'accessibilité est identique à celle évoquée pour le premier objectif et elle a été générée pour chaque variable qui constitue l'indice. L'indice final obtenu, l'indice CIPQAY, représente la qualité des parcs accessibles à partir des lots résidentiels pour la ville de Montréal.

Le troisième objectif portait sur l'étude de l'association entre les différentes mesures d'accessibilité calculée et l'accessibilité auto-déclarée aux parcs et espaces verts. L'accessibilité auto-déclarée d'un échantillon représentatif a été mesurée par le biais d'un sondage diffusé en ligne auprès des résidents de la ville de Montréal. Ensuite, la relation entre l'accessibilité auto-déclarée et chaque mesure calculée, notamment le nombre de parcs accessibles, la surface des parcs accessibles et l'indice CIPQAY, a été évaluée à l'aide de trois modèles logistiques ordonnés distincts, tout en contrôlant pour les caractéristiques individuelles des répondants. Aussi, une analyse d'inadéquation a été faite entre chacune des mesures d'accessibilité calculée et l'accessibilité auto-déclarée.

Les résultats ont démontré que l'accessibilité varie fortement en fonction des facteurs pris en compte lors de la modélisation. Les différences sont notamment considérables entre le nombre de parcs accessibles et la surface des parcs accessibles, ainsi que selon le type d'activité considéré. De plus, les résultats ont démontré que l'indice CIPQAY, qui prend en considération les attributs détaillés des parcs, se distingue des mesures conventionnelles du nombre de parcs et de la surface des parcs.

Ensuite, l'étude de l'association entre l'accessibilité auto-déclarée et les mesures d'accessibilité calculée a montré que l'accessibilité calculée tenant compte des attributs des parcs reflète davantage l'accessibilité auto-déclarée en comparaison aux autres mesures d'accessibilité calculée. Les résultats obtenus dans les modèles logistiques démontrent aussi que les caractéristiques individuelles influencent l'accessibilité auto-déclarée, même lorsqu'on contrôle pour l'accessibilité calculée.

En somme, ce mémoire met en lumière la pertinence de considérer les attributs des parcs dans les mesures d'accessibilité calculée ainsi que de considérer la dimension individuelle dans les analyses d'accessibilité aux parcs. En plus de combler une lacune importante de la littérature, les résultats permettront de mieux outiller les villes pour réaliser un diagnostic de l'accessibilité de leurs résidents aux parcs et espaces verts.

ABSTRACT

In recent years, the increase in the proportion of the population living in urban areas has highlighted the objective, as well as the challenge, for public authorities to make cities inclusive and sustainable. Several strategies have been developed to achieve this objective based on the fields of transport and land use planning. Among these strategies, accessibility to destinations is increasingly seen as an alternative to the transportation planning paradigm that was often focused on the concept of mobility.

Parks and green spaces are destinations of interest due to their contribution to the quality of life of individuals in urban areas. Parks are places of various activities as well as spaces for social interactions that contribute to the improvement of mental and physical health. Parks also have many social, economic and environmental benefits. To take advantage of these benefits, the quality of the parks as well as the accessibility to them must be ensured.

Considering this context, the thesis aims to model accessibility to parks and green spaces considering the attributes of destinations and the perceptions, preferences and needs of individuals. Along with considering park attributes, it is crucial to understand how these measures relate to different groups of the population. One method to accomplish this is to understand how different groups of the population perceive their access. The literature review showed that few studies consider the park attributes and individuals' perceptions when modeling accessibility to parks despite the fact that the importance of these components has already been proven. The majority of studies have model accessibility using simple measures, the number of accessible parks for example or the surface area of accessible parks.

This research has three specific objectives. The first was to measure the calculated accessibility to parks and green spaces in the city of Montreal, considering the number of parks, the surface area and the types of activities present in the parks. Three measures of calculated accessibility then were generated by the cumulative-opportunity method for 1,000 meters walking distance from residential lots using geospatial data of the city of Montreal. The first measure simply counts the number of accessible parks. The second measure sums the surface area of accessible parks. The last measure counts the number of accessible activities for five types of activities.

The second objective was to develop a method that considers the parks attributes and quality of parks in the accessibility measure. The accessibility measure developed for this objective was inspired by an index already developed that measures the quality of a single park using geospatial data. The method proposed for this study aimed firstly at adapting the index according to the context and the data availability. Then, the method required the adaptation of the index already developed so that it applies to a group of parks. This adaptation was made by changing the scoring approach for each variable depending on the accessibility results obtained for each variable. The accessibility measure method used is identical to the one developed in the first objective. The final index obtained, the CIPQAY index, represents the quality of the accessible parks from the residential lots for the city of Montreal.

The third objective focused on assessing the relationship between the different calculated accessibility measures and self-reported accessibility to parks and green spaces. The self-reported accessibility of a representative sample was measured through a survey diffused online for the residents of the city of Montreal. Then, the relationship between self-reported accessibility and each calculated measure, including the number of accessible parks, the area of accessible parks and the CIPQAY index was evaluated in three separate ordered logistic models, while controlling for individual characteristics. Also, a mismatch study was made between each of the calculated accessibility measures and the self-reported accessibility.

The results showed that accessibility varies greatly depending on the factors taken into account during the modeling. The differences are notably considerable between the number of parks accessible and the surface area of the parks accessible. Variations are also present by the type of activity considered. Moreover, the results demonstrated that the CIPQAY index, which takes into consideration the different attributes of the parks, differs from conventional measures, the number and the accessible surface area of parks.

Moreover, the study of the relationship between self-reported accessibility and calculated accessibility measures showed that the calculated accessibility taking into account the attributes of the parks reflects more the self-reported accessibility compared to other calculated accessibility measures. The results obtained in the logistic models also demonstrate that individual characteristics influence self-reported accessibility, even when controlling for calculated accessibility.

This thesis demonstrates the relevance of considering the attributes of parks in calculated accessibility measures as well as considering the individual dimension in analyzes of accessibility to parks. In addition to filling an important gap in the literature, the results will better equip cities to carry out an accessibility analysis to parks and green spaces.

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ARTM	Autorité régionale de transport métropolitain
DA	Dissemination Area
CIPQAY	Combined Index of Park Quality and Accessibility for Youth
QUINPY	QUality Index of Parks for Youth
PPQI	Peri-Urban Park Quality Index
H-2SFCA	Improved two-step floating catchment area

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CHAPITRE 1 INTRODUCTION

1.1 Mise en contexte

Au cours du dernier siècle, le taux d'urbanisation a augmenté dans tous les coins du monde (UN, 2018). Les villes sont désormais devenues le premier espace de vie humaine. En effet, plus de la moitié de la population mondiale vit dans des zones urbaines (UN, 2018). Ces chiffres devraient augmenter dans les années à venir pour atteindre 68 % de la population présente dans des zones urbaines en 2050 (UN, 2019). Rendre les villes inclusives et durables est ainsi devenu un défi et donc une priorité des autorités publiques (Griggs et al., 2013). À cet effet, la mobilité et le transport sont considérés comme des domaines clé d'intervention politique pour atteindre ces objectifs dans les villes. Plusieurs stratégies ont été mises en place récemment et ont pour but de promouvoir des systèmes de transport et d'aménagement du territoire qui mènent à un changement des comportements et habitudes de déplacement des individus. Avec l'augmentation de la taille des régions métropolitaines, ces stratégies de planification s'accompagnent de structures urbaines polycentriques à la place des structures urbaines centrales (Brezzi & Veneri, 2015; Veneri, 2018).

Ce passage se traduit de nos jours par des planifications urbaines comme par exemple la ville de 15 minutes, la ville de 30 minutes ou tout simplement la ville des courtes distances. La ville des courtes distances est une ville dans laquelle une densité résidentielle relativement élevée et des quartiers multifonctionnels sont favorisés et qui repose sur un système de transport, en commun et actif, efficace. Ce concept urbain est exécuté ou en cours de développement dans différents contextes mondiaux (Graells-Garrido, Serra-Burriel, Rowe, Cucchietti, & Reyes, 2021; Hamiduddin, 2018; Sydney, 2018). Les interventions favorisant ces plans sont basées principalement sur des aspects d'aménagement du territoire et de planification de transport durable. Autrement dit, les villes visent à accroître l'accessibilité des individus à une diversité de destinations, tels que les emplois, les établissements de soins de santé, les restaurants, les transports en commun, les écoles, les loisirs et les parcs et espaces verts, en créant des quartiers durables et accessibles en transport actif (Artmann, Kohler, Meinel, Gan, & Ioja, 2019; Veneri, 2018).

Les parcs et espaces verts sont des composantes essentielles des villes (Latinopoulos & Mallios, 2016). Ces destinations sont d'une importance stratégique pour la qualité de vie des individus en leur apportant divers avantages et bénéfices (Chiesura, 2004). Ces avantages peuvent être classés sous différents aspects : environnemental, économique et social. Premièrement, les parcs présentent des avantages environnementaux dans les villes en réduisant la pollution de l’air et en contrôlant le ruissellement des eaux pluviales (Groth, Miller, Nadkarni, Riley, & Shoup, 2008). La présence de parcs atténue aussi l’effet d’îlots de chaleur urbain, ce dernier étant plus fréquent avec l’urbanisation et le changement de l’utilisation du sol (Feyisa, Dons, & Meilby, 2014; Gartland, 2012). Ensuite, investir dans un système de parcs peut avoir un impact considérable sur le plan économique d’une ville. En effet, la valeur économique des propriétés résidentielles augmente plus rapidement avec la présence des parcs dans leurs quartiers (Crompton, 2000; Kovacs, 2012; Nicholls, 2004). Cet effet est valable également sur les propriétés commerciales : notamment, l’étude de cas populaire de la rénovation du Bryant Park à New York montre l’augmentation significative de la valeur des bureaux commerciaux à proximité (Young, 2003). Ainsi, les parcs participent à la revitalisation économique de la ville en attirant des entreprises et en renforçant le développement des villes lors des événements touristiques (Crompton, 2000; Gies, 2009). Sur le plan social, les parcs transforment les quartiers en des espaces plus agréables à vivre et offrent des possibilités de loisirs et d’activités pour tout âge. Ainsi, les parcs sont des endroits qui assurent une inclusion et une intégration sociale des individus ainsi qu’un sentiment d’appartenance à la communauté (Seaman, Jones, & Ellaway, 2010; Sherer, 2006). Plus encore, l’engagement communautaire aux activités dans les parcs de quartiers et l’accessibilité aux parcs ont été liés à des niveaux de criminalité plus faibles dans les quartiers (Sherer, 2006; Witt & Crompton, 1996). Enfin, les parcs fournissent des avantages au niveau de la santé physique et mentale des individus. La disponibilité des parcs dans les quartiers est associée à des niveaux d'activité physique plus élevés, en offrant des espaces pour marcher et pratiquer du sport et divers exercices (Cohen et al., 2007; Floyd et al., 2011). La disponibilité des parcs à la communauté est également associée à des taux d’obésité plus faibles (Lachowycz & Jones, 2011). Le contact avec la nature en complément de l’activité physique améliore directement la santé mentale des individus (Sherer, 2006).

Pour que les retombées positives des parcs et espaces verts se matérialisent, ces derniers doivent être visités et fréquentés. Les recherches ont démontré que la fréquentation des parcs est fortement associée à la qualité des parcs et à l'accessibilité des parcs (Giles-Corti et al., 2005; Knapp, Gustat, Darensbourg, Myers, & Johnson, 2019). La qualité des parcs inclut des caractéristiques telles que la présence d'aménagements bien entretenus (par exemple : des aires de jeux, des terrains de sport, des piscines, etc.), la possibilité d'effectuer une variété d'activités de loisir et de plein air et l'affue d'un environnement sécuritaire. L'association positive de la qualité des parcs et la fréquentation des parcs est démontrée pour les différents groupes d'âge (Kaczynski et al., 2014; Loukaitou-Sideris & Stieglitz, 2002). À cet effet, la qualité des parcs est typiquement quantifiée et mesurée, pour les différents groupes d'âge, dans une perspective d'aménagement de paysage tenant compte des aspects physiques du parc ainsi que les activités et les caractéristiques de ce dernier (Rigolon & Németh, 2018; Van Herzele & Wiedemann, 2003).

Quant à l'accessibilité, elle est définie par la facilité d'atteindre des destinations (El-Geneidy & Levinson, 2006). L'accessibilité aux parcs est fortement associée à une plus grande fréquentation des parcs et donc à de plus importantes retombées positives sur les individus (Macfarlane, Boyd, Taylor, & Watkins, 2020; Xie, An, Zheng, & Li, 2018). En conséquent, différentes normes ont été fixées par des autorités publiques: avoir accès aux parcs à moins de 15 minutes à pied (Barbosa et al., 2007), avoir accès aux parcs à moins de 30 minutes en transport en commun (Svanerud, 2017) ou l'accessibilité à un espace vert à moins de 300 mètres du domicile (Nature, 2005). L'accessibilité aux parcs est souvent mesurée sous l'angle de l'aménagement du territoire et le transport, en considérant la plus courte distance, ou le nombre de parcs accessibles pour une distance fixée (Comber, Brunsdon, & Green, 2008; C. Wang, Li, Wang, Yang, & Wang, 2021).

1.2 Problématique

Les avantages que les parcs et espaces verts présentent aux individus ont poussé les chercheurs dans le domaine du transport et de l'aménagement du territoire à modéliser l'accessibilité à ce type de destinations. En parallèle, les autorités publiques se sont intéressées à assurer l'accessibilité aux parcs et ont donc mis en place des normes et standards quant à l'accessibilité.

Cependant, une lacune dans ces travaux de recherche est identifiée concernant l'accessibilité. La majorité de ces études ainsi que les standards développés se basent sur des mesures simples d'accessibilité. Ces mesures reposent principalement sur l'accessibilité basé sur la localisation, la « *place-based accessibility* » telle que définie par Geurs and Van Wee (2004). L'accessibilité aux parcs est donc majoritairement représentée par la distance ou le temps de déplacement vers le parc le plus proche ou par le nombre de parcs accessibles à partir d'un point donné pour une distance limite fixée (Comber et al., 2008; Hass, 2009; Huang, 2021; Rojas, Páez, Barbosa, & Carrasco, 2016; C. Wang et al., 2021).

Toutefois, la fréquentation des parcs est fortement associée à la qualité des parcs et aux attributs de ces derniers (Knapp et al., 2019). Cependant, les attributs des parcs sont moins souvent considérés dans les mesures d'accessibilité. Certaines études ont considéré la surface des parcs accessibles à partir d'un point donné (Reyes, Páez, & Morency, 2014; Talen, 1997). Par des différentes méthodes de calculs, ces études somment la surface des parcs accessibles. D'autres études ont considéré, par exemple, les activités présentes dans les parcs, les aires de jeux pour enfants le plus souvent (Cheng, Caset, De Vos, Derudder, & Witlox, 2019; De Alvarenga, Apparicio, & Séguin, 2018; Talen, 1997). De plus, quelques études ont considéré différentes attributs des parcs dans les mesures d'accessibilité (Dony, Delmelle, & Delmelle, 2015; Xing, Liu, Wang, Wang, & Liu, 2020). Par exemple, Xing et al. (2020) mesure la qualité des parcs en considérant huit attributs liés à la nature (canopée, présence d'eau) et aux activités présentes (activités sportives, aires de jeux, etc.). Ensuite, la qualité de chaque parc est considérée individuellement en pondérant chacun par un coefficient pour capturer son attractivité. Si ces études contribuent à prendre en considération la qualité des parcs, il importe de mentionner que, de la perspective des individus, ce n'est pas nécessairement la qualité de chaque parc qui compte, mais de l'ensemble des parcs auxquels ils ont accès. Cependant, peu d'études ont regardé cet aspect dans la littérature.

Un autre aspect important dans la modélisation de l'accessibilité est l'aspect individuel. En effet, l'accessibilité varie d'une personne à une autre. Cette variation peut notamment être liée aux caractéristiques individuelles, préférences et perceptions ainsi que les contraintes et besoins différenciés des individus (Dixit & Sivakumar, 2020; D. Wang, Brown, Zhong, Liu, & Mateo-Babiano, 2015). L'aspect individuel est peu considéré dans les mesures d'accessibilité simples qui sont le plus souvent utilisées dans la modélisation de l'accessibilité aux parcs. Toutefois, de récentes études ont démontré que si les caractéristiques individuelles ou les perceptions ne sont pas considérées, les mesures d'accessibilité peuvent surestimer les niveaux d'accessibilité pour certains groupes et ainsi sous-estimer la variabilité et l'iniquité en matière d'accessibilité (Dixit & Sivakumar, 2020; J. Ryan & Pereira, 2021).

Récemment, des mesures d'accessibilité auto-déclarée aux parcs et espaces verts ont été développées (Pham, Labbé, Lachapelle, & Pelletier, 2019; D. Wang, Brown, Zhong, et al., 2015; Wendel, Zarger, & Mihelcic, 2012). Ces mesures prennent en considération l'aspect individuel de l'accessibilité et sont donc différentes des mesures d'accessibilité calculée. Elles représentent les perceptions et préférences des individus quant à leur accessibilité. L'accessibilité auto-déclarée par l'individu peut différer de l'accessibilité calculée en raison de l'omission ou de la simplification des composantes d'accessibilité lors de son calcul (Pot, Van Wee, & Tillema, 2021). Ainsi, la mesure de l'accessibilité ne reflétera l'accessibilité auto-déclarée par l'individu que si elle considère les perceptions, les capacités et les préférences de l'individu conjointement avec les composantes spatiales de l'accessibilité (Pot et al., 2021). Cependant, peu de comparaisons sont effectuées entre l'accessibilité auto-déclarée et l'accessibilité calculée pour les parcs et espaces verts. La comparaison entre les mesures s'avère néanmoins pertinente pour évaluer comment ces dernières se complètent et sont liées les unes aux autres.

En résumé, dans l'optique d'assurer une meilleure fréquentation des parcs et d'assurer une matérialisation des bénéfices liés à ces destinations, une meilleure compréhension et modélisation de l'accessibilité aux parcs est nécessaire. En effet, bien que les attributs et les composantes individuelles jouent un rôle important dans l'accessibilité aux parcs, ceux-ci sont peu considérés lors de la modélisation de l'accessibilité aux parcs et espace verts. La modélisation de l'accessibilité aux parcs est donc insuffisamment approfondie dans la littérature scientifique. Cette quête de compréhension constitue donc l'essence de ce mémoire.

1.3 Objectifs de la recherche

La présente recherche a pour objectif principal de modéliser l'accessibilité aux parcs et espaces verts en considérant d'une part, les attributs des destinations et d'autre part, les perceptions, préférences et besoins des individus. L'étude se base principalement sur les données ouvertes de la Ville de Montréal et des données recueillies par un sondage en ligne visant à explorer les perceptions des résidents de la ville de Montréal quant à leur accessibilité aux parcs.

Le projet se décline en trois objectifs spécifiques :

- Mesurer l'accessibilité calculée aux parcs et espaces verts de la ville de Montréal en considérant le nombre de parcs, la surface et les types d'activités présentes dans les parcs ;
- Développer une méthode qui considère les différents attributs et la qualité des parcs dans les mesures d'accessibilité ;
- Étudier l'association entre les différentes mesures d'accessibilité calculée et l'accessibilité auto-déclarée aux parcs et espaces verts.

Les résultats du projet permettront de mieux comprendre l'influence des attributs des destinations ainsi que des perceptions des individus sur l'accessibilité aux parcs. À la lumière de ceux-ci, cette étude permettra de repenser et d'améliorer les méthodes de modélisation de l'accessibilité aux parcs par les villes et les autorités publiques en proposant une compréhension plus complète de l'accessibilité. De plus, des améliorations concernant les mesures d'accessibilité calculée pourront être recommandées. Ces réflexions contribueront à bonifier les méthodes de planification afin d'assurer une meilleure accessibilité pour l'ensemble de la population et ainsi une meilleure qualité de vie des individus.

1.4 Plan du mémoire

Ce mémoire par article est divisé comme suit : le présent chapitre s'agit d'une introduction et contient une mise en contexte du sujet avec une présentation de la notion d'accessibilité en plus de présenter la problématique liée à la recherche, les objectifs fixés et la structure du mémoire.

Le deuxième chapitre présente un cadre conceptuel définissant et mettant en relation les concepts centraux du mémoire. Ce cadre conceptuel présente l'aspect multidimensionnel de l'accessibilité, spécifiquement aux parcs et espaces verts. Le cadre conceptuel se base sur une synthèse des revues de la littérature des articles présentés aux chapitres 5 et 6.

Le troisième chapitre résume la méthodologie générale développée pour atteindre les objectifs de recherche, notamment l'approche utilisée pour générer les différentes mesures d'accessibilité calculée et la conception de la mesure d'accessibilité auto-déclarée, ainsi que les sources de données utilisées pour ces mesures. Les méthodes d'analyse sont aussi présentées.

Ensuite, les trois chapitres suivants (4, 5 et 6) présentent trois articles permettant chacun de répondre à un des sous-objectifs de la recherche.

Le septième chapitre contient une discussion globale quant aux analyses et résultats obtenus dans les trois articles et donc une discussion sur l'importance des attributs des destinations et des perceptions dans le concept de l'accessibilité aux parcs.

Enfin, le huitième chapitre rappelle les grandes conclusions de l'étude et présente les limitations de la méthodologie utilisée. En s'appuyant sur le reste du mémoire, il propose des perspectives de recherche sur l'accessibilité aux parcs et espaces verts.

CHAPITRE 2 REVUE CRITIQUE DE LA LITTÉRATURE

Ce chapitre présente le cadre conceptuel du mémoire à partir des revues critiques de la littérature. Les articles du Chapitre 5 et 6 contiennent chacun une revue de la littérature. La revue de littérature du chapitre 5 est relative aux parcs et espaces verts et à leurs impacts positifs sur la qualité de vie des individus. Les concepts de qualité des parcs et d'accessibilité aux parcs sont également abordés dans cette revue. Une seconde revue de littérature est présentée dans le chapitre 6 et aborde le concept d'accessibilité et les différents types de mesure d'accessibilité. Précisément, cette revue permet de faire le point sur les mesures d'accessibilité calculée et auto-déclarée aux parcs développées auparavant en plus de la notion d'association entre ses deux types d'accessibilité. Puisque le but de ce chapitre n'est pas de répéter le contenu des revues, il présente tout d'abord une présentation de la notion de l'accessibilité et les différentes mesures développées. Ensuite, ce chapitre présente une synthèse et assure ainsi une compréhension du cadre conceptuel du mémoire. Ce chapitre est donc très bref et réfère les lecteurs aux sections 5.2 et 6.2, où ils peuvent consulter les revues de la littérature dans leur entièreté.

2.1 L'accessibilité

Dans le domaine du transport, l'accessibilité est définie comme le potentiel d'un individu à atteindre des opportunités spatialement dispersées (Preston & Rajé, 2007). Cette notion a été introduite par Hansen (1959) afin d'étudier l'interaction entre le système de transport et l'aménagement des territoires. Plus spécifiquement, Geurs and Van Wee (2004) ont identifié quatre composantes de l'accessibilité à partir d'une revue de littérature approfondie : la composante du transport, la composante de l'aménagement du territoire, la composante individuelle et la composante temporelle.

La composante du transport est liée aux caractéristiques des réseaux de transport, par exemple le temps de déplacement, les coûts de déplacement d'un point à un autre. La composante d'aménagement du territoire est basée sur la localisation et les caractéristiques des destinations ainsi qu'à la localisation des individus. Ces destinations sont nombreuses telles que les emplois, l'éducation, les services de santé et les commerces. Ensuite, la composante individuelle reflète les caractéristiques individuelles qui peuvent affecter les perceptions, les besoins ou la capacité de déplacement d'un individu. Enfin, la dernière composante est la composante temporelle, définie par la disponibilité des opportunités tout au long de la journée (exemple, les heures d'ouverture des commerces), les contraintes personnelles de l'individu, ainsi que l'horaire du transport en commun.

2.1.1 Mesures d'accessibilité

De multiples mesures d'accessibilité ont été développées dû aux grands nombres de facteurs qui affectent l'accessibilité (Geurs & Van Wee, 2004; Handy & Niemeier, 1997; Páez, Scott, & Morency, 2012).

Premièrement, les mesures d'accessibilité basées sur l'individu sont générées au niveau individuel et concernent le niveau d'accessibilité vécu par une personne spécifique (Geurs & Van Wee, 2004). Ces mesures intègrent la contrainte spatiale et temporelle de l'individu, en complément des caractéristiques liées au système de transport et d'aménagement du territoire en une seule mesure (H. J. Miller, 2005). Toutefois, ces mesures comportent des défis importants lors de l'opérationnalisation dû à leurs complexités.

Le deuxième type de mesures est basée sur l'utilité. Ces mesures capturent les avantages économiques apportés par le changement du système de transport et d'aménagement du territoire. Les mesures basées sur l'utilité peuvent être considérées comme analogue à l'analyse coûts-avantages traditionnelle (Van Wee, 2016).

Ensuite, les mesures basées sur la localisation indiquent la facilité d'accès aux destinations à partir d'un emplacement spécifique et tiennent compte de la répartition spatiale des opportunités (Geurs & Van Wee, 2004). Parmi ces mesures, deux mesures sont très communes dans la littérature : la mesure d'opportunité cumulative et la mesure gravitaire. La mesure d'opportunité cumulative est modélisée par une équation (Figure 2-1) qui compte toutes les opportunités qui peuvent être atteintes dans un seuil de coûts de déplacement, une distance ou un temps de déplacement. Une fonction de coût est alors associée à cette opportunité, cette fonction prenant soit une valeur de 1 si l'opportunité peut être atteinte à l'intérieur du seuil défini, ou bien de 0 si ce n'est pas le cas. Par exemple, le nombre d'épiceries qui se trouvent à moins de 30 minutes de temps de déplacement en transport en commun à partir d'un lieu précis est une mesure d'opportunité cumulative. La mesure gravitaire considère les opportunités en fonction d'une fonction de décroissance de la distance. Par conséquent, les opportunités situées plus loin reçoivent moins de poids que les opportunités plus proches.

$$A_i = \sum_{j=1}^{n} O_j f(C_{ij})$$

$$f(C_{ij}) = \begin{cases} 1 \text{ si } C_{ij} \leq t_{ij} \\ 0 \text{ si } C_{ij} > t_{ij} \end{cases}$$

Source: Bhat et al. (2000)

Figure 2-1 Équations du modèle d'opportunités cumulées

Enfin, les mesures basées sur l'infrastructure analysent le niveau de service des infrastructures de transport, telles que le niveau de congestion par exemple ou la vitesse moyenne de déplacement sur le réseau routier (Geurs & Van Wee, 2004). Ces types de mesures sont généralement spécifiques à un mode de transport.

2.2 Cadre conceptuel

Puisque l'accessibilité est un facteur multidimensionnel, il importe de bien comprendre la relation entre les différentes composantes considérées de l'accessibilité. Ces relations sont illustrées dans le cadre conceptuel de l'accessibilité présenté dans la Figure 2-2.

Comme mentionné ci-dessus, l'accessibilité est influencée par différentes composantes. La première composante repose sur le transport. En effet, l'accessibilité est fonction des modes de transport disponibles et utilisés, du coût de transport entre l'origine et la destination, comme la distance, le temps et le coût monétaire (Geurs & Van Wee, 2004), mais aussi des obstacles possibles lors des déplacements. La seconde composante repose sur l'aménagement du territoire. Ce critère se concentre non seulement sur le nombre et la distribution spatiale des activités et destinations (Geurs & Van Wee, 2004), mais sur les attributs des destinations ou autrement dit la qualité des destinations. Dans le cas des parcs, la qualité de ces derniers est cruciale pour les individus ainsi que sur leurs habitudes de fréquentation (Knapp et al., 2019). De plus, la notion de l'offre et de demande ou bien la compétition aux activités sont des points est à mentionner concernant l'aspect de l'aménagement du territoire : (Barboza, Carneiro, Falavigna, Luz, & Orrico, 2021). Les destinations sont typiquement caractérisées par une capacité physique et ainsi cette dernière limite l'offre et donc l'accessibilité lorsque la demande est supérieure à l'offre. Cette notion est particulièrement applicable pour les parcs et espaces verts (M. Guo, Liu, Tian, & Xu, 2020; Lee, Hong, & Planning, 2013). C'est le cas, par exemple, lorsqu'un terrain de sport dans un parc est accessible alors que plusieurs groupes de personnes veulent pratiquer ce genre d'activité en même temps. La troisième composante repose sur l'aspect temporel. L'accessibilité varie au cours de la journée temporellement dépendamment des types de destinations et du mode de transport, notamment l'horaire du transport en commun (Neutens, Schwanen, & Witlox, 2011). Les heures d'ouvertures des destinations peuvent influencer l'accessibilité. Dans le cas des parcs, l'aspect temporel a une moins grande influence, ceux-ci ayant typiquement des heures d'ouverture homogènes à travers un même territoire. Bien que pertinent, l'aspect temporel n'est pas abordé dans le cadre de ce mémoire. La quatrième composante est basée sur la composante individuelle de l'accessibilité. En effet, plusieurs aspects individuels peuvent influencer l'accessibilité. Les caractéristiques individuelles affectent largement l'accessibilité (Dixit & Sivakumar, 2020). Par exemple, les personnes âgées sont plus susceptibles d'avoir une accessibilité plus faible étant la diminution probable de leurs capacités physiques et de mobilité relativement aux jeunes. D'autres aspects peuvent influencer l'accessibilité comme les préférences et le processus d'auto-sélection (Bohte, Maat, & Van Wee, 2009). Par exemple, un individu ayant une forte relation avec la nature et les espaces verts est plus probable de choisir son lieu de domicile avec une accessibilité plus élevée aux parcs. Également, des caractéristiques liées à l'environnement bâti comme la sécurité ont été prouvées d'avoir affecté l'accessibilité (D. Wang, Brown, Zhong, et al., 2015).

Théoriquement, une mesure adéquate d’accessibilité prendra en considération les quatre composantes mentionnées ci-haut (Geurs & Van Wee, 2004). Toutefois, des enjeux d’opérationnalisation peuvent se produire. Ces enjeux peuvent être liés aux besoins de données qui ne sont pas toujours disponibles (Geurs & Van Wee, 2004; Handy & Niemeier, 1997). De même, la mesure d’accessibilité doit être facilement interprétable et communicable (Páez et al., 2012).

Ces enjeux peuvent influencer le niveau de désagrégation choisi pour les mesures d’accessibilité. En effet, le niveau de désagrégation est souvent lié à la disponibilité et à la qualité des données (Malekzadeh & Chung, 2020). Le niveau de désagrégation à son tour influence l’analyse de l’accessibilité. Spécifiquement, lorsque l'accessibilité calculée est agrégée spatialement, tous les individus d’une zone sont considérés comme ayant le même niveau d'accessibilité (Hanson & Schwab, 1987). Cette considération est loin de la réalité vu qu’en complément des composantes d’aménagement du territoire et de transport, la composante individuelle distingue les uns des autres par des perceptions et besoins différents qui peuvent faire varier l’accessibilité entre les individus (Geurs & Van Wee, 2004). Pot et al. (2021) ont suggéré que l'utilisation de mesures d'accessibilité qui incluent davantage de composantes à un niveau désagrégé peut réduire l'écart entre l'accessibilité calculée et l’accessibilité auto-déclarée par les individus.

Enfin, les individus sont intéressés par la disponibilité d’une variété d’opportunités et non uniquement par la présence d’une unique opportunité (Martens, 2016), ce qui est applicable aux parcs et espaces verts. Pour cette raison, la question « *qu’est ce qui est mesuré ?* » doit toujours être posée lors de la modélisation de l’accessibilité.

Ainsi, pour une meilleure modélisation de l’accessibilité aux parcs, plus cette série de composantes est prise en considération, mieux l’accessibilité est représentée. Ce chapitre a permis de présenter et de mettre en relation les notions centrales de ce mémoire, qui reposent sur la littérature existante liée à la modélisation de l’accessibilité aux parcs. Les revues spécifiques à chaque article sont présentes à la section 5.2 et 6.2 respectivement.

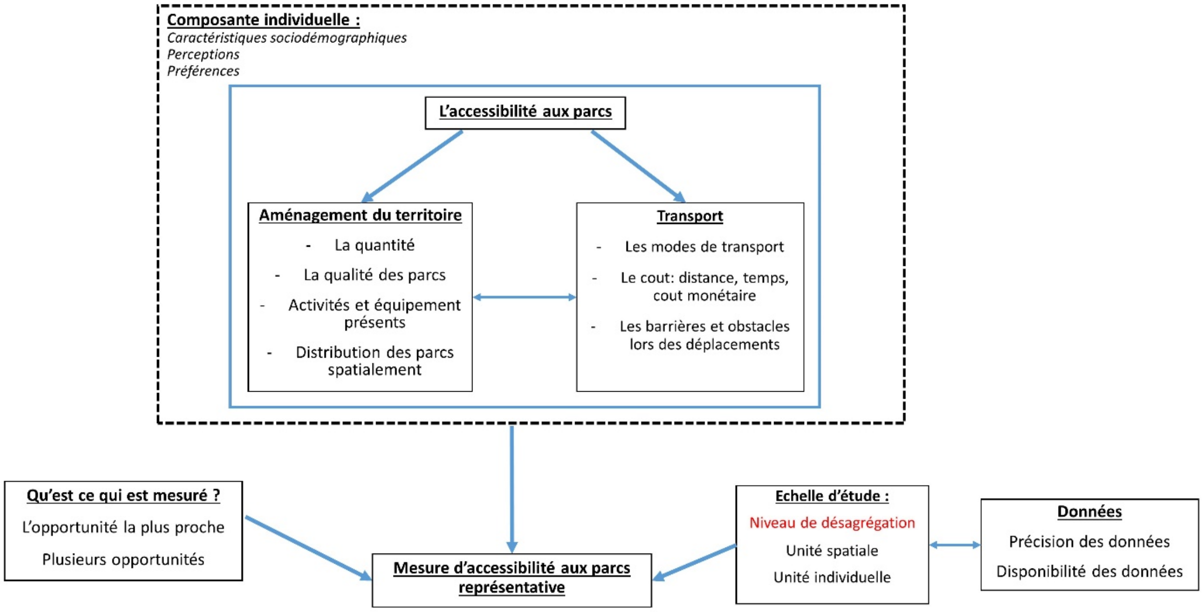

Figure 2-2 Schéma des relations entre les différentes composantes de l'accessibilité

CHAPITRE 3 DÉMARCHE DU TRAVAIL DE RECHERCHE

Cette section présente le processus méthodologique développé afin d'atteindre l'objectif principal de l'étude, qui est de modéliser l'accessibilité aux parcs et espaces verts en considérant d'une part, les attributs des destinations et d'autre part, les perceptions, préférences et besoins des individus. Cette démarche a été structurée de façon à répondre aux trois sous-objectifs définis dans l'introduction.

3.1 Méthodologie générale

La présente recherche s'arrime avec l'intérêt de la Ville de Montréal et de Jalon Montréal de générer et améliorer les mesures d'accessibilité aux différents types de destinations. Vu l'importance de la présence des parcs et espaces verts dans la vie urbaine et les défis méthodologiques liés aux indicateurs d'accessibilité aux parcs, une meilleure compréhension de l'accessibilité aux parcs s'est avérée nécessaire.

La recherche a débuté avec une revue de la littérature qui aborde les aspects importants qui caractérisent les parcs ainsi que la notion d'accessibilité aux parcs et les différentes mesures développées. À partir des constatations de cette revue, l'amélioration de la modélisation de l'accessibilité aux parcs a été identifiée comme avenue de recherche pertinente afin de combler les lacunes dans la littérature. En effet, les recherches existantes s'appuient majoritairement sur des mesures d'accessibilité calculée relativement simples considérées comme des indicateurs objectifs qui ne se concentrent que sur l'interaction entre l'aménagement du territoire et le transport négligeant ainsi la composante individuelle de l'accessibilité. De plus, la considération détaillée des différents attributs des parcs, notamment dans un contexte d'accessibilité à plusieurs parcs, a fait l'objet de peu d'attention. C'est de même pour les caractéristiques individuelles et les perceptions des individus. Pour répondre à ces lacunes, ce mémoire vise à intégrer les perceptions et les attributs des destinations dans la modélisation de l'accessibilité.

À la suite de la revue de la littérature, les objectifs et la méthodologie de la recherche ont été définis. La Figure 3-1 schématise la démarche générale ayant guidé la recherche. Elle rappelle les trois objectifs spécifiques précisés dans l'introduction et présente les principales sources de données et étapes méthodologiques du projet.

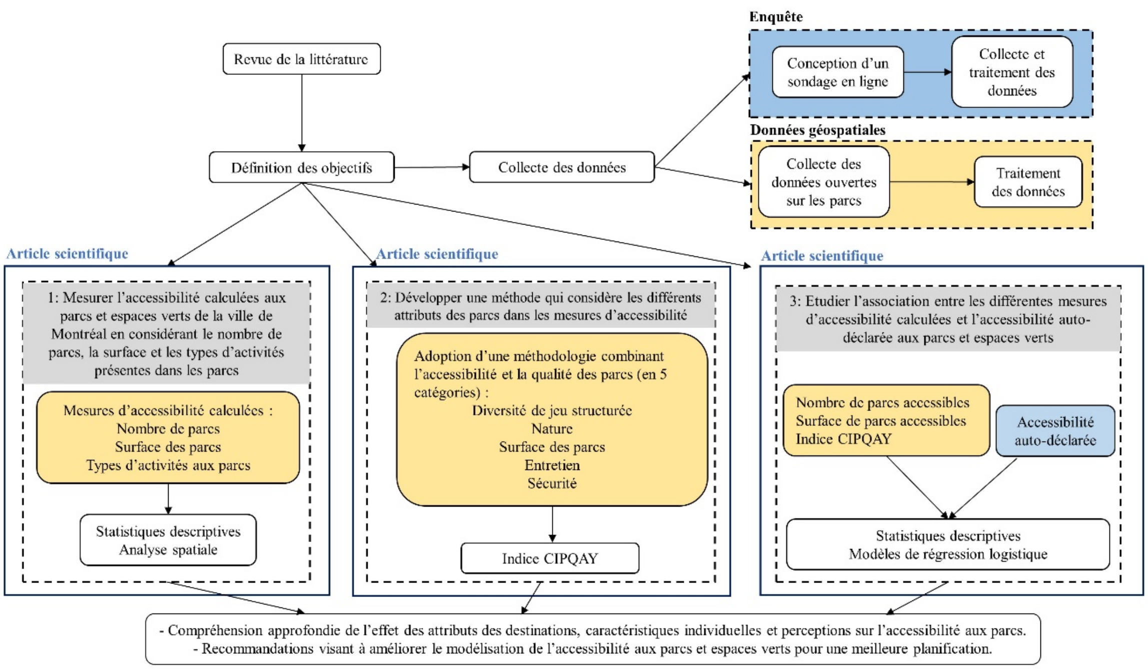

Figure 3-1 Méthodologie générale du travail de recherche

Pour répondre aux trois objectifs (voir Figure 3-1), il fallait rassembler des données géospatiales sur les parcs et espaces verts de la ville de Montréal, leurs localisations et caractéristiques, ainsi que sur les perceptions, les préoccupations et les préférences des résidents de la ville de Montréal au sujet de leur accessibilité aux parcs. Les données liées aux parcs et espaces verts de Montréal étaient disponibles sous forme de données ouvertes sur le portail de la ville de Montréal. Toutefois, aucune donnée concernant les perceptions n'était disponible pour la ville de Montréal. Il a donc été décidé de mener une enquête auprès des Montréalais par l'entremise d'un sondage en ligne. Le questionnaire de l'enquête a été conçu sur la base de la revue de la littérature et du contexte montréalais, avant d'être diffusé au sein de la population. Il a été partagé avec le Service des grands parcs, du Mont-Royal et des sports de la Ville de Montréal pour rétroaction. Les données utilisées, le processus de collecte ainsi que le traitement des données sont détaillés dans chacun des articles (chapitres 4, 5 et 6).

À partir des données préparées, le **premier objectif** du mémoire consiste à mesurer l'accessibilité aux parcs en considérant le nombre de parcs, la surface et les types d'activités présentes aux parcs. L'étude est faite dans le contexte de la ville de Montréal en utilisant des données ouvertes. La méthode de calcul adoptée pour l'accessibilité calculée repose sur les mesures d'opportunité cumulative et a été conçue spécifiquement pour les parcs et espaces verts. Les résultats du nombre de parcs, la surface, et le nombre d'activités par type à partir des lots résidentiels de la ville de Montréal accessible à la marche ont été présentés spatialement à des fins de comparaison. Toutes ces informations ont été présentés sous la forme d'un court article scientifique publié en octobre 2021 dans la revue *Transport Findings* et intitulé « *Walking Accessibility to Parks : Considering Number of Parks, Surface Area and Type of Activities* », et présenté au Chapitre 4 de ce mémoire.

Le **deuxième objectif** de la recherche est abordé en développant une mesure qui prend en considération conjointement la qualité et l'accessibilité des parcs. Dans cet objectif, la mesure de la qualité des parcs accessibles est inspirée d'une étude antérieure qui génère un indice visant à mesurer la qualité d'un parc à partir de données ouvertes. La qualité d'un parc est fonction de divers attributs caractérisant ce dernier. Le principal défi de cet objectif était d'adapter l'indice déjà développé pour qu'il s'applique à un groupe de parcs, et non pas à chaque parc de façon indépendante. Il a aussi fallu adapter la méthodologie en fonction du contexte et des données disponibles. Le nouvel indice, qui représente une mesure d'accessibilité calculée considérant les attributs des parcs, est ensuite généré et testé pour la ville de Montréal. La méthodologie et les résultats qui découlent de cet objectif ont été présentés sous la forme d'un article scientifique présenté au Chapitre 5 et soumis en juin 2022 à la revue *Landscape and urban planning* et intitulé « *How Good is Your Basket of Parks ? A Combined Index of Park Quality and Accessibility for Youth*». Des informations complémentaires à ce chapitre sont présentées dans l'Annexe A de ce mémoire.

Enfin, le **troisième objectif** de la recherche repose sur l'étude de l'association entre les différentes mesures d'accessibilité calculée et l'accessibilité auto-déclarée aux parcs. Il importe de spécifier ici que l'association a été évaluée pour trois mesures d'accessibilité calculée différentes. Les mesures sont le nombre de parcs accessibles et la surface des parcs accessibles, développées au Chapitre 4 ainsi que l'indice d'accessibilité considérant les attributs des parcs développés au Chapitre 5. L'accessibilité auto-déclarée a été calculée à partir des données recueillies par le biais du sondage en ligne. Trois modèles de régression logistique ordonnée ont été utilisés pour explorer la relation entre les trois mesures d'accessibilité calculée et l'accessibilité auto-déclarée. Une analyse d'inadéquation entre les deux types de mesures a aussi été réalisée. Les résultats obtenus pour cet objectif ont été présentés également sous la forme d'un article scientifique. L'article intitulé «*Measuring Accessibility to Parks : Analyzing the Relationship Between Self-Reported and Calculated Measures*» a été soumis au Congrès international du *Transportation Research Board 2023* et est présenté au Chapitre 6 de ce mémoire. Des informations complémentaires à ce chapitre sont présentées dans l'Annexe B de ce mémoire.

L'atteinte de ces trois objectifs permet de développer une compréhension approfondie de l'influence des attributs des destinations et des perceptions des individus sur les mesures d'accessibilité calculée et auto-déclarée. En plus de répondre aux lacunes de la littérature, le projet permet de répondre aux besoins de planification des villes en matière d'espaces verts. Effectivement, en analysant les résultats des différentes méthodologies mises en place pour mesurer l'accessibilité aux parcs, le projet permet d'identifier les améliorations les plus pertinentes et les mieux adaptées aux mesures d'accessibilité aux parcs pour les études futures ainsi que pour les autorités publiques.

CHAPITRE 4 ARTICLE 1: WALKING ACCESSIBILITY TO PARKS: CONSIDERING NUMBER OF PARKS, SURFACE AREA AND TYPE OF ACTIVITIES

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Abstract

Parks and green spaces are desirable destinations for a variety of reasons including exercising, playing, relaxing, and socializing. In this paper, we demonstrate that simultaneously considering number of parks, surface area and type of activity provides an improved understanding of walking accessibility to parks in urban areas. Using open datasets and a configurable tool, we find that in Montreal, 95% of the population have access to three or more parks, 83% can access three or more playgrounds, and 10% can access three or more open air activities within a 1 km walk. The accessible surface area varies considerably across the region. The tool reveals distinct patterns that better reflect the diversity of needs and uncovering specific inequalities, and can therefore contribute to improved decision-making.

4.1 Questions

Parks play a significant role as free recreational spaces in urban areas (Tempesta, 2015). Knowing that proximity to parks is associated with increased use and physical activity (Hartig, Mitchell, De Vries, & Frumkin, 2014), several efforts have been put on developing measures of accessibility to parks, with a focus on distances to the nearest park or on the number of parks accessible within a specific threshold. Yet, individuals visit parks for a variety of reasons (Sundevall & Jansson, 2020) and this can influence the need for different equipment and/or more or less space. Understanding accessibility to parks in a disaggregated manner is thus essential.

Our research seeks to answer the following question: "How does accessibility to parks vary spatially across the City of Montreal considering the number of parks, surface area and type of potential activities?" This research stems from the hypothesis that the accessibility outcomes will differ depending on the chosen variable (and activity type), which each reflect distinct needs and opportunities. A greater number of accessible parks may increase the likelihood of an appropriate park existing for the individual, while a greater surface area may be associated with a greater supply of green areas, perhaps better facilitating certain games and sports, relaxing, or socializing. The type of activities directly reflects the availability of specific opportunities.

4.2 Methods

This study was conducted using land use and transport data available on the open data portal of the City of Montreal (Ville de Montreal, 2021). First, three land use datasets were used: (i) residential lots, (ii) parks and green spaces (hereafter simply referred to as parks), and (iii) outdoor recreational, cultural and sport amenities. Numerous green spaces were removed from the parks dataset as they are not freely accessible (e.g., golf, private, institutional), for a total of 1,475 remaining parks. Activities located inside the remaining parks, obtained from the third dataset, are classified into five different categories by the City: sports, recreational (e.g., chess, climbing wall), open air (e.g., trail, wooded area), leisure (e.g., sliding area, ping pong table), and playgrounds, for a total of 3,078 activities. Second, a pedestrian network was generated from the public road dataset to only include pedestrian links, streets with sidewalks and residential streets without sidewalks. Finally, population data within the dissemination areas were retrieved from the 2016 census data (Statistics Canada, 2016). The 1,704,689 residents of Montreal are thus counted in the 2,805 dissemination areas (DA).

Cumulative-opportunity accessibility measures were generated using a configurable tool currently under development (using the ArcGIS software). This tool first distributes the population from each DA inside the residential lots according to the surface area they occupy. It then determines the parks and activities that can be reached from each residential lot within a 1,000 m pedestrian network distance (roughly equivalent to a 15-minute walk), which represents the average distance walked by Montrealers for all trip purposes (Lachapelle, Boisjoly, & Vermesch, 2020). The tool is transferable to other contexts based on data availability, knowing that the user specified inputs are the following: population data within residential zones, origin and destination points, road network, and distance threshold.

In this study, service areas were generated based on the pedestrian network for each park and activity. Since parks are represented by polygons, the service area of a single park comprises all service areas calculated from each access point along the perimeter (following Apparicio, Cloutier, Séguin, and Ades (2010)'s approach). For the activities, represented by points, access is considered by assigning the point to the closest street (representing an access point).

Finally, the tool intersects the service areas with the centroids of the residential lots to identify all parks and activities that are within the 1,000 m threshold of each residential lot. From this output, the number of parks and activities accessible from each residential lot are counted, and the accessible surface area corresponds to the sum of the surface of the parks that are accessible.

4.3 Findings

Figure 4-1 presents the number of parks accessible (as commonly measured in research and practice) from each residential lot in Montreal. Accessibility is quite uniform across the City, and approximately 95% of the population of Montreal can reach three or more parks within 1,000 m of walking (Table 4-1).

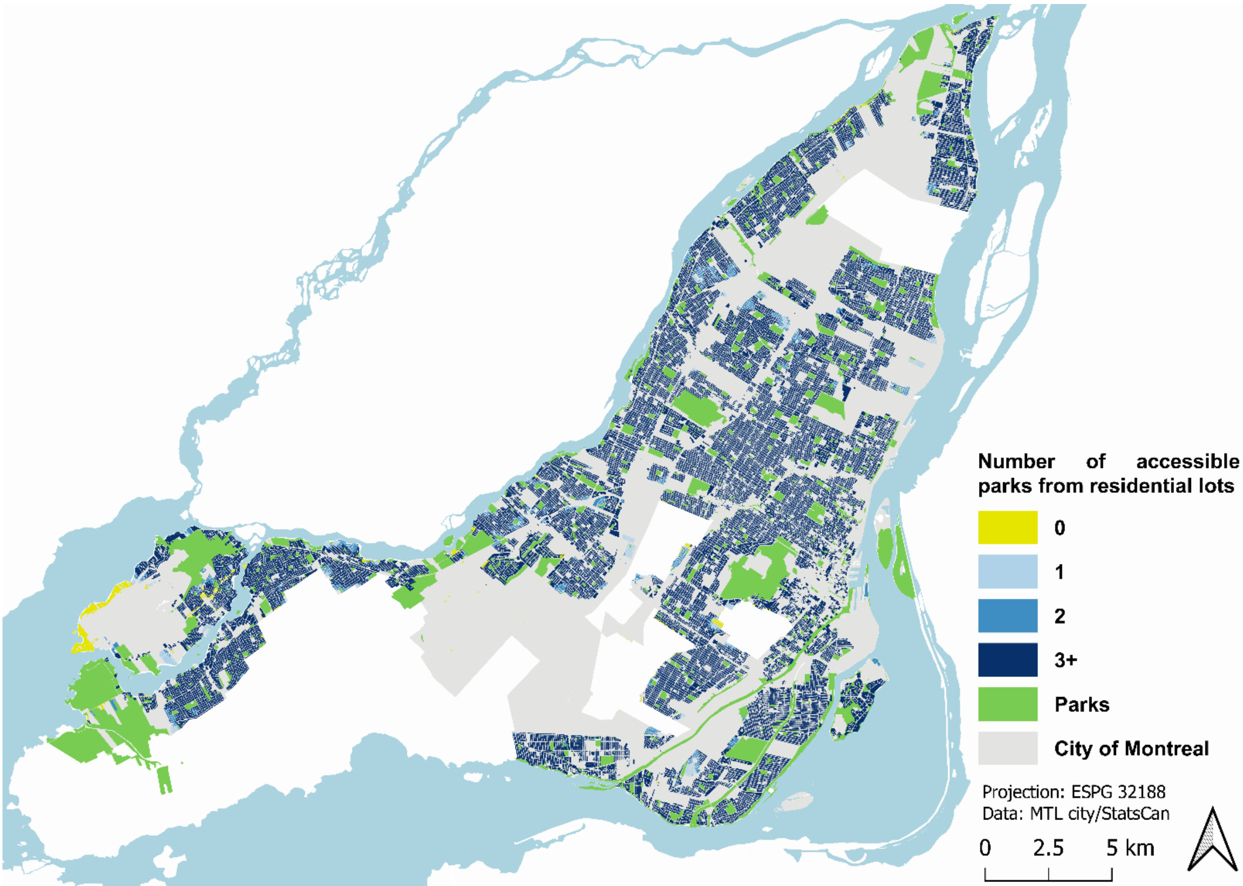

Figure 4-1 Number of accessible parks from residential lots in Montreal

Table 4-1 Distribution of the population based on the number of parks accessible

	Population with access to 0 or more opportunities	**Population with access to 1 or more opportunities**	**Population with access to 2 or more opportunities**	**Population with access to 3 or more opportunities**
Parks	100%	99.6%	98.4%	95.0%

Figure 4-2 illustrates the total surface area (km^2) that is accessible from each residential lot, while Table 4-2 distributes the population according to the total surface area of accessible green spaces. An equivalent area has been assigned to each surface area for ease of interpretation. This accessibility indicator shows that even if 95% of the population has access to three or more parks, access with respect to surface area varies considerably. Most of the population has access to at least the equivalent area of one urban park (76%), whereas only 18.4 and 12.8% of the population have access to at least more than 0.5 km^2 and 1 km^2 respectively. This latter is highly concentrated around the few largest parks of the city. This spatial pattern (Figure 4-2) highlights spatial inequalities that are not captured by the number of accessible parks.

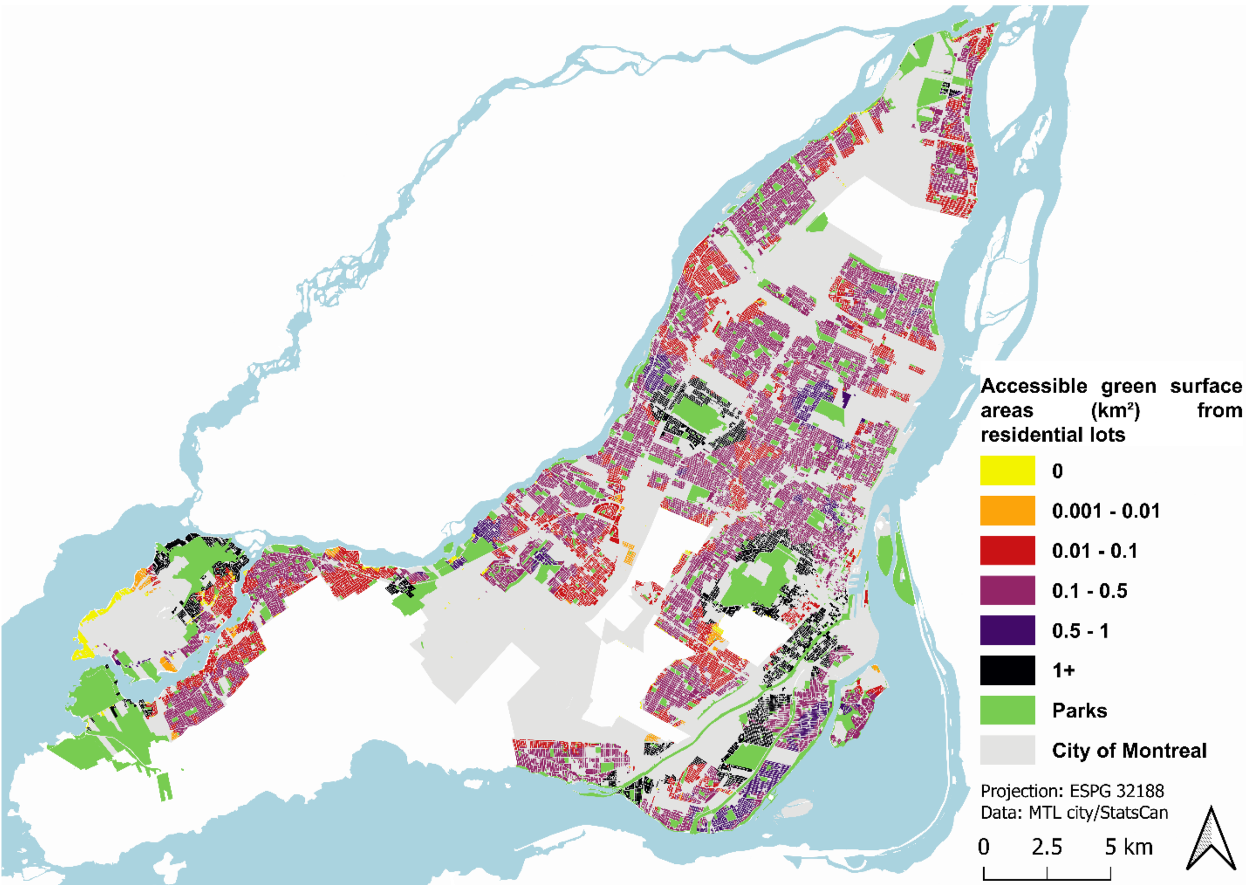

Figure 4-2 Accessible green surface areas (km^2) from residential lots in Montreal

Table 4-2 Distribution of the population based on the surface areas accessible

Surface area (km^2)	Equivalent surface area	Population with access to at least the equivalent surface area
0	-	100%
0.001+	Football or Swimming pool	99.6%
0.01+	Neighborhood Park	98.6%
0.1+	Urban Park	76%
0.5+	Hyde Park, London	18.4%
1+	Central Park, New York	12.8%

Table 4-3 presents the number of activities (located within parks) accessible from residential lots, by type of activity. Most of the population (82.9%) has access to three or more playgrounds and three or more recreational activities. Conversely, only 10% of the population has access to three or more open air activities, and nearly half of the population has no access to open air activities.

To illustrate these discrepancies, Figure 4-3 compares accessibility to playgrounds with accessibility to open air activities. Stark contrasts are visible. On the one hand, accessibility to playgrounds, which mainly caters to children, is consistently high across the City of Montreal, except for specific areas that would require attention. It should be noted that providing children with walking accessibility to key destinations such as playgrounds is especially relevant, as they do not typically have the same levels of mobility as adults do with restrictions placed on their travel spheres (Waygood, Friman, Olsson, & Taniguchi, 2017). On the other hand, access to open air activities varies significantly, with large areas without access to open air activities being scattered across the territory.

Table 4-3 Distribution of the population based on the number of activities accessible by type

Type of activity	Population with access to 0 activity	Population with access to 1 activity	Population with access to 2 activities	Population with access to 3+ activities
Playgrounds	2.6%	2.5%	12.1%	82.9%
Open Air	46.2%	27.6%	15.7%	10.4%
Sports	15.4%	16.8%	15.2%	52.6%
Recreational	9.5%	6.3%	7.4%	76.9%
Leisure	16.1%	15.9%	16.9%	51.0%

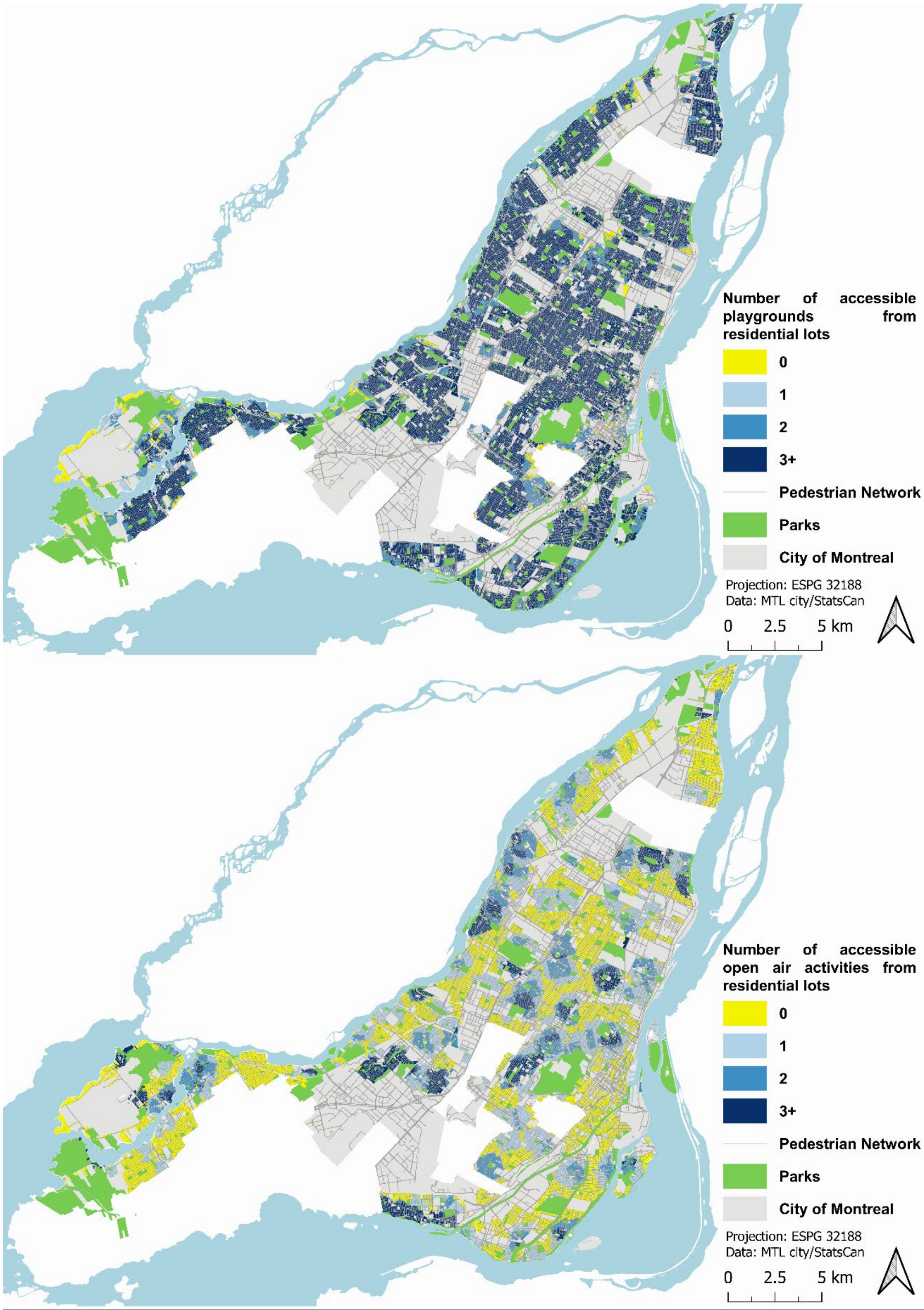

Figure 4-3 Number of accessible playgrounds vs. number of accessible open air activities from residential lots in Montreal

The results show clearly distinct patterns with respect to number and type of activities, surface area and number of parks. The development of a tool that simultaneously computes these distinct indicators with the same data allows for a more nuanced understanding of accessibility to parks and green spaces in a region. While this study focuses on Montreal, the approach is transferable to other contexts and can be used to assess how different measures relate to parks' use and to improve decision-making.

4.4 Acknowledgments

The authors would like to acknowledge Jalon Montreal for collaborating in the development of the configurable accessibility tool based on open datasets in the City of Montreal.

CHAPITRE 5 ARTICLE 2: HOW GOOD IS YOUR BASKET OF PARKS? A COMBINED INDEX OF PARK QUALITY AND ACCESSIBILITY FOR YOUTH

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Abstract

Parks and green spaces are essential components of urban areas as they provide ecological, economic, health and social functions. Their positive outcomes are closely linked with both the quality of the parks as well as their accessibility, especially via walking and cycling. This is especially relevant for youth who largely depend on active modes for independent travel. To date, most studies have focused on a single component (quality or accessibility). To our knowledge, no study has measured the quality of a group of parks. This study, therefore, proposes a methodology to generate an index that combines accessibility and quality of parks: the Combined Index of Parks Quality and Accessibility for Youth (CIPQAY). The index is designed by combining a recently developed replicable index of quality, the "QUality Index of Parks for Youth" (QUINPY) with cumulative-opportunity accessibility measures, and is then applied to the city of Montreal. To do so, the QUINPY variables and scores are adapted to reflect the combined quality of surrounding parks. Using open data, the CIPQAY is then operationalized based on the study context and data availability. The final index for Montreal contains 17 variables for a total (maximum) score of 30. The CIPQAY index is computed for each of the 374,599 residential lots in Montreal. The spatial representation of the index allows identifying areas that should be prioritized for interventions. This research provides researchers, planners and decision-makers with a systematic methodology, transferable to other contexts, to specifically measure the quality of parks accessible to individuals.

Keywords: parks, spatial analysis, active transportation, youth, accessibility indicators, transport and land use

5.1 Introduction

With an increasing proportion of the population living in urbanized areas (Nabielek, Hamers, & Evers, 2016), parks and green spaces are of a strategic importance for the quality of life of individuals (Chiesura, 2004). The presence of parks in a neighborhood is associated with social (Seaman et al., 2010), health (Cohen et al., 2007; Lachowycz & Jones, 2011), economic (Nicholls, 2004) and environmental (Feyisa et al., 2014) benefits. Youth's (2-18 years old) well-being is greatly enhanced when they spend time in parks, especially when it comes to their physical and mental health (Chawla, 2015; Maas et al., 2009). The positive outcomes are closely linked with the quality of the parks, which includes features such as the presence of well-maintained amenities (e.g., playgrounds, pools, sports fields), the possibility to conduct a variety of leisure and outdoor activities and the provision of a safe environment. In addition to the quality of parks, their accessibility, especially via walking and cycling, contributes to a greater use of these public spaces (Giles-Corti et al., 2005), and in turn, to greater associated outcomes (Macfarlane et al., 2020; Xie et al., 2018). Access by active modes is used as such modes are available at all times to all ages, which is not the case for private motor vehicles.

To support planning and decision-making, several studies have developed methodologies to measure park quality and accessibility. To date, most of these studies have focused on a single component, either park quality (Byrne, Wolch, Swift, & Ryne, 2005; Cavnar et al., 2004; Rigolon & Németh, 2018) or park accessibility (Fan, Xu, Yue, & Chen, 2017; S. Guo et al., 2019; Reyes et al., 2014). Park quality indices are typically developed from a landscape planning perspective, whereas measures of accessibility to parks relate more closely to land use and transport planning. Yet, from the individuals' perspective, it is likely the quality of the combined park spaces and amenities that are accessible to them that influences their interest and ability to conduct activities in parks. In other words, what matters to individuals is the set of amenities and activities that are accessible to them, regardless of whether they are in the same park.

This study proposes a methodology to generate an index that combines accessibility with the quality of (accessible) parks, with a focus on youth (in this study referring to children and teenagers between two and 18 years old). More specifically, the proposed methodology merges cumulative-opportunity accessibility measures with a recently developed quality of park index for youth (QUINPY) (Rigolon & Németh, 2018) into a single index: the Combined Index of Parks Quality and Accessibility for Youth (CIPQAY). In doing so, the study integrates this established measure on the quality and features of parks with a well-known and commonly used accessibility indicator, and allows for the consideration of all parks accessible from a location when measuring the quality of parks. The study is applied to the city of Montreal, which displays important discrepancies in spatial accessibility to parks and activities (El-Murr, Robillard, Waygood, & Boisjoly, 2021; Reyes et al., 2014). First, the QUINPY variables and scores are adapted to reflect the combined quality of surrounding parks. Second, the newly developed CIPQAY variables and scores are operationalized based on the study context and data availability. Using open data, the CIPQAY index is then generated for each residential lot, thereby demonstrating the applicability of the methodology. The designed output is a unique score for each origin (residential lot) that represents the quality of the parks individuals have access to. This research provides researchers, planners and decision-makers with a systematic methodology to specifically measure the quality of park spaces and amenities accessible to individuals. While the methodology is applied to the city of Montreal, the approach is transferable to other contexts, all depending on data availability regarding park characteristics and transport networks.

5.2 Literature review

5.2.1 Quantifying park quality

Researchers have demonstrated a positive and significant association between park quality and park use among adults (Kaczynski et al., 2014; Knapp et al., 2019; Leslie, Cerin, & Kremer, 2010) and youth (Loukaitou-Sideris & Stieglitz, 2002; McCormack, Rock, Toohey, & Hignell, 2010). More specifically, the positive relationships to physical activity (Roemmich et al., 2006; Tucker et al., 2009) and lower obesity rates (Cohen et al., 2014; Hughey et al., 2017) for youth have been demonstrated.

Measures of a park's quality and attractiveness are based on a series of features considering the park's physical composition and condition, and the features available (Rigolon & Németh, 2018; Van Herzele & Wiedemann, 2003). These features are generally classified into park infrastructure, amenities, safety, aesthetic, nature and landscape (Ahn, Kim, Lucio, Corley, & Bentley, 2020). Bird, Datta, Van Hulst, Kestens, and Barnett (2015) used children-specific activities, environmental quality, and service components. Building on these attributes, researchers have developed quantitative approaches to measure park quality to inform decision-making. Quantitative indicators, which are often context-dependent, have been developed in different urban regions around the world. These indicators are mainly designed for on-site observations of parks, where field raters assign quality scores based on a series of park features (Bird et al., 2015; Gidlow, Ellis, & Bostock, 2012; Kaczynski, Stanis, & Besenyi, 2012). Other methods have also been put forward: remote sensing including satellite, aerial imagery (Edwards et al., 2013) and geospatial open data (Rigolon & Németh, 2018).

Noteworthy to the present study is that the indicators found in the literature are designed to quantify the quality of a single park. An individual will likely have access to multiple parks. Those parks may have different characteristics such as a sports field in one, and a community garden in another. A measure of just one park would not give an accurate measure of the joint quality of all parks accessible to the individual. To the authors' knowledge, no quality index has been set up for a group of parks (e.g., parks in a neighborhood, parks accessible from individuals' place of residence).

5.2.2 Measuring accessibility to parks

The notion of accessibility is used in a wide range of research and planning applications, including the field of land use and transport (Hansen, 1959). Scholars generally measure access to a specific type of service considering accessibility, broadly defined as the ease of reaching destinations (El-Geneidy & Levinson, 2006). Accessibility studies are often based on counting the number of opportunities that can be reached from an origin point within a specified threshold (time or distance) and using a specific mode. This measure is known as the cumulative-opportunity accessibility and is by far the most widely used metric for accessibility (Boisjoly & El-Geneidy, 2017).

Accessibility to parks specifically was measured previously in several case studies using a wide range of accessibility measures with differences in operational methods (Apparicio et al., 2010; Comber et al., 2008; Reyes et al., 2014). For example, Reyes et al. (2014) measured children's walking accessibility to parks in Montreal considering the accessible surface area. This study is based on a cumulative-opportunity measure that sums rasterized park areas. Whereas Comber et al. (2008) measured greenspace access by counting the number of accessible parks in a city. Regardless of their type and method, accessibility measures are typically based on either the number or surface area of parks, thereby neglecting the quality/amenity aspects.

A few studies have considered parks amenities directly, mainly playgrounds (De Alvarenga et al., 2018). De Alvarenga et al. (2018) measured accessibility to playgrounds within parks using proximity (closest playground) and availability (supply and demand) from an equity perspective. Other studies have accounted for multiple types of amenities. Dony et al. (2015) considered nine amenities representing park quality (e.g., playgrounds, picnic areas), while Xing et al. (2020) considered eight youth preferences for park quality (e.g., number of playgrounds, tree coverage). These studies incorporate park features, measured for each park separately, in a floating catchment area accessibility method in order to consider park attraction as a weighting term for the supply side (coefficient).

Interestingly, a recent study integrated park quality in the generation of an accessibility measure. Zhang, Cheng, and Zhao (2021) measured accessibility to peri-urban parks by combining a quality index of peri-urban parks, park size, and travel time to parks. The researchers first designed a peri-urban park quality index (PPQI) based on 23 variables. Second, PPQI was calculated for each peri-urban park of the case study. Finally, the PPQI scores were used to weight the parks in the calculation of the accessibility measures, in this case based on the improved two-step floating catchment area (H-2SFCA). The comprehensive supply coefficient, park size, was therefore weighted based on the PPQI scores. While this approach does consider park quality, the quality index is first generated for each single park and then incorporated into the accessibility calculations.

To the authors' knowledge, no study has jointly measured the quality of a group of parks. Yet, to better reflect the level of accessibility to park spaces and amenities that is provided to individuals, it is essential to jointly consider all amenities and spaces together when developing the quality index. This study directly addresses this research gap and contributes to integrate park quality in the measurement of accessibility. In doing so, it brings together the literature on park quality and accessibility. The study also contributes to testing and demonstrating the transferability of the QUINPY features.

5.3 Case study area

The study area (Figure 5-1) represents the city of Montreal, divided into four regions: Downtown, Center, East and West. The Center consists mainly of central neighborhoods with a relatively high density and mixed use, while the East and West regions comprise mainly medium- and low-density neighborhoods. A diversity of park types exists in Montreal: 19 "Nature-parks" (*Parc-natures*), equivalent to metropolitan parks and managed by the City of Montreal, and more than 1175 urban and neighborhood parks managed by the 19 boroughs of the City. Urban parks and green spaces vary spatially by type and size across the territory of the city (Figure 5-1). Noteworthy, a total of 3078 activities, considered as a major reason for individuals to visit green spaces and parks (Chen & Jim, 2008), are distributed across 1075 parks located in the city and are divided by the City into five different types: playgrounds, leisure, recreational, sports and open-air activities. As well, active transport infrastructure, from simple sidewalks to exclusive pedestrian streets, are present in almost all the neighborhoods.

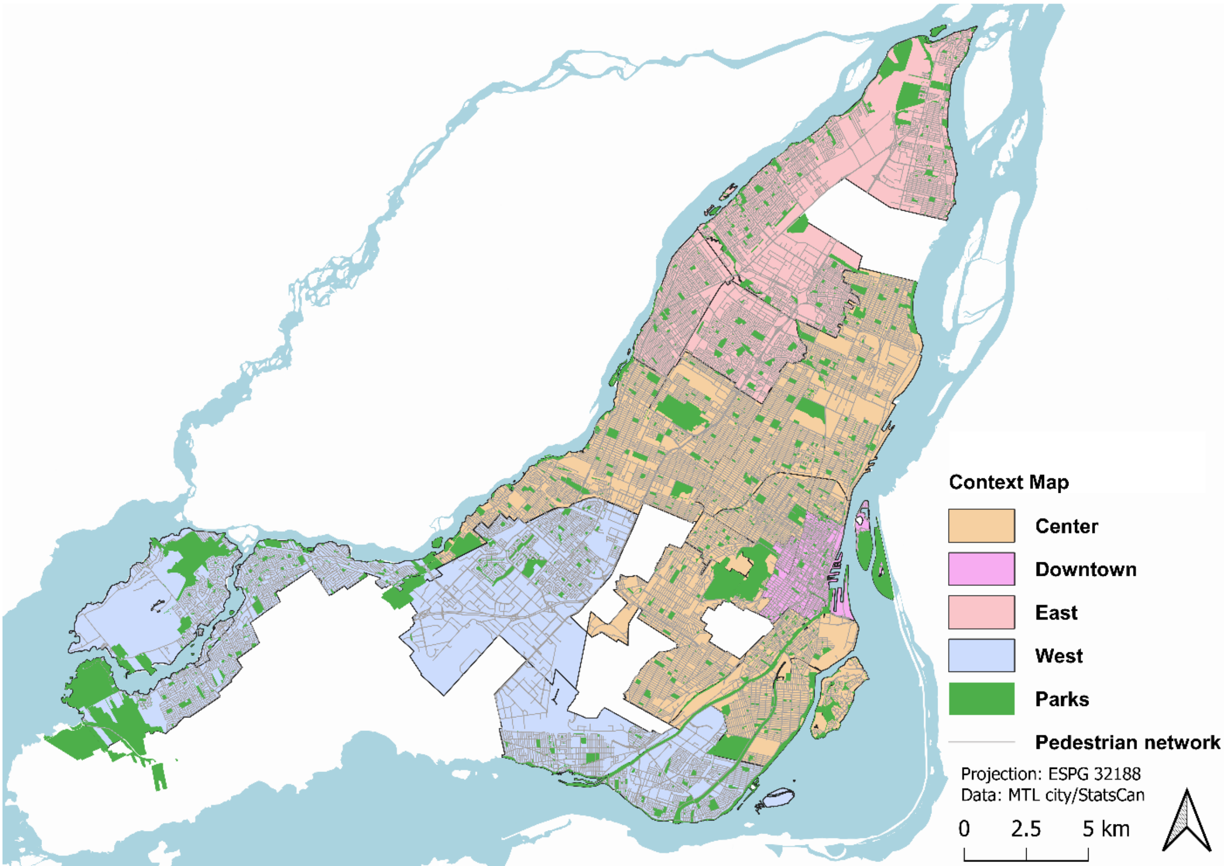

Figure 5-1 Context map of the city of Montreal including parks and the pedestrian network

5.4 Data and Methods

Accessibility can be measured in different ways and from different perspectives: infrastructure-based, location-based, person-based and utility-based (Geurs & Van Wee, 2004). In this study, we adopt a land use and transport perspective and focus on location-based accessibility, which provides an indication of the level of accessibility at a specific location. These measures are well suited to provide a spatial diagnosis of accessibility and can in turn be combined with socio-demographic characteristics to include individual and equity components (G. Boisjoly & A. El-Geneidy, 2017).

This study builds on the commonly used cumulative-opportunity accessibility measures. These measures have been proven to be highly correlated with a "more complex" and theoretically-sound measure, the gravity-based measure (Boisjoly & El-Geneidy, 2016). Given the complexity already associated with the scaling-up of the QUINPY index (as will be discussed in the next sections) and the number of variables included in our measure, we opted for the cumulative-opportunity approach. This measure avoids unreadability of the results and ensures an adequate ease of interpretation and communication of the accessibility measures incorporated in the designed quality index discussed in the next sections.

The remainder of this section first briefly describes the QUINPY index and then presents how it is adapted to reflect the quality of parks within the surrounding area and thereby develop our combined index of parks quality and accessibility for youth (CIPQAY). It then goes on to present the data sources and preparation required to generate the index for Montreal. Finally, we conclude with the specific methods used to generate the CIPQAY index.

5.4.1 QUINPY Index

The QUINPY (QUality INdex of Parks for Youth) (Rigolon & Németh, 2018) was selected as a starting point for this study. It is an assessment tool for the quality of parks for youth developed in 2018 in the United States. QUINPY measures the quality of a single park based on geospatial open data that can be analyzed using a geographic information system (GIS) software. In detail, the QUINPY includes 18 variables that are distributed into five weighted categories: structured play diversity, nature, park size, maintenance and safety[1]. For each variable, scores (mainly between 0 and 3) are assigned.

As an example, Table 5-1 presents a few variables that are included in the QUINPY index, together with their scoring approach (more details regarding the QUINPY index can be found in Rigolon and Németh (2018). In the case of QUINPY, each variable is evaluated by a score that is either binary (0 or 1) or numerical (typically ranging from 0 to 2 or 0 to 3). The score value

[1] Le poids de chaque catégorie est fixé par les auteurs par le biais d'une méthode qui consiste à calculer la proportion des articles d'une revue de la littérature préparée qui mentionnent l'effet positif de la catégorie sur la fréquentation des parcs par les jeunes.

attributed for each variable relies on numerous scoring approaches. The authors relied on the following approaches: *count* approach (function of the number of a specific feature in the park with a superior threshold: 0-1-2+), *binary* approach (a feature is not present (0), a feature is present (1)), a *combined binary* approach based on the presence or not of different categories of amenities (number of the categories present in the parks in one variable: 0, 1 category of the variable, 2 categories of the variable) and a *rank* approach. For the ranking approach, the score is relative to the region results. For example, for numerical variables, the ranks are based on the distribution of the variable (e.g., quartiles, tertiles, median). For ordinal variables, ranks are assigned based on the existing categories (from low to high).

Table 5-1 QUINPY variables examples with their associated scoring approach

Variable*	**Score***	**Scoring approach**
Playground	0: no playground 1: 1 playground 2: 2 or more playgrounds	Count
Public swimming pool	0: no swimming pool 1: a swimming pool is included	Binary
Supporting facilities	0: no picnic area/BBQ/benches or bathroom/water fountain 1: picnic area/BBQ/benches or bathroom/water fountain 2: picnic area/BBQ/benches and bathroom/water fountain	Combined binary
Park acreage	0: park acreage in the lower quartile in the city 1: park acreage in the middle-lower quartile in the city 2: park acreage in the middle-upper quartile in the city 3: park acreage in the upper quartile in the city	Rank (based on numerical variables)
Maintenance standards	0: Lowest maintenance level (e.g natural areas) 1: Mid-low maintenance level 2: Mid-high maintenance level 3: Highest maintenance level (metropolitan park…)	Rank (based on ordinal variables)

*Variables and scores taken from **Rigolon and Németh (2018)**

QUINPY is doubly validated since variables are chosen and categories weighted following a detailed literature review (youth "2-18 years old" and parks) with variables then validated by experts. For the latter approach, scholars and practitioners with expertise in planning, urban design, and landscape architecture ranked different parks of a city. Then, the average experts' ranking was compared to the QUINPY ranking. Further, QUINPY is easy to generate (relying on open geospatial data) and provides a comprehensive assessment of the parks' features and quality (18 variables). Therefore, after conducting an extensive review of the literature, the QUINPY index was considered as the most suitable for this study's purpose.

5.4.2 CIPQAY: Scaling-up the QUINPY variables and scores

The proposed CIPQAY index relies on the same five categories and weights[2]. As for the variables, when possible, the exact same variables were used. In some cases, minor adaptations were necessary given the data available for Montreal. Further, to ensure that the CIPQAY adequately captures the quality of a group of parks, two modifications were necessary: (i) modifying the variable definitions and operationalization and (ii) adapting the scoring method.

5.4.2.1 Variable definitions and operationalization

Since the aim is to simultaneously assess the quality of all parks accessible considering the features of accessible parks, the variables are computed for all parks (and features) accessible at the same time, rather than for each park separately. For example, the playground variable score is assigned depending on the number of playgrounds in all the parks that are accessible.

However, particularity exists for the following variables: tree canopy, violent crime density and park maintenance standards. Given the nature of these variables, it is not possible to directly count the features. The definitions and their operationalization, as presented in the QUINPY, were thus adapted. First, tree canopy ratio is now the sum of the tree canopy in the accessible parks over the surface area of these accessible parks. Second, the violent crime density variable is now the total number of violent crimes that occurred during the last year within a 100 m buffer around all

[2] Les mêmes poids sont utilisés vu qu'ils sont validés par des experts pour l'index de base, le QUINPY.

accessible parks divided by the combined surface of the accessible parks (including the 100 m buffers). Finally, park maintenance standards are calculated by a weighted mean, based on the surface area of accessible parks, of each maintenance level.

5.4.2.2 Scoring approaches

Scoring approaches modifications are essential to scale up the index and make it relevant for a group of parks. The idea is to determine a quality score that will closely reflect the options provided to individuals. Ideally, the score would be associated with demonstrated outcomes (e.g., knowing that having access to X types of sport fields has a positive and significant influence on youth's physical activity or wellbeing). However, within the accessibility literature, there are very few guidelines on which numbers to use. In the absence of normative guidelines, most studies select thresholds either in an arbitrary manner, based on the local context, or on planning standards or objectives.

The scoring framework developed in this study consists of five scoring approaches: binary approach, combined binary approach, count approach, rank approach and standardized approach. First, binary approach is used when access to at least one opportunity (amenity/activity) is the objective. This approach is typically used in accessibility studies concerned with whether individuals have access at all to a specific service (e.g., pharmacy, post office) and when access to more than one opportunity of this type does not matter (Lucas, Van Wee, & Maat, 2016). It can also be used to implement normative standards (for example, access to a minimum surface area). These standards are, however, almost non-existent for park amenities. Accordingly, the scoring approach will often be based on the area of study, to identify access to scarcely distributed features. For example, community gardens are not common in Montreal in terms of number per residential lots (41 gardens for 374599 residential lots), thus binary scoring fits well the context. However, it could not be the case for Taipei, Taiwan, where community gardens are present in much greater numbers (Hsiao, 2021).

Second, combined binary approach is used when the scoring approach depends simply on the variable's definition in which numerous features' category exist. It is applicable for variables that are divided into multiple categories. For example, consider the case of supporting facilities in this index, where supporting facilities are divided into two categories: (i) picnic area/BBQ/benches and (ii) bathroom/water fountain. In this case, a full score is given if the two categories are present in the surrounding parks, half score (one) if one of the categories exists, and zero if no category is accessible.

Third, count number approach can be used in a similar way as the binary variable, when a sufficient threshold is known or applied based on the study area's accessibility results (e.g., access to at least two football fields in your neighborhood). In this case, the highest score is attributed to origin points having access to at least the sufficient threshold. For example, if the sufficient threshold is having access to two football fields, the number will be as follow: 0 for no accessible football field, one for one accessible football field and two for two and more accessible football fields.

Fourth, standardized approach in this study normalizes the values based on the maximum value. This scoring approach is also relative to the whole region, but based on the maximum value. This score type is relevant mainly by reflecting a variety of choices available in a context study. For example, an individual can have access to numerous sports-court types. Let us say an individual has access to eight sports-court types (for a total of 12 sports-court types in the area of study), a score of 1.75/2 is attributed.

Lastly, rank approach (generally relative to the whole region of analysis) is considered. Assigning a rank score (e.g., quartiles, terciles, median) is most appropriate when accessibility results have a wide distribution and high variation. In this case, variables are assigned a score based on their ranking relative to the rest of the region. This approach is typically applied in accessibility studies to present the level of accessibility relative to the rest of the region (Widener, 2017; Widener, Farber, Neutens, & Horner, 2015). This approach is typically used when no guidelines exist to indicate what a sufficient level is. It can be applied for numerical variables based on the distribution of the variable (e.g., quartiles, tertiles, median) as well as for ordinal variables based on the existing categories (from low to high). In all these cases, this scoring approach helps identify spatial disparities and areas that have the lowest levels of provision.

5.4.3 Data sources and preparation

This study is conducted using available open geographic data (Ville de Montreal, 2021). Since this study combines accessibility and park quality measurements, data management is divided into two parts: (i) parks and park features data, and (ii) residential lots and public road network data. The parks data availability check is done in order to design the final CIPQAY for Montreal, while residential lots and public road network preparation (namely extracting the pedestrian network) is required for the calculation of the accessibility measures.

With respect to parks and park features, Table 5-2 presents the dataset available for this study in relation to the 18 QUINPY variables plus the added variables for Montreal. Two land-use datasets were used for the majority of the variables: (i) parks and green spaces and (ii) outdoor recreational, cultural and sport amenities at parks. Parks and green spaces are geospatial polygons with features for each park (namely type of the park). Note that the terms parks and green spaces do not refer to distinct concepts in the database of the City and are therefore used interchangeably in this paper. The second dataset contains points for each activity located in parks, with features for each activity (namely type of activity, subtype of activity).

Additional datasets were obtained to cover variables that were not captured by the previous datasets. The additional datasets are the following: “community gardens”, “tree canopy”, “trails”, “water fountain”, “natural areas protected or under protection” and “criminal acts”. Only the features located inside the parks (except the “2020 criminal acts” located in a 100m buffer around the parks) were extracted.

Table 5-2 Data availability, sources and preparation for the case study of Montreal

Variable	Availability	Datasets	Extraction	Merged datasets
Playground number	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	All playgrounds	
Playground surface	NA			

Table 5-2 Data availability, sources and preparation for the case study of Montreal (suite)

Sports-fields (by type)	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	5 sports-fields: soccer, Frisbee, football, baseball, rugby	
Sports-courts (by type)	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	10 sports-courts	
Walking/bike paths and hiking/horseback trail	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	"trails"; "cycling paths"	√
		"trails" (POLYGONS)	located in the parks	
Public swimming pool	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	"Swimming Pool"	
Splash parks*	√	*outdoor recreational, cultural and sport amenities at parks.* (POINTS)	*"splash parks"; "paddling/play pools"*	√
Supporting facilities (picnic areas, benches, BBQ, bathrooms/water fountain)	√ (not all features)	outdoor recreational, cultural and sport amenities at parks. (POINTS)	Picnic areas	
		Water fountain (POINTS)	located in the parks	
Organized sport activities (after school programs or recreation centers)	NA			

Table 5-2 Data availability, sources and preparation for the case study of Montreal (suite)

Water as visual amenity	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	"lake"; "fountain"	√
		Wetlands (POINTS)	"marsh"; "pond" in the parks	
Access to water for recreation	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	"beach"; "kayak"	√
Tree canopy ratio	√	Tree canopy (POLYGONS)	over the parks	
Vegetation/shading around behavior settings	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	Shaded sports activities"; Shaded playgrounds	
		Tree canopy (POLYGONS)	over the parks	
Natural areas, nature preserves, or nature centers	√	Natural areas protected or under protection (POLYGONS)	"Accessible areas for the public" located in the parks	
Community gardens	√	Community gardens (POINTS)	located in the parks	
Distant views (from waterfront or hills)	√	outdoor recreational, cultural and sport amenities at parks. (POINTS)	"Belvedere" (view points for example)	
		Parks and green spaces (POLYGONS)	Parks with waterfront	
Park acreage	√	Parks and green spaces (POLYGONS)	all the dataset	

Table 5-2 Data availability, sources and preparation for the case study of Montreal (suite)

Park maintenance standards	√	Parks and green spaces (POLYGONS)	all the dataset	
Violent crime density	√	Criminal acts (POINTS)	"2020 criminal acts" located around 100m of the parks	
		Parks and green spaces (POLYGONS)	all the dataset	

(*) This variable is not present in the QUINPY index. It was added specifically for the case study context of Montreal.

Further, some data manipulation was required to ensure the operationalization of the variables based on the available datasets[3]. Starting by the "trail" specific dataset (Table 5-2), each trail was converted from polygon data to points separated by an average distance of 65 m since a trail's linearity makes it accessible from any location (point) along it. Second, shaded behavior settings are located by extracting playgrounds and sport activities where 50% of their 30 radial lines of a length of 15 m and 60 m respectively intersect with tree canopy polygons. The length of the radial lines was determined through trial-and-error in this study for playgrounds and sports fields/courts area exposure. At last, parks with waterfront are extracted by selecting parks where their perimeters are up to 100m away from a waterfront (using buffers).

For this case study, two variables have no available data: (i) organized sport activities and (ii) playground surface. Conversely, a variable was added in relation to the splash parks, for a total of 17 variables instead of 18. A "splash parks" variable was added in place of the "organized sport activities". Whereas no data related to organized sport activities was available, splash parks and paddling/play pools (total of 248 in Montreal) are important components of parks and largely

[3] Un tableau qui résume les manipulations des données est présent dans l'Annexe A de ce mémoire.

visited by youth. These splash parks are generally enjoyed by children with an added play value (Lewis, 2005).

Finally, parks maintenance standards were not available: the variable was replaced with the type of park as a proxy for the maintenance standards: green islands and promenades (low maintenance), neighborhood parks (mid-low maintenance), urban parks (mid-high maintenance) and metropolitan and large parks (high maintenance).

5.4.4 Generation of the measures

Once the data were prepared, the measures were generated at the residential lot level using a configurable tool developed by the research team on ArcGIS. This tool determines the parks or park features that can be reached from each residential lot within a specific pedestrian network distance. The pedestrian network is generated from the public road network data: it includes all pedestrian links as well as the streets with sidewalks. For the threshold, a 1,000 m pedestrian network distance is fixed which is considered a reasonable distance for children to walk (Waygood et al., 2017). Older youth may have a longer reasonable walking distance, but the lower threshold was used to be more inclusive.

The pedestrian network distance is calculated from each destination point to each residential lot centroid. The tool identifies all parks and features that are within the 1,000 m threshold of each residential lot. Park access is inspired from an Apparicio et al. (2010) study by considering multiple access (destination) points along the perimeter of the park, while park features (represented by points) access is considered by snapping the feature point to its closest street.

Accessibility is then computed for each variable (or feature) for each of the 17 variables. The most appropriate scoring approach is selected based on the accessibility results and criteria presented in the section above. The scores are then computed for each variable and residential lot, then allowing the calculation of the CIPQAY index for the 374,599 residential lots in Montreal. The accessibility results, the scoring approach and scores, as well as the index results are presented in the next section.

5.5 Results

5.5.1 Development of the CIQPAY index for the city of Montreal

Table 5-3 summarizes the accessibility results of all the variables, or features required to build the variables, for the 374,599 residential lots. Alongside the statistical results, the proportion of residential lots that do not have access to the variable is given. This proportion as well as the number of the features (N) for each variable are useful indicators for the binary scoring.

Table 5-3 Summary statistics of the accessibility results for the different variables and separated features

Variables (features)		Accessibility results from residential lots					
Name	**Variable**	N	Min	Max	Mean	SD	No access (%)
Playground	Number of accessible playgrounds	979	0	23	5.78	3.54	3.15
Sports-field types	Number of accessible types of sports-fields	5	0	3	0.69	0.57	36.61
Sports-court types	Number of accessible types of sports-courts	10	0	8	1.84	1.59	20.53
Walking/bike paths and hiking trail	*Number of accessible points located across walking/bike paths and hiking trails**	*1399 points**	0	146	3.21	7.09	48.97
Public swimming pool	Number of accessible public swimming pools	70	0	3	0.33	0.55	70.65

Table 5-3 Summary statistics of the accessibility results for the different variables and separated features (suite)

Supporting facilities: picnic area	Number of accessible picnic areas	74	0	4	0.32	0.64	75.06
Supporting facilities: water fountain	Number of accessible water fountains	812	0	24	5.05	3.95	8.74
Splash parks	Number of accessible splash parks	248	0	8	1.57	1.34	23.33
Water as visual amenity	Number of accessible water areas considered as visual amenities	183	0	16	0.39	1.05	78.94
Water for recreation	Number of accessible water areas for recreation	7	0	2	0.02	0.12	98.52
Tree canopy ratio	Tree coverage of accessible parks / accessible surface area of parks ratio	NA	0	1	0.31	0.16	NA
Vegetation/shading around behavior settings: 50% of playgrounds enclosed	Number of accessible playgrounds that are at least half enclosed by vegetation or shading	533	0	13	3.49	3.42	13.94
Vegetation/shading around behavior settings: 50% of sport activities enclosed	Number of accessible sport activities that are at least half enclosed by vegetation or shading	280	0	12	1.56	1.58	29.94

Table 5-3 Summary statistics of the accessibility results for the different variables and separated features (suite)

Natural areas	Number of accessible natural areas	123	0	11	0.278	0.87	82.46
Community gardens	Number of accessible community gardens	41	0	3	0.24	0.5	79.08
Distant views (waterfront)	Number of accessible parks with a waterfront	241	0	16	0.68	1.54	74.97
Distant views (hills)	Number of accessible parks with a hill view	31	0	3	0.09	0.33	92.39
Park surface area	Total surface of accessible parks	1475 parks	0	5.65	0.41	0.53	0.4
Park maintenance standards proxy	Weighted mean of the maintenance level of accessible parks	4 standards	0	3	1.81	0.72	NA
Violent crime density	Number of violent crimes that occurred during the last year within a 100 m buffer around all accessible parks divided by the combined surface of the accessible parks	19703 crimes	0	1100	119.41	130.31	NA

(*) Not representative since each trail is represented by numerous points.

Since very little theoretical guidance or standards exist in the literature, several scoring approaches were selected based on the distribution of the results across the region. These scoring approaches were then associated to the variables as described in Table 5-4.

First, *natural areas*, *community gardens*, *distant views*, *water for recreation*, *water as visual amenity*, and *public swimming pool* are evaluated by a binary approach based on statistical results. This choice is due to their low accessibility across the city (more than 70% of the population with no access) (Table 5-3). Binary approach was also selected for *trails*. Since the latter is represented by multiple points, the assumption is based on the following two statistics: (i) access to an average of 3.21 points and (ii) 48.97% of residential lots have no access to at least 1 point. In this case, we consider that having access to multiple trails is rare as a unique trail is represented on average by 12 points. Finally, binary approach was also attributed to *splash parks* based on the variable's definition. Although the number of splash parks (N=248) is bigger than the number of swimming pools (N=70) in Montreal, the same scoring type is chosen for consistency reasons. Splash parks and swimming pools both involve water activities, and the former are only enjoyed by children.

Second, combined binary approach is chosen for the *supporting facilities* simply due to the definition of the variable. This variable is based on having access to picnic area and/or a water fountain.

Third, rank approach was attributed for the *playgrounds*, *tree canopy*, *violent crime density* and *park surface area*. The four variables have varying accessibility results across the region: they have a wide distribution and high variation. The scoring fits well the context and is relative to the city's results by dividing values into terciles and quartiles. For the *maintenance standards* proxy, the number also represents an order, although a decimal is present since it is a surface-weighted average. A particularity shows for the *vegetation/shaded around behavior settings* variable. The latter is evaluated by a rank approach. It is a variable of two rank scoring features (shaded playgrounds and shaded sports activities) based on their accessibility results (Table 5-3). The median is used as a relative value so that the index highlights residential lots having access to less than the median value (3 for playgrounds, 1 for sport activities) in the city.

Finally, eight *sports-courts* and five *sports-fields* are present in this study. For each variable, having access to several types (by variable) highlights the diversity aspect that can be evaluated by scoring these variables. Standardized approach is chosen then, with a value that ranges between zero, equivalent to not having access for any sports type of the variable and two representing a full diversity in access (e.g., 1.5 is equivalent to having access to 75% of the types).

It is important to mention that the scoring approach is determined here based on the Montreal accessibility results, and direct application to another city using the same thresholds is not advised. The same logic can nonetheless be applied.

As a final result, Table 5-4 presents the CIPQAY, the quality index of the surrounding parks for youth, for the case study of Montreal, with 17 variables and a total score of 30 in comparison to the initial QUINPY index. The scoring values for the CIPQAY variables are binary (0 or 1),) or numerical (typically ranging from 0 to 2 or 0 to 3)[4].

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[4] La valeur des scores attribués pour chaque variable est respectée afin de conserver le même poids que chaque variable représente relativement par rapport au score total de 30.

Table 5-4 Final model of the CIPQAY for the city of Montreal vs. initial QUINPY index

	Combined Index of Parks Quality and Accessibility for Youth (CIPQAY)		QUINPY (Rigolon & Németh, 2018)*	
Categories	Variables	Score	Variables*	Score*
Structured play diversity **(weight: 44%)**	Playground number	0: no accessible playground	Playground number	0: no playground
		1: number of accessible playgrounds in the first tercile in the city		1: 1 playground
		2: number of accessible playgrounds in the second tercile in the city		2: 2 or more playgrounds
		3: number of accessible playgrounds in the third tercile in the city		
	NA		Playground surface	0: below median playground surface for parks in city
				1: above median playground surface for parks in city
	Sports field (by type)	Continuous value between 0 (no accessible sport field) and 2 (all the sports-field types are accessible). (e.g, 1 is an equivalent value to 50% of sports-field types are accessible)	Sports field (soccer, baseball, football, rugby and lacrosse)	0: no sports-field
				1: sports-field of one type
				2: sports-fields of two or more types

Table 5-4 Final model of the CIPQAY for the city of Montreal vs. initial QUINPY index (suite)

Structured play diversity **(weight: 44%)**	Sports courts (by type)	Continuous value between 0 (no accessible sport courts) and 2 (all the sports-court types are accessible). (e.g., 1 is an equivalent value to 50% of sports-court types are accessible)	Sports courts (basketball, tennis, skateboard and handball)	0: no sports-court
				1: sports-court of one type
				2: sports-courts of two or more types
	Walking/bike paths and hiking trail	0: no accessible paths or hiking trails	Walking/bike paths and hiking/horseback trail	0: no paths or hiking trails
		1: accessible paths or hiking trails		1: paths or hiking trails are included
	Public swimming pool	0: no accessible swimming pool	Public swimming pool	0: no swimming pool
		1: a swimming pool is accessible		1: a swimming pool is included
	Supporting facilities (picnic areas, water fountain)	0: no accessible picnic area or water fountain	Supporting facilities (picnic areas, benches, bbq, bathrooms/water fountain)	0: no picnic area/BBQ/benches or bathroom/water fountain
		1: accessible picnic area or accessible water fountain		1: picnic area/BBQ/benches or bathroom/water fountain
		2: accessible picnic area and accessible water fountain		2: picnic area/BBQ/benches and bathroom/water fountain

Table 5-4 Final model of the CIPQAY for the city of Montreal vs. initial QUINPY index (suite)

Structured play diversity **(weight: 44%)**	NA		Organized sport activities (after school programs or rec centers)	0: no organized sport activities
				1: organized sport activities
	Splash parks	0: no accessible splash park or paddling/play pool	NA	
		1: accessible splash park or paddling/play pool		
Nature (weight: 28%)	Water as visual amenity (lakes, fountains)	0: no water as visual amenity is accessible	Water as visual amenity (lakes, streams, fountains, or beach)	0: no water as visual amenity
		1: water as a visual amenity is accessible		1: water as a visual amenity is included
	Access to water for recreation (water-to-swim, canoe or kayak)	0: no access to water for recreation	Access to water for recreation (water-to-swim, canoe or kayak)	0: no access to water for recreation
		1: water for recreation is accessible		1: access to water for recreation is included
	Tree canopy: (accessible tree coverage-park size ratio)	0: tree coverage- accessible park size ratio in the lower tercile for residential lots in the city 1: tree coverage- accessible park size ratio in the middle tercile for residential lots in the city 2: tree coverage- accessible park size ratio in the higher tercile for residential lots in the city	Tree canopy: Tree coverage in relation to park acreage	0: tree coverage-park acreage ratio in the lower tercile for parks in city 1: tree coverage-park acreage ratio in the middle tercile for parks in city 2: tree coverage-park acreage ratio in the upper tercile for parks in city

Table 5-4 Final model of the CIPQAY for the city of Montreal vs. initial QUINPY index (suite)

Nature (weight: 28%)	Vegetation/shading around behavior settings (by type): tree cover enclosed settings for more than 50% of perimeter	0: no accessible behavior settings are enclosed 1: number of accessible enclosed behavior settings of one type is higher than median in the city (playground or sport facility) 2: number of accessible enclosed behavior settings of two types is higher than median in the city (playground and sport facility)	Vegetation/shading around behavior settings: tree cover enclosed settings for more than 50% of perimeter	0: no behavior settings are enclosed 1: one type of behavior setting is enclosed (playground or sport facility) 2: two types of behavior settings are enclosed (playground and sport facility)
	Natural areas or nature preserves	0: no accessible natural areas/preserves	Natural areas, nature preserves, or nature centers	0: no natural areas/preserves/centers
		1: natural areas/preserves are accessible		1: natural areas/preserves centers are included
	Community gardens	0: no accessible gardens	Community gardens	0: no gardens
		1: accessible gardens		1: gardens
	Distant views (from waterfront or hills)	0: no accessible distant views	Distant views (from waterfront or hills)	0: no distant views
		1: accessible distant views		1: distant views

Table 5-4 Final model of the CIPQAY for the city of Montreal vs. initial QUINPY index (suite)

Park size (weight: 9%)	Park surface area	0: accessible park surface area in the lower quartile in the city	Park acreage	0: park acreage in the lower quartile in the city
		1: accessible park surface area in the middle-lower quartile in the city		1: park acreage in the middle-lower quartile in the city
		2: accessible park surface area in the middle-upper quartile in the city		2: park acreage in the middle-upper quartile in the city
		3: accessible park surface area in the upper quartile in the city		3: park acreage in the upper quartile in the city
Maintenance (weight: 10%)	Park maintenance standards	Continuous value between 0 (lowest maintenance level) and 3 (highest maintenance level). (e.g, 1 is equivalent to a mid-low maintenance level; 2 is equivalent to a mid-high maintenance level)	Park maintenance standards	0: Lowest maintenance level (e.g natural areas)
				1: Mid-low maintenance level
				2: Mid-high maintenance level
				3: Highest maintenance level (metropolitan park…)

Table 5-4 Final model of the CIPQAY for the city of Montreal vs. initial QUINPY index (suite)

Safety (weight: 9%)	Violent crime density (total number of violent crimes in accessible parks and in 100m buffer around accessible parks divided by the combined surface of the accessible parks and of its 100m buffer)	0: violent crime density in the higher quartile for accessible parks in the city	Violent crime density (total number of violent crimes in park and in 100-yard buffer around a park divided by the combined surface of the park and of its 100-yard buffer	0: violent crime density in the higher quartile for parks in the city
		1: violent crime density in the mid-higher quartile for accessible parks in the city		1: violent crime density in the mid-higher quartile for parks in the city
		2: violent crime density in the mid-lower quartile for accessible parks in the city		2: violent crime density in the mid-lower quartile for parks in the city
		3: violent crime density in the lower quartile for accessible parks in the city		3: violent crime density in the lower quartile for parks in the city

To better understand the distribution of the scores across the residential lots, Figure 5-2 represents the distribution of the index scores by number of residential lots. With a mean of 12.77, the results vary between 0 (residential lots with no access to parks) and 23.21 as maximum value, with approximately 55% of the residential lots having a score between 10 and 15. This distribution ensures the presence of discriminated groups of residential lots in terms of the quality of their accessible parks for youth across the city.

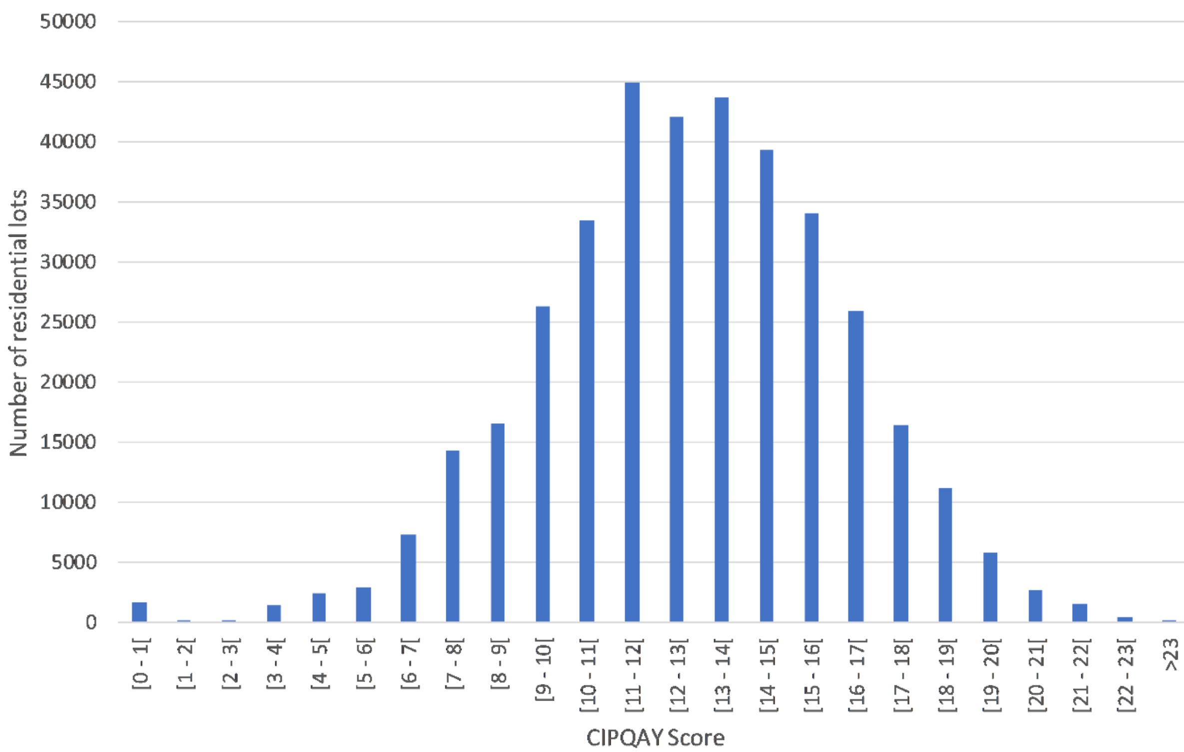

Figure 5-2 Number of residential lots by CIPQAY score's interval in Montreal

Figure 5-3 presents the CIPQAY results for all the 374,599 residential lots across the region. As illustrated, high and low scores are spatially dispersed across the city, with several local clusters[5]. High score (above 16.5) clusters can be found namely near large parks and near water bodies. As for low scores (below 8), spatially distributed gaps in access are present across the city

[5] De futures études pourraient s'intéresser aux corrélations spatiales et à l'analyse des facteurs expliquant les faibles scores et ainsi que les scores élevés.

with a concentration in the West region of the city as well as downtown. These results highlight areas that could prioritized for further investigations and interventions. While other considerations such as deprivation levels would likely need to be taken into account, the CIPQAY index provides a diagnostic tool to identify areas with low levels of quality of the surrounding parks for youth.

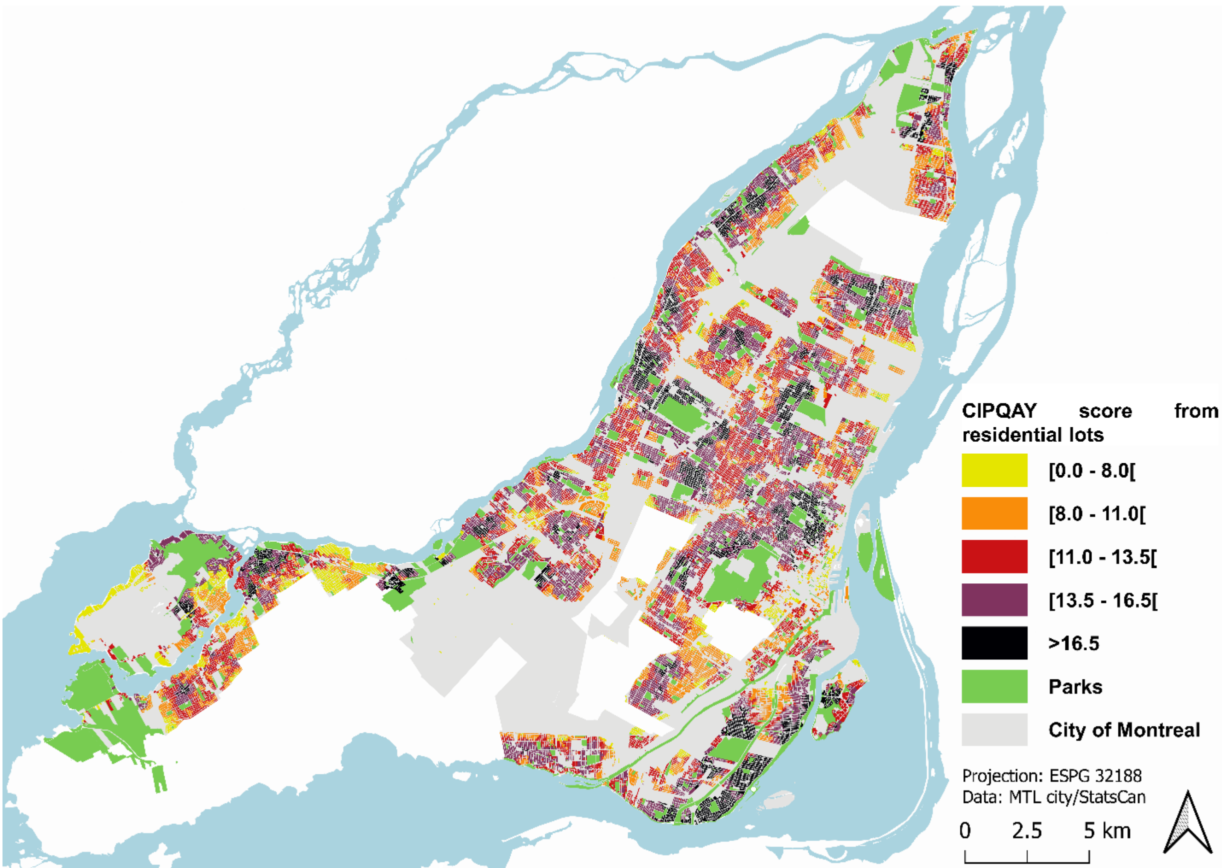

Figure 5-3 CIPQAY scores of residential lot in Montreal

5.6 Conclusion

In this paper, we proposed a methodology to generate an index that combines the quality and accessibility of parks. Specifically, the Combined Index of Parks Quality and Accessibility for Youth (CIPQAY) integrates a recently developed quality index of parks for youth, QUINPY (Rigolon & Németh, 2018), within cumulative-opportunity measures (as measures of accessibility). To test the applicability of the methodology, the index was applied to the city of

Montreal. The QUINPY variables and scores were first adapted to reflect the combined quality of surrounding parks. Second, using open data, CIPQAY variables and scores were defined and operationalized based on the study context of Montreal and data availability. The final index for Montreal contains 17 variables for a total (maximum) score of 30 and was computed for the 374,599 residential lot.

There are nonetheless limitations and further potential developments that are worth mentioning. First, methods such as this one, that rely on open data, are susceptible to flawed data or missing data. This index, with 17 variables, needed numerous datasets in which each dataset is susceptible to have incomplete data. Particularly for the open data of Montreal, some data (supporting facilities for example) are present only for large parks, that are under the supervision of the City, but not for the 1000+ other urban parks, that are managed by other administrative entities, namely boroughs. Second, the type of geospatial data has effects on results: the majority of the data here are represented by points, thus the operationalization of the different variables is less precise or not achievable. This is the case for playgrounds and sport activities: the playground surface variable was, therefore, removed from the index, while assumptions were taken to calculate the proportion of vegetation around behavior settings. As for the level of maintenance, it was assigned based on the type of parks since no maintenance data was available. This might not reflect actual park conditions. Third, several assumptions were made to set the scoring approaches and thresholds. As such, the absence of normative guidelines requires that some arbitrary choices are made, largely based on the case study. Considering that binary scoring is chosen due to the current reality of a city, it does not mean that having access to at least one specific feature is reasonable, yet it is a planning tool based on the context results. The presence of guidelines would allow for improved index results which would help to identify problematic areas. It would also allow for comparison across cities. Moreover, the distribution of the accessibility results is based on the residential lot. Further studies could calculate the distribution based on the general population or on specific population groups. In addition to demographic characteristics (youth in this case), each group of individuals can have different priorities and perceptions for parks and recreation (Smiley et al., 2016). Perceptions and competition could also be incorporated into the accessibility measures. At last, this developed index should be validated by experts similarly to the validation of the QUINPY index. The CIPQAY index could also be assessed in relation to individuals' perceptions, behavior and health outcomes. Despite the limitations of this study, this research proposes a new methodology to measure the quality and accessibility of park within a single index. Future research can build on the present methodology to further improve and validate the index.

5.7 CRediT author statement

The authors confirm contribution to the paper as follows: **El-Murr** : Conceptualization; Data curation; Formal analysis; Methodology; Writing – original draft; Writing – review & editing; Validation **Boisjoly** : Conceptualization; Supervision; Writing – review & editing; Validation **Waygood** : Conceptualization; Supervision; Writing – review & editing; Validation.

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CHAPITRE 6 ARTICLE 3: MEASURING ACCESSIBILITY TO PARKS: ANALYZING THE RELATIONSHIP BETWEEN SELF-REPORTED AND CALCULATED MEASURES

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Abstract

Accessibility to all types of destinations is an important research field in transport. Parks and green spaces are key destinations due to their contribution to individuals' well-being. Most studies focus on calculated accessibility to parks (e.g., number of parks within walking distance), typically neglecting how needs, preferences and constraints may vary across individuals. More recently, a few studies have assessed self-reported accessibility. Yet, little attention has been paid to the relationship between these two types of measure. This study evaluates the relationship between calculated and self-reported accessibility to parks in the city of Montreal. Three calculated measures were generated based on the cumulative-opportunity method considering (i) the number of parks, (ii) the surface area, and (iii) the parks' attributes. The self-reported measure was collected from a representative sample of city residents through an online survey (n=873). Three ordered logistic regressions were used to model the relationship between self-reported and calculated accessibility, while controlling for individual characteristics, followed by an analysis of the mismatch between the two measures. Findings show that the two types of accessibility are positively associated when considering park attributes, but a negative association is observed between the number of parks and self-reported accessibility. The study also confirms that individual characteristics influence self-reported accessibility and suggests that the mismatch between self-reported accessibility and the number of parks is explained by both spatial and individual factors. This research highlights that researchers, planners and decision-makers should consider destinations' attributes, individual characteristics and perceptions when assessing accessibility to parks.

Keywords: parks, spatial analysis, accessibility indicators, transport and land use, perceptions

6.1 Introduction

Parks and green spaces are central for individuals' well-being, as they provide important features for leisure-time activities (Bedimo-Rung, Mowen, & Cohen, 2005). Further, along with offering natural environments, parks are places of diverse activities as well as spaces for social interactions that contribute to improving mental and physical health (Cohen et al., 2007; Peters, Elands, & Buijs, 2010). Overall, parks have numerous benefits such as social (Seaman et al., 2010), health (Cohen et al., 2007), economic (Nicholls, 2004) and environmental (Feyisa et al., 2014).

The contribution of parks to individuals' well-being makes accessibility to this type of destination a crucial component to consider in urban policies and planning. However, accessibility is a multidimensional concept, which makes it challenging to assess (E. J. Miller, 2018). As such, one's ability to reach destinations depends on a variety of interacting factors, namely the land use and transport systems, as well as individual preferences, needs and constraints. Further, in the case of parks, the characteristics of the destinations play a key role in meeting individual needs (Knapp et al., 2019).

Conventional analyses used in previous studies and public policies rely heavily on quantitative accessibility measures that consider mainly the land use and transport components (G. Boisjoly & A. M. El-Geneidy, 2017). In the case of parks, the most common accessibility measures consider the number of parks within a certain distance, the surface area of the park(s) within a certain distance, or the distance to the closest park (El-Murr et al., 2021; Reyes et al., 2014; C. Wang et al., 2021). These measures typically neglect the variety in individuals' needs, perceptions and characteristics, in addition to mode availability and destinations attributes and features.

Another approach to assessing accessibility to destinations and specifically to parks is through self-reported accessibility (Pham et al., 2019; D. Wang, Brown, & Liu, 2015; D. Wang, Brown, Zhong, et al., 2015). As such, how accessibility is experienced by individuals differs from one another and self-reported accounts directly investigate individuals' perceptions of accessibility. In addition to individual characteristics such as gender, age and income – which are known to affect accessibility (Dixit & Sivakumar, 2020) – plenty of factors can affect individual perceptions and answers. These include personal preferences and self-selection biases (Bohte et al., 2009), which might distort frequency of use and expectations. Other implications of self-reported accessibility data collection include the chance of collecting biased results, for example, due to subjective interpretation of the questions or a tendency to give socially desirable responses (J. Ryan & Pereira, 2021).

Neither calculated nor self-reported measures of accessibility give a complete picture. Studying the relationship between the self-reported and the calculated measures can help researchers and planners to better understand, measure and plan for accessibility. While a few recent studies have examined this relationship (Curl, Nelson, & Anable, 2015; Laatikainen, Tenkanen, Kyttä, & Toivonen, 2015; Lättman, Olsson, & Friman, 2018; J. Ryan & Pereira, 2021), very little research has specifically evaluated the relationship between self-reported accessibility and calculated accessibility to parks and green spaces.

The objective of this study is to investigate the relationship between self-reported accessibility and calculated accessibility measures to parks and green spaces. The study is conducted in the city of Montreal, characterized by high discrepancies in spatial accessibility to parks (El-Murr et al., 2021). Self-reported accessibility is measured with an online survey. Then, three calculated measures are developed based on the location of respondents in order to assess accessibility to parks considering distinct characteristics: (i) the number of parks accessible, (ii) the surface area of accessible parks, and (iii) the attributes of the accessible parks, based on an index previously developed by the authors (El-Murr, Boisjoly , & Waygood, 2022). The two types of measures (self-reported and calculated accessibility) are first compared through regression analyses: three ordered regressions model self-reported accessibility as a function of each of the three calculated accessibility measures, while controlling for individual characteristics. Second, a mismatch analysis is conducted for each calculated accessibility measure by combining the calculated and self-reported accessibility of each respondent. This study explores how various measures of calculated accessibility are linked to self-reported accessibility. By answering how a calculated measure can better represent one's perceived "reality", the study will give a better representation of accessibility to academics and practitioners.

6.2 Literature review

Accessibility is increasingly considered as an alternative to the mobility-oriented transport planning paradigm (Geurs, Krizek, & Reggiani, 2012). As such, it is now included as an objective in several land use and transport plans across the world (G. Boisjoly & A. M. El-Geneidy, 2017). Despite being defined in different ways, such as the ease of reaching destinations (El-Geneidy & Levinson, 2006) or the potential to reach opportunities (Hansen, 1959), accessibility is broadly understood as a multidimensional concept. The concept of accessibility includes four components: infrastructure, land-use, temporal and individual (Geurs & Van Wee, 2004). Due to having multiple components, a large number of indicators assessing accessibility have been developed (Handy & Niemeier, 1997; Páez et al., 2012). Of the available metrics, accessibility can be measured either as person-based, taking into account the individual components, or place-based, focusing on the land-use and transport components (H. J. Miller, 2005). Given their ease of operationalization, place-based accessibility measures such as the cumulative-opportunity and gravity measures, are the most commonly used (E. J. Miller, 2018). These two measures have been proven to be highly correlated, which has led to the cumulative opportunity measure, easier-to-communicate, becoming more popular in use (Boisjoly & El-Geneidy, 2016). However, the individual dimension of accessibility is most of the time ignored in place-based measures. The individual perspective is usually represented at best by sociodemographic variables (e.g., age, income, gender) using a segmentation approach (Titheridge, Mackett, & Achuthan, 2010).

Another type of accessibility measures has been developed to specifically account for the individual dimension, the person-based measures. These measures focus on the interaction between individual characteristics and land use and transport systems. However, these measures are more complex to generate and operationalize, and are therefore seldom used in practice. More recently, measures of self-reported accessibility have been developed and tested in different contexts (Lättman, Olsson, & Friman, 2016; M. Ryan, Lin, Xia, & Robinson, 2016). This type of measure reflects the individual's perceived ability to reach opportunities and participate in their (preferred) activities using the transport system, thus capturing the individual dimension (Lättman, Friman, & Olsson, 2016).

Calculated and self-reported accessibility are expected to differ. Self-reported accessibility is generally seen to complement calculated measures by capturing missing factors, such as perceptions, knowledge, preferences and abilities (Lättman, Olsson, et al., 2016). Pot et al. (2021) argue that accessibility measures that do not account for the individual component poorly reflect the individual's perceived participation potential and may cause a mismatch between calculated and self-reported accessibility. In line with this, a few studies have examined the relationship between calculated and self-reported accessibility to assess how these measures complement and relate to each other (Budd & Mumford, 2006; Curl et al., 2015; Laatikainen et al., 2015; Lättman et al., 2018; J. Ryan & Pereira, 2021; M. Ryan et al., 2016). Budd and Mumford (2006) indicated the presence of gaps between calculated and self-reported accessibility to workplaces and jobs. Similarly, M. Ryan et al. (2016) found that calculated accessibility and self-reported accessibility to train stations did not match. Finally, J. Ryan and Pereira (2021) found that calculated methods tend to overestimate accessibility levels and underestimate accessibility inequalities to healthcare centers and supermarkets among elderly. Altogether, these studies highlight how examining self-reported accessibility can contribute to improving calculated accessibility measures by providing a complementary measure.

Parks and green spaces are destinations of interest due to their contribution to the quality of life of individuals in urban areas. To support the positive outcomes associated with visiting parks, several studies have focused on developing indicators of accessibility to parks. Accessibility to parks was mostly estimated with a calculated method using a wide range of measures such as the number of parks (Comber et al., 2008; El-Murr et al., 2021), surface area (El-Murr et al., 2021; Reyes et al., 2014) and park features (De Alvarenga et al., 2018; Dony et al., 2015; Xing et al., 2020). For example, Comber et al. (2008) counted the number of parks accessible for different ethnic and religious groups in the United Kingdom. Reyes et al. (2014) measured children's walking accessibility to parks in Montreal considering the accessible surface area. De Alvarenga et al. (2018) measured accessibility to activities located in parks, notably playgrounds, in Montreal. Self-reported accessibility to parks was also assessed in previous research (Pham et al., 2019; D. Wang, Brown, & Liu, 2015; D. Wang, Brown, Zhong, et al., 2015; Wendel et al., 2012). A recent study assessed self-reported accessibility to parks from an environmental equity perspective, while controlling for sociodemographic characteristics and accessible surface area (Yasumoto, Nakaya, & Jones, 2021). Although the study did not focus on the relationship between self-reported and calculated accessibility, results showed a positive association between the accessible park area and self-reported accessibility.

To the authors' knowledge, no previous study specifically assessed the relationship between calculated and self-reported accessibility to parks and green spaces. Understanding how different calculated measures of accessibility relate to self-reported accessibility will provide insight on how to generate a more comprehensive and accurate assessment of accessibility to parks and green spaces.

6.3 Data and methods

To analyze the relationship between self-reported and calculated accessibility to parks, these two measures were generated for the city of Montreal, Canada, using complementary data sources. Figure 6-1 presents the study area. Note that the study is restricted to the 19 boroughs of the city of Montreal (and not the whole island) based on data availability. For interpretation purposes, the city is divided into four main regions, based on the zones defined by the Autorité régionale de transport métropolitain (ARTM, 2018)

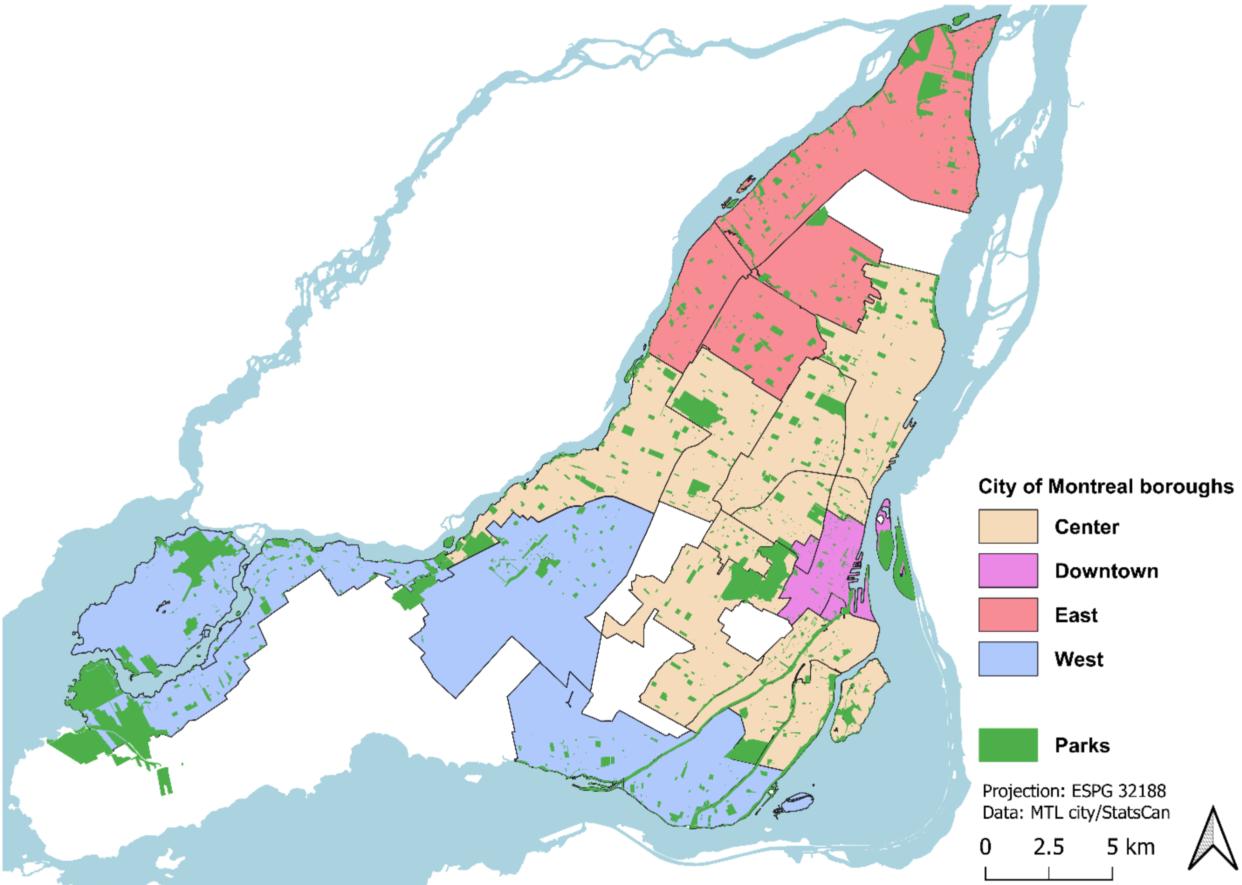

Figure 6-1 Context map of the city of Montreal

6.3.1 Self-reported accessibility

Individuals' perceptions of their accessibility to parks in the city of Montreal, referred to in this study as the self-reported accessibility, were collected using an online survey. The survey was administered online in November 2021 by Leger Opinion, a company specialized in data collection with a large proprietary panel in Canada. The data was collected from an initial representative sample (by gender and age) of adults (18 years and older) residing in the city of Montreal (n=1017). The sample was reduced to 873 after removing respondents who failed the trap questions (to test whether they are paying attention).

Information on respondents' self-reported accessibility to parks (overall accessibility to parks and green spaces, number of parks, and presence of parks meeting respondent's needs), travel behavior and socio-demographic profile was obtained, together with their home location. Due to privacy, the respondents had the choice between specifying their postal code or specifying the closest street intersection to their home on a digital map included in the survey.

This study focuses on a specific variable that represents the global self-reported accessibility, along with numerous individual characteristics. The global self-reported accessibility was captured through the following question "*How would you rate your overall access to parks and greenspaces from your home?"* with a 5-point scale varying from "*very low"* to "*very high",* in addition to a "none" option.

6.3.2 Calculated accessibility

This study adopts a land use and transport perspective and focuses on location-based accessibility (Geurs & Van Wee, 2004), which evaluates the level of accessibility to destinations at a specific location. The calculated accessibility was generated using available open geographic data from the City of Montreal (Ville de Montreal, 2021). Three main datasets were retrieved. First, the *parks and green spaces* dataset provided the geometry and the location of the parks. Numerous green spaces were removed from the dataset as they are not freely accessible (e.g., golf courses, private and institutional spaces), for a total of 1,475 remaining parks. Second, activities located in the parks were retrieved from the *outdoor recreational, cultural and sport amenities at parks* dataset. Complementary datasets (e.g., tree canopy) were also retrieved to develop the measure that considers park attributes. The full list can be seen in El-Murr et al. (2022). Finally, a pedestrian network was generated from the *public road dataset* to only include pedestrian links, streets with sidewalks and residential streets without sidewalks.

All the measures were inspired from a recently developed method that measures accessibility to parks using open data (El-Murr et al., 2021). In brief, the method rests on the commonly used cumulative-opportunity accessibility measures (i.e., a count of the number of opportunities within a specific travel time or distance threshold), calculated at the residential lot level. A 1,000 m threshold using the pedestrian network is used for two reasons: it represents the average distance walked by Montreal residents for all trip purposes (Lachapelle et al., 2020); it reflects the average time that respondents' reported that they are willing to walk in order to reach a neighborhood park (15 minutes).

The three calculated accessibility measures are generated as follows. Park access is considered based on multiple access points along the perimeter of the park, inspired by Apparicio et al. (2010). Service areas based on the pedestrian network were then calculated from each access point. The centroids of the residential lots, projected to the closest street, are then intersected with the service areas to identify which parks are within the 1,000 m pedestrian network. Accessibility is then calculated for the three measures: (i) by simply counting the number of accessible parks within this threshold, (ii) by summing the surface of all parks accessible, and (iii) by giving an index score for each residential lot depending on the quality and amenities of the accessible parks. The last measure, known as the CIPQAY index ("Combined Index of Parks Quality and Accessibility for Youth"), gives a score over 30 to each residential lot depending on the features and characteristics of all the accessible parks. The features and characteristics are represented by variables divided into five weighted categories: *Structured play diversity, nature, park size, maintenance,* and *safety*. More details about the conception and the calculation of the last measure are available in El-Murr et al. (2022). The three measures were done for all the 374,599 residential lots in the city of Montreal.

Finally, to compare calculated accessibility to self-reported accessibility, the calculated measures were matched to each respondent of the survey. To do so, the calculated measures were aggregated from the residential lot to the postal code level, by calculating the average score of the residential lots within the postal code. Then, each respondent was assigned the score of their postal code. A final sample of 683 respondents was obtained after removing individuals residing in areas where necessary geographic data was not available.

6.3.3 Assessing the relationship between self-reported and calculated accessibility

Three ordered logistic regressions were generated to explore the relationship between self-reported accessibility and each of the three calculated accessibility measures, while controlling for individual characteristics. A stepwise approach was used to build the final model[6]. The dependent variable is the general self-reported accessibility variable ("*How would you rate your overall access to parks and green spaces from your home?"*).

Table 6-1 presents the summary statistics of all variables included in the analysis. Individual characteristics were selected based on previous studies studying the association between accessibility and individual characteristics. The selected variables have been shown to influence travel behavior as well as accessibility to parks (Lu & Pas, 1999; Pham et al., 2019; D. Wang, Brown, & Liu, 2015; D. Wang, Brown, Zhong, et al., 2015). Individual income level and age were grouped into three categories. An ethnicity variable has been tested in the regression, but the coefficient was not significant, and the model remained stable when removing the variable. It was therefore not included in the final regressions. The number of parks accessible, the surface area accessible and the CIPQAY index score were tested separately in distinct regression models, in order to assess the relationship of each measure with the self-reported accessibility.

Table 6-1 Summary statistics of the variables included in the ordered logistic regressions (N = 683)

Survey data	**Number of observations (%)**
Self-reported accessibility	
None	1(0.1)
Very low	13(2)
Low	26(4)
Moderate	175(26)
High	290(42)
Very high	198(29)
Age group	
18 – 34 years old	208(31)
35 – 59 years old	315(46)
60 years and older	160(23)

[6] Un test de corrélation a également été fait entre les variables indépendantes de ces régressions, en considérant la méthode du chi-carré pour les variables catégorielles. Les résultats confirment que les variables indépendantes des trois régressions sont faiblement corrélées avec des coefficients inférieurs à 0.3.

Table 6-1 Summary statistics of the variables included in the ordered logistic regressions (N = 683) (suite)

Gender of respondent				
Man		328(48)		
Woman		355(52)		
Income level				
Low		275(40)		
Medium		217(32)		
High		116(17)		
No answer		70(10)		
Mode used most to reach parks				
Walking		356(52)		
Public transport		88(13)		
Cycling		59(9)		
Car		165(24)		
	Min	Median	Max	Mean
Number of cars	0	1	11	1.037
Number of children	0	0	11	0.323
Calculated accessibility measures				
Number of parks accessible	0.7	8	66.79	11.41
Accessible surface area	0.0011	0.22	3.17	0.44
CIPQAY index	4.23	13.29	22.59	13.18

Inspired by the method developed by J. Ryan and Pereira (2021), a mismatch index was then calculated by comparing the self-reported and calculated measures for each individual. It was done by converting the numerical variables, in this case the calculated accessibility measures, into categorical variables. Two categories were created: values up to and including the mean were categorized as “low accessibility” and those above categorized as “high accessibility.” This classification was made for the number of parks accessible with a mean of 11.41 parks, the surface area with a mean of 0.44 km^2 and the CIPQAY index with a mean of 13.18 (Table 6-1). This threshold is not proposed as a universal one; it is a context-dependent threshold. Then, a new categorical variable, *mismatching results,* was generated with three categories. First, the “*match*” category was given when the calculated accessibility matched with the self-reported accessibility of the respondent. Second, the “*mismatch underestimation*” category is attributed when the calculated accessibility underestimates the respondent's reported accessibility. Last, the "*mismatch overestimation*" category is when the calculated accessibility measure overestimates the perceived accessibility of the respondent.

This method is applied for the three calculated accessibility measures[7]. The *mismatching results* are then assessed spatially for each of the calculated measures. Further, three multinomial logistic regressions are generated, with the *mismatching results* variable of each calculated accessibility measure as the dependent variable. The category "*match*" is set as the reference. The independent variables used in these three regressions are the same variables used in the ordered logit regression above (Table 6-1).

6.4 Results

6.4.1 Calculated accessibility

Figure 6-2 shows the spatial distribution of the three calculated measures of accessibility to parks, represented by quintiles to allow comparison between the number of parks accessible, the accessible surface area of parks and the CIPQAY index. Starting with the number of accessible parks, accessibility is higher in central Montreal and especially in Downtown, where most of respondents are within the 1st and 2nd quintiles. This is due to the presence of a high number of parks in these areas, regardless of their surface area or their features (El-Murr et al., 2021). In contrast, respondents located farther away from Downtown are characterized by lower accessibility in terms of number of parks accessible. This is especially the case for the East and the West region of the city, with the highest share of respondents within the 3rd to 5th quintile.

For the accessible surface area of parks, respondents located near large metropolitan parks are within the 1st quintile. The spatial distribution represented by quintiles is now different across the city, where respondents living in Downtown are not as frequently found in the first or second quintiles due to the smaller size of parks located Downtown.

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[7] La procédure détaillée de cette méthode est présentée dans l'Annexe B de ce mémoire.

Finally, the CIPQAY index results vary depending on park features and they differ from the two previous measures. A considerable proportion of respondents in Downtown are within the 5th quintile of the CIPQAY index score, implying a lack of park features. The highest accessibility scores are found near large parks and near waterfronts or water bodies.

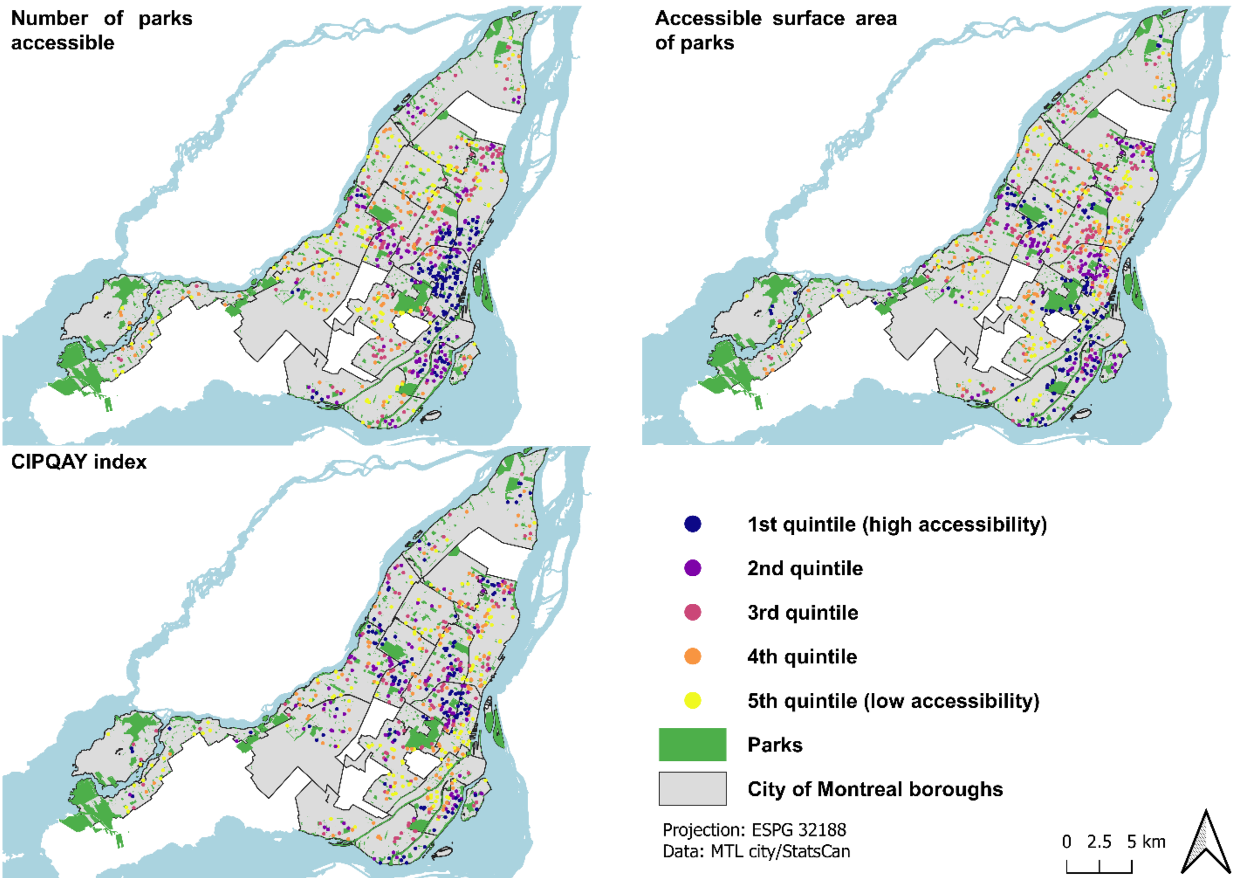

Figure 6-2 Three calculated accessibility to parks measures results of the survey respondents

A correlation test of the three calculated accessibility measures was also conducted to assess the relationship between these three measures[8]. The coefficients indicate a low correlation between each pair of measures. Specifically, the lowest coefficient value is between the number of parks and surface area with a value 0.12 and the highest one is between the surface area and the CIPQAY

[8] Les résultats détaillés du test de corrélation sont présentés dans l'Annexe B de ce mémoire.

index with a value of 0.25. The coefficient between the number of parks and the surface area is 0.18.

6.4.2 Relationship between self-reported and calculated accessibility

To explore the relationship between each calculated accessibility measure and self-reported accessibility, Figure 6-3 shows the bivariate analyses of the relationship between each calculated accessibility measure and self-reported accessibility[9]. Results show that the median value of the number of parks accessible decreases with respondents having higher self-reported accessibility. However, the trend is inverse for the accessible surface area and the CIPQAY index. For example, the median value of the number of parks accessible decreases from 10 parks for respondents reporting "*very low*" to seven for respondents reporting "*very high*". This is not the case for the accessible surface area and the CIPQAY index, where the median value of respondents answering "*very low*" to respondents answering "*very high*" slightly increases. In the two latter measures, the overall values of the upper and lower limits as well as quantiles values increase.

[9] De futures études pourraient s'intéresser aux raisons pour lesquelles des répondants ayant une accessibilité auto-déclarée très faible ont une accessibilité calculée relativement élevée.

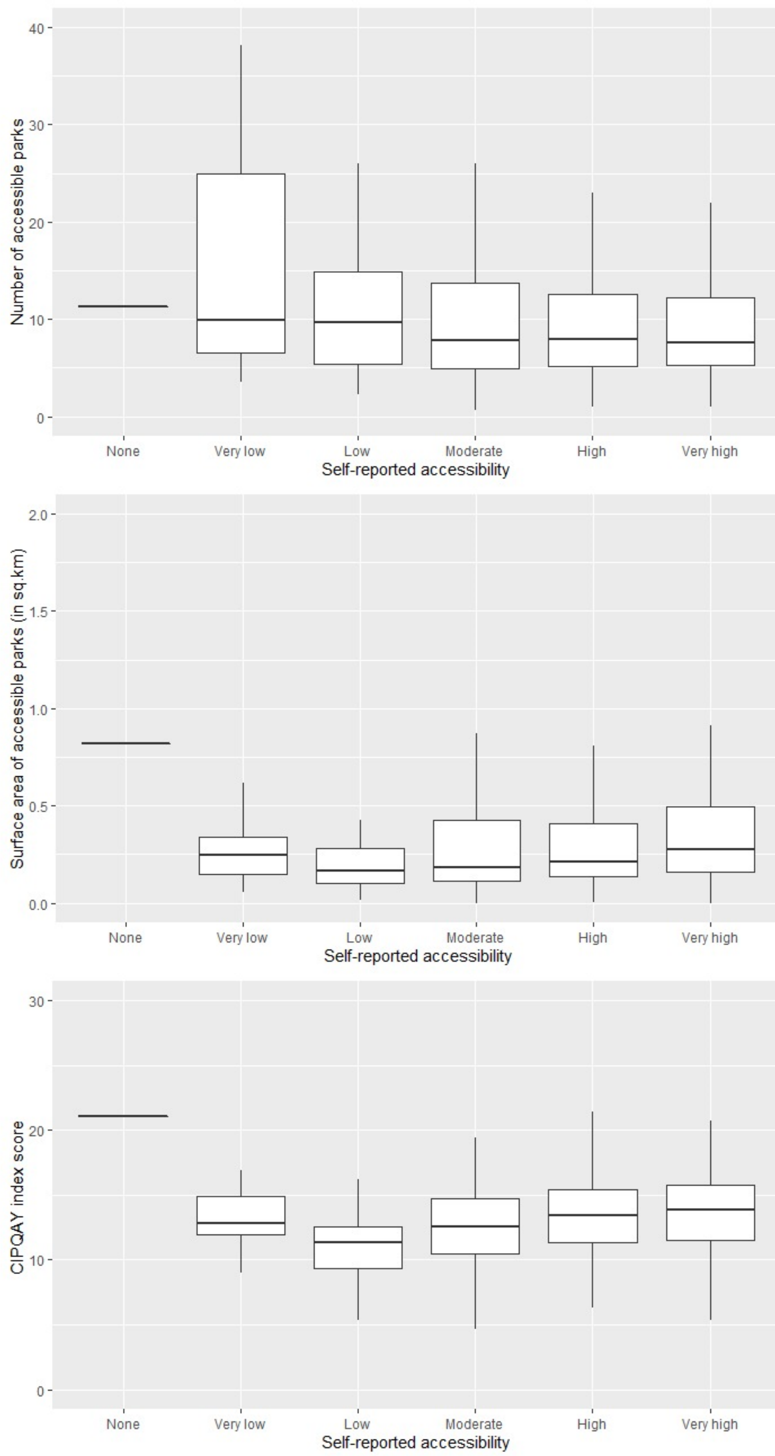

Figure 6-3 Descriptive statistics of the calculated measures according to respondents' self-reported accessibility categories

A deeper investigation is done by generating ordered logistic regressions in order to examine the trends found in Figure 6-3, while controlling for socio-demographic characteristics. Table 6-2 presents the results of the three ordered logistic regressions with the self-reported accessibility as the dependent variable.

Starting with the socio-demographic characteristics, the results are consistent with the literature and are stable across the three regressions. As expected, several individual characteristics are closely associated with self-reported accessibility[10]. Having a low income is significantly associated with a lower self-reported level of accessibility to parks, as found in a previous study conducted in two locations: Brisbane, Australia and Zhongshan, China (D. Wang, Brown, & Liu, 2015). Men have a higher likelihood of reporting higher accessibility than women. Previous studies found gender disparities in terms of park use (Wendel et al., 2012) that could be linked with differences in self-reported accessibility. Findings also indicate that being 60 years and older is associated with a higher self-reported accessibility, as compared to individuals aged between 18 and 34 years old. This might be related to more time available to access parks or that the park amenities better suit their needs. When the number of children increases, the self-reported accessibility decreases. This could be explained by the presence of children affecting parents' travel behavior (Zwerts, Janssens, & Wets, 2007) or that needs are different between households with and without children. Interestingly, visiting a park on foot is significantly associated with a greater self-reported accessibility than reaching parks by car, as found in some other literature (D. Wang, Brown, Zhong, et al., 2015). However, the number of cars is significantly associated with a higher self-reported accessibility.

[10] L'association entre les caractéristiques individuelles et l'accessibilité auto-déclarée est également analysée à partir d'une régression logistique ordonnée de l'accessibilité auto-déclarée (variable dépendante) et les caractéristiques individuelles uniquement (variables indépendantes). Cette analyse est présentée dans l'Annexe B de ce mémoire.

Table 6-2 Results of the ordered logistic regressions of the self-reported accessibility

Independent Variables	**Coefficient estimate**		**prob-value**	**Coefficient estimate**		**prob-value**	**Coefficient estimate**		**prob-value**
Number of parks accessible	-0.01	.	0.045						
Accessible surface area				0.11		0.41			
CIPQAY index							0.11	***	<0.001
Age Group (ref: 18 – 34 years old)									
35 - 59 years old	0.09		0.57	0.09		0.61	0.11		0.51
60 years and older	0.42	*	0.04	0.43	*	0.03	0.44	*	0.03
Gender (ref: Woman)	0.27	.	0.07	0.24		0.11	0.24	.	0.09
Number of cars	0.09		0.09	0.11	.	0.06	0.12	.	0.05
Number of children	-0.12	*	0.05	-0.11	.	0.08	-0.12	*	0.04
Income level (ref: high)									
Low	-0.61	**	<0.001	-0.62	**	<0.001	-0.59	**	<0.001
Medium	-0.33		0.13	-0.31		0.14	-0.32		0.13
No answer	-0.32		0.21	-0.32		0.27	-0.28		0.34
Mode used most to reach parks (ref: car)									
Walking	0.96	***	<0.001	0.93	***	<0.001	0.91	***	<0.001
Public transport	0.31		0.17	0.35		0.17	0.31		0.23
Cycling	0.18		0.14	0.14		0.61	0.11		0.69
Intercept									
None | Very low	-6.32			-6.13			-4.85		
Very low | Low	-3.73			-3.46			-2.18		
Low | Moderate	-2.61			-2.36			-1.08		
Moderate | High	-0.48			-0.27			1.04		
High | Very High	1.46			1.67			3.03		
Signif. Codes: (***) 0 0.001; (**) 0.01; (*) 0.05; (.) 0.1									
Log-Likelihood	-836.21			-839.78			-830.47		
Number of observations	683			683			683		

Looking at the three variables of interest, representing the calculated accessibility, notable differences are visible. In line with Figure 6-3, the number of parks accessible is negatively associated to self-reported accessibility, even when controlling for individual characteristics. However, it is not the case for the accessible surface area as well as the CIPQAY index. Having a higher access to park surface area is associated with a higher self-reported accessibility. In this study, the relationship is not statistically significant, contrary to a previous study, where a positive association between accessible park surface area and superior self-reported accessibility was found (Yasumoto et al., 2021). When considering park features and quality, in the CIPQAY index, the relationship is positive and significant at a 99% confidence interval. This suggests that considering destination's attributes increases the odds of better representing self-reported accessibility, contrary to the number of parks accessible, where the relationship is negative.

6.4.3 Mismatch between self-reported and calculated accessibility

To better understand the differences in the results, the *mismatching results* variable is evaluated. Table 6-3 presents the proportion of *"match"*, *"mismatch overestimation"* and *"mismatch underestimation"* for each calculated accessibility measure. The proportions of *"match"* are respectively 42.02% and 42.75% for the number of parks accessible and the accessible surface. This indicates that for more than half of the respondents, the calculated accessibility does not match the self-reported one. The calculated accessibility tends to underestimate self-reported accessibility. However, the matching proportion increases to 57.83% when considering the CIPQAY index. The CIPQAY index also tends to underestimate the self-reported accessibility, but less frequently than the two other calculated accessibility (29.87% as compared to 46.85% and 49.49%).

Table 6-3 Proportion of mismatching results for each of the calculated measures

	Match	**Mismatch**	
		Overestimation	Underestimation
Number of parks accessible	42.02%	11.13%	46.85%
Accessible surface area	42.75%	7.76%	49.49%
CIPQAY index score	57.83%	12.30%	29.87%

Figure 6-4 presents the spatial distribution of the respondents as a function of the mismatching results for each of the calculated accessibility measure. For ease of interpretation, only the mismatch values (overestimation and underestimation) are presented. The spatial distribution shows that the calculated accessibility measures tend to overestimate self-reported accessibility in the Downtown region of the city of Montreal, specifically for the number of parks and the surface area. The overestimation is less visible in Downtown for the accessible surface area and is present near large parks too. However, when considering the CIPQAY index, the accessibility overestimation is no longer concentrated in Downtown, but the measure tends to overestimate accessibility across the city.

A Moran's I autocorrelation test[11] was done for each measure to verify whether the spatial patterns of the *mismatching results* of the respondents are random. P-values inferior to 0.01 were obtained in the three cases, indicating that there is a less than 1% likelihood that the spatial clustered pattern could be the result of random chance. In other words, the results show that the spatial distributions are clustered. Overall, the results suggest that there are spatial factors that contribute to the discrepancies between the self-reported and calculated measures of accessibility to parks.

[11] Le test d'autocorrélation est fait pour les trois variables *mismatching results* (underestimation, match, overestimation) de chaque mesure calculée pour un seuil de distance minimal de 2095 mètres calculée par la méthode de distance euclidienne.

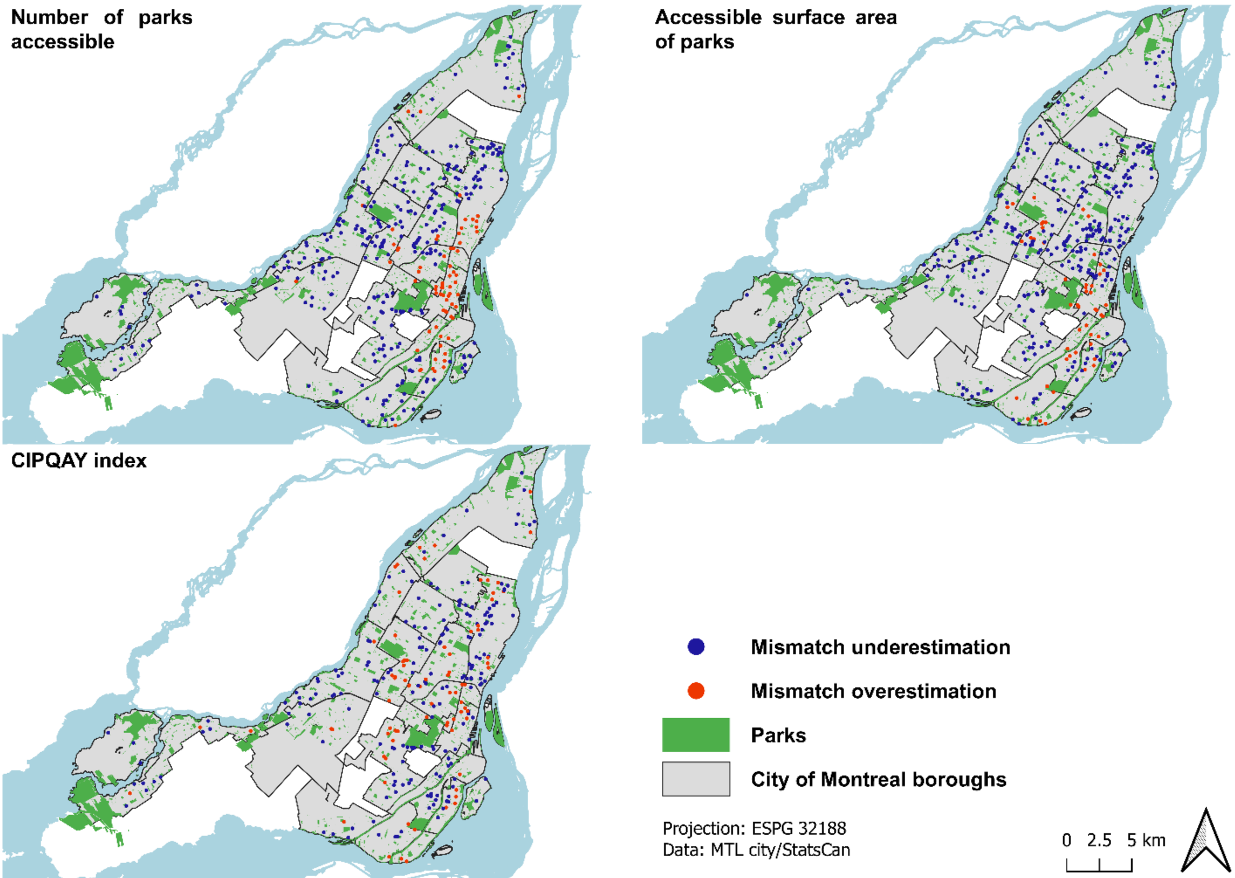

Figure 6-4 Mismatching results between calculated and self-reported measures for the survey respondents

The relationship between individual characteristics and the *mismatching results* was also explored. Table 6-4 presents the multinomial logistic regression of the *mismatching results* variable for the three calculated accessibility measures. Starting with the number of parks accessible, individuals aged 60 years and older are more likely to be characterized by an underestimation than 18-34 years-old individuals. Men are less likely to have an overestimation of their self-reported accessibility. Individuals that consider walking as their most used mode to reach parks are more likely to be characterized by an underestimation than individuals who typically use a car to access parks. Finally, the number of cars is positively associated with a mismatch underestimation and negatively associated with a mismatch overestimation. The regressions for the *mismatching results* of the accessible surface area as well as the CIPQAY index show that that there are fewer variables with significant coefficients. Concerning the accessible surface area, the variables, "the walking mode as the mode most used to reach parks" and "being 60 years old or older" are significant. Being 60 years old or older (as compared to being 18-34 years old) is associated with a lower probability of overestimation. Finally, no variables show a significant association with the *mismatching results* for the CIPQAY index.

The results of the three multinomial logit regressions show that some sociodemographic characteristics are associated with the *mismatching results*, particularly age group and mode used to reach parks, for the number of parks accessible, and to a lower extent, the surface area. It suggests that when considering only the number of parks without considering any other characteristics, the measure deviates from the self-reported accessibility more importantly for specific groups. More efforts would be warranted to investigate the land use, transport and park characteristics that explain the observed mismatch for different individuals.

Table 6-4 Results of the logistic regression model explaining the mismatching results for the three calculated accessibility measures

	Number of parks accessible (ref: match)						**Accessible surface area (ref: match)**						**CIPQAY index (ref: match)**					
	Mismatch Underestimation			Mismatch Overestimation			Mismatch Underestimation			Mismatch Overestimation			Mismatch Underestimation			Mismatch Overestimation		
Independent Variables	Coefficient estimate		prob-value	Coefficient estimate		prob-value	Coefficient estimate		prob-value	Coefficient estimate		prob-value	Coefficient estimate		prob-value	Coefficient estimate		prob-value
Age Group (ref: 18 - 34 years old)																		
35 - 59 years old	0.32		0.11	0.09		0.74	0.37		0.05	0.34		0.32	0.23		0.28	-0.51	.	0.07
60 years and older	1.02	***	<0.001	-0.11		0.79	0.37		0.11	-1.24	*	0.03	0.38		0.13	-0.29		0.39
Gender (ref: Woman)	-0.11		0.53	-0.63	**	0.02	0.05		0.75	0.11		0.75	0.15		0.93	-0.16		0.53
Number of cars	0.24	**	0.01	-0.58	**	0.01	-0.01		0.8	-0.25		0.25	0.06		0.31	-0.17		0.25
Number of children	0.01		0.98	-0.22		0.34	0.01		0.85	-0.04		0.79	0.09		0.34	0.21	.	0.06
Income level (ref: high)																		
Low	-0.22		0.39	-0.01		0.99	-0.21		0.41	0.78		0.12	-0.13		0.61	0.57		0.18
Medium	-0.03		0.89	0.19		0.66	0.09		0.69	0.38		0.47	-0.17		0.51	0.43		0.33
No answer	-0.06		0.86	-0.71		0.27	0.09		0.76	-1.16		0.29	0.04		0.91	-0.01		0.99
Mode used most to reach parks (ref: car)																		
Walking	0.59	***	<0.001	0.09		0.79	0.41	*	0.04	-0.16		0.71	0.35		0.12	-0.57		0.07
Public transport	0.42		0.16	-0.33		0.52	0.56	.	0.06	0.01		0.99	0.71	*	0.02	0.47		0.23
Cycling	0.39		0.23	0.37		0.45	0.26		0.39	0.01		0.97	0.13		0.71	-0.15		0.74
Intercept	-0.77	**	0.03	-0.64		0.31	-0.39	.	0.23	-1.88	*	0.23	-1.15	***	<0.001	-1.31	**	0.02

Signif. Codes: (***) 0 0.001; (**) 0.01; (*) 0.05; (.) 0.1

Log-Likelihood	-625.42	-602.64	-620.67
Number of observations	683	683	683

6.5 Discussion and conclusion

This paper assessed the relationship between calculated and self-reported accessibility measures to parks and green spaces in the city of Montreal, using complementary data sources. For the calculated accessibility, three measures were generated for comparison purposes: the number of parks, the surface area, and a recently developed index - the CIPQAY - which considers park attributes. For the self-reported accessibility, an online survey was conducted and collected data from a representative sample of adult city residents.

The results show different spatial patterns for the three calculated accessibility measures, demonstrating that the accessibility results highly vary depending on the factors that are considered in the measure. Further, the regression analysis shows that there is a negative and significant relationship between the number of parks accessible and the self-reported accessibility. However, the relationship turns positive when considering the accessible surface area and the CIPQAY index score, where the latter is strongly significant. The results of the ordered regressions also confirm that individual characteristics affect self-reported accessibility. The analysis of the mismatch between the calculated and self-reported accessibility reveals that the CIPQAY index results in a lower proportion of mismatch. Further, a spatial analysis of the mismatch shows that calculated measures overestimate accessibility in the Downtown area, when considering the number of parks or the surface area. Finally, findings show that the mismatch overestimation or underestimation resulting from these two latter measures can be partially explained by individual characteristics.

These results have significant implications in terms of developing future accessibility measures. First, the results suggest that considering the destination attributes, as done with the CIPQAY, more closely reflects self-reported accessibility. Another point to mention is the demonstrated relationships between individual characteristics and self-reported accessibility in this study, even when controlling for calculated accessibility. This calls for specific calculated accessibility measures by socio-demographic group in the future. Finally, the study results demonstrate the importance of combining and comparing self-reported and calculated accessibility, as highlighted by J. Ryan and Pereira (2021).

There are limitations and further potential developments to this study that are worth mentioning. First, these measures are susceptible to flawed or missing data. Due to the high number of datasets, especially for the CIPQAY index (El-Murr et al., 2022), it was not possible to do an in-depth validation of each dataset. Second, the aggregation of the calculated accessibility from the residential lot to the postal code level, due to how the home location data was collected, tends to decrease the precision of the analysis. Third, one distance threshold was fixed for all respondents in the survey. Further efforts could be deployed in order to test different thresholds depending on individual characteristics, for example age group. Similarly, the CIPQAY, used in this study to capture park features, was designed specifically for youth. The measure was not developed for adults and may require adjustments. Nonetheless, using this index appears to be relevant as it incorporates several park features and attributes non-specific to youth in the accessibility measure and was found to be positively and significantly associated with self-reported accessibility. It is also important to mention that, to the authors' knowledge, no such index exists for the general population. For the survey, different points must be mentioned. The survey was disseminated in November 2021 and seasonality could be explored by conducting the survey in different seasons. Moreover, self-reported accessibility considered in this study is a global one. Further efforts could be made on the present study to assess self-reported accessibility by park type and transport mode. At last, mismatch categories were defined based on comparing calculated accessibility measures results to the mean value of the sample. Further methods of classification should be tested.

Nonetheless, the study has contributed to shedding light on the relationship between self-reported and calculated accessibility and demonstrated the relevance of considering destination attributes in the calculated measures. Moreover, the results also show the importance of considering the individual dimension in accessibility analyses.

6.6 Authors Contributions

The authors confirm contribution to the paper as follows: study conception and design: El-Murr, Boisjoly and Waygood; data collection: El Murr; analysis and interpretation of results: El-Murr, Boisjoly and Waygood; draft manuscript preparation: El-Murr. All authors reviewed the results and approved the final version of the manuscript.

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CHAPITRE 7 DISCUSSION

Au cours de ce mémoire, l'importance de considérer les différentes composantes de l'accessibilité aux parcs et espaces verts a été mise en évidence. À cet effet, différentes mesures d'accessibilité calculée ont été générées et analysées. Le développement d'une nouvelle méthode incluant la qualité des parcs accessibles, et donc les attributs des parcs, lors de la modélisation de l'accessibilité a été crucial pour résoudre une lacune dans la littérature. Cette lacune omettait les attributs des destinations dans les mesures de l'accessibilité et donc négligeait l'effet de l'aspect de l'aménagement du territoire. Les chapitres 4 et 6 ont par ailleurs démontré que les résultats des analyses d'accessibilité varient de façon importante selon la mesure considérée. Au chapitre 4, les trois mesures d'accessibilité calculée, considérant le nombre de parcs, la surface des parcs et les types d'activités présentes dans les parcs ont été générées pour la ville de Montréal. Les résultats diffèrent entre ces mesures d'accessibilité, démontrant que l'accessibilité varie fortement en fonction des facteurs pris en compte lors de la modélisation. Les différences sont notamment considérables entre le nombre de parcs accessibles et la surface des parcs accessibles. Les variations sont présentes aussi par le type d'activité considérée lors des mesures d'accessibilité. De plus, au chapitre 6, les résultats ont démontré que la mesure générée au chapitre 5, l'indice CIPQAY, qui prend en considération les attributs détaillés des parcs, se distingue des mesures conventionnelles du nombre et de la surface des parcs accessibles. On observe en effet de faibles corrélations des mesures et des patrons spatiaux distincts.

La modélisation de l'accessibilité auto-déclarée était également nécessaire afin d'évaluer la composante individuelle de l'accessibilité aux parcs pour ensuite étudier l'association entre l'accessibilité auto-déclarée et l'accessibilité calculée par ses différentes représentations. Au chapitre 6, l'étude de l'association entre l'accessibilité auto-déclarée, mesurée pour la ville de Montréal dans ce chapitre, et les trois mesures d'accessibilité calculée générées, le nombre de parcs et la surface des parcs au chapitre 4 et l'indice CIPQAY au chapitre 5 ont permis de confirmer l'importance de considérer les attributs des parcs dans les mesures d'accessibilité calculée. Les résultats obtenus dans les modèles logistiques démontrent premièrement que les caractéristiques individuelles influencent l'accessibilité auto-déclarée, même lorsqu'on contrôle pour l'accessibilité calculée. De plus, les résultats confirment que l'accessibilité calculée tenant compte des attributs des parcs (l'indice CIPQAY dans ce mémoire) reflète davantage l'accessibilité auto-déclarée en comparaison aux autres mesures d'accessibilité calculée. Cela témoigne de la pertinence de considérer les attributs des parcs dans les mesures d'accessibilité calculée ainsi que de considérer la dimension individuelle dans les analyses d'accessibilité aux parcs.

En somme, le mémoire démontre que la modélisation de l'accessibilité aux parcs et espaces verts est largement influencée par les attributs des parcs et les perceptions des individus. De plus, les résultats indiquent l'importance de considérer les différentes composantes de l'accessibilité lors de la modélisation.

CHAPITRE 8 CONCLUSION

Le présent chapitre consiste à conclure les travaux de recherche présentés dans ce mémoire. Les résultats de ces travaux ainsi que la méthodologie employée pour les obtenir sont d'abord synthétisés. Cette synthèse est suivie de la présentation des contributions et des limites de la recherche et enfin, de la proposition de perspectives de recherche.

8.1 Synthèse des travaux de recherche

Ce projet de recherche est né du besoin d'atteindre l'objectif principal de recherche qui est de modéliser l'accessibilité aux parcs et espaces verts en considérant d'une part, les attributs des destinations et d'autre part, les perceptions, préférences et besoins des individus. Cet objectif de recherche permet de combler une lacune dans la littérature quant à la considération des attributs des parcs et des perceptions lors de la modélisation de l'accessibilité.

Cet objectif a pu être atteint par le biais de trois sous-objectifs de recherche. Le premier était de mesurer l'accessibilité calculée aux parcs et espaces verts de la ville de Montréal en considérant le nombre de parcs, la surface et les types d'activités présentes dans les parcs. Pour ce faire, les données géospatiales à partir du portail des données ouvertes de la Ville de Montréal (Ville de Montreal, 2021) des parcs et espaces verts et des installations récréatives, sportives et culturelles extérieures ont été utilisées. Trois mesures d'accessibilité calculée ont été générées par la méthode d'opportunités cumulatives pour une distance de 1,000 m à pied à partir des lots résidentiels de la ville. La première mesure compte simplement le nombre de parcs accessibles. La seconde mesure additionne la surface des parcs accessibles. La dernière mesure compte le nombre d'activités accessibles pour cinq types d'activités définies par la Ville : les aires de jeu pour enfants, les activités sportives, les activités de loisir, les activités récréatives et les activités en plein air.

Les résultats ont montré une différence marquée entre les différentes mesures d'accessibilité. 95% des résidents de la ville de Montréal ont accès à trois parcs et plus. Cependant, la surface des parcs accessibles varie considérablement par lot résidentiel. L'accessibilité aux activités varie également dépendamment du type d'activité considéré dans la mesure d'accessibilité.

Le second objectif était de développer une méthode qui considère les différents attributs et la qualité des parcs dans les mesures d'accessibilité. Pour ce faire, la mesure d'accessibilité développée pour cet objectif a été inspirée d'un indice déjà développé qui mesure la qualité d'un seul parc à partir de données géospatiales, et selon cinq catégories : la diversité de jeux structurées, la nature, la surface des parcs, l'entretien et la sécurité. La méthode proposée dans ce mémoire visait premièrement à adapter l'indice en fonction du contexte et des données disponibles. Pour ce faire, les données géospatiales concernant les attributs des parcs disponibles pour l'étude de cas de la ville de Montréal ont été identifiées. Ensuite, la méthode requérait l'adaptation de l'indice déjà développé pour qu'il s'applique à un groupe de parcs, et non pas à chaque parc de façon indépendante. Cette adaptation a été réalisée en changeant l'approche de notation pour chaque variable dépendamment des résultats d'accessibilité obtenus pour chaque variable. La méthode de mesure d'accessibilité est identique à celle évoquée au Chapitre 4 et elle a été générée pour chaque variable qui constitue l'indice. L'indice final obtenu, le CIPQAY, représente la qualité des parcs accessibles, autrement dit l'accessibilité aux parcs en considérant les attributs et la qualité des parcs, pour la ville de Montréal. Il est composé de 17 variables pour une note maximale de 30. Les résultats obtenus sont normalement distribués autour de la moyenne de 12,77 et varient entre 0 (lots résidentiels n'ayant pas accès à un parc) et 23,21 sur 30. La représentation spatiale identifie des régions locales nécessitant une amélioration de la qualité de leurs parcs. Ces régions locales sont distribuées dans toute la ville de Montréal.

Le troisième objectif portait sur l'étude de l'association entre les différentes mesures d'accessibilité calculée et l'accessibilité auto-déclarée aux parcs et espaces verts. L'accessibilité auto-déclarée d'un échantillon représentatif a été mesurée par le biais d'un sondage publié en ligne pour les résidents de la ville de Montréal. Ensuite, les trois mesures d'accessibilité calculée déjà générées, le nombre de parcs accessibles et la surface des parcs accessibles au Chapitre 4 et l'indice CIPQAY au Chapitre 5, ont été associées à chaque répondant à partir de leur code postal. L'association entre chaque mesure calculée et l'accessibilité auto-déclarée a ensuite été évaluée dans trois modèles logistiques ordonnés distincts, tout en contrôlant pour les caractéristiques individuelles des répondants. Aussi, une étude d'inadéquation a été faite entre chacune des mesures d'accessibilité calculée et l'accessibilité auto-déclarée. Les résultats ont par la suite été analysés spatialement et pour les caractéristiques individuelles par des modèles de régression logistique multinomial.

Les résultats des régressions ordonnées montrent qu'il existe une relation négative et significative entre le nombre de parcs accessibles et l'accessibilité auto-déclarée. Cependant, la relation est positive lorsque l'on considère la surface accessible et le score de l'indice CIPQAY, où ce dernier est fortement significatif. Les résultats confirment également que les caractéristiques individuelles affectent l'accessibilité auto-déclarée. L'analyse d'inadéquation entre l'accessibilité calculée et l'accessibilité auto-déclarée révèle que l'indice CIPQAY entraîne une proportion d'inadéquation plus faible que les autres mesures calculées. Les résultats explorent également une distribution spatiale non aléatoire par groupe d'inadéquation. Précisément, les mesures calculées surestiment l'accessibilité dans le centre-ville, lorsqu'on considère le nombre de parcs ou la surface des parcs. Enfin, les résultats de l'inadéquation pour le nombre de parcs accessibles et la surface des parcs accessibles démontrent que ceux-ci s'expliquent partiellement par des caractéristiques individuelles.

En conclusion, cette recherche démontre que la modélisation de l'accessibilité en considérant les attributs des parcs reflète davantage l'accessibilité auto-déclarée que les autres mesures d'accessibilité simples. Cette recherche démontre aussi que les caractéristiques individuelles affectent l'accessibilité auto-déclarée et donc démontre l'importance de la composante individuelle de l'accessibilité. L'étude conduite permet alors de mieux comprendre comment les différentes composantes de l'accessibilité aux parcs peuvent être prises en considération afin de mieux représenter comment les parcs répondent aux besoins des différents individus.

8.2 Contributions

Cette recherche propose plusieurs contributions. Tout d'abord, la recherche présente une nouvelle méthodologie qui peut être utilisée pour considérer la qualité des parcs dans les mesures d'accessibilité aux parcs. Cette mesure, qui considère les attributs des parcs de façon détaillée, est transférable dans différents contextes et peut être opérationnalisée à partir de données géospatiales. Le fait de combiner les attributs des parcs et leur accessibilité permet de mieux représenter ce à quoi les individus ont accès en matière de parc. Cette méthodologie contribue à la littérature sur le sujet, la combinaison de ces deux aspects n'ayant pas été abordée de cette façon dans les études antérieures.

Ensuite, les données collectées par le biais du sondage ont permis d'étudier l'influence de différentes caractéristiques individuelles sur l'accessibilité auto-déclarée aux parcs et espaces verts. Cette analyse a permis de tirer les caractéristiques clé qui affectent l'accessibilité comme le groupe d'âge, le genre, le mode le plus utilisé pour se déplacer aux parcs et le niveau de revenu. Ce mémoire a ainsi confirmé l'influence des caractéristiques individuelles sur l'accessibilité auto-déclarée, dans le contexte montréalais.

Cette recherche s'est aussi penchée sur l'association des mesures d'accessibilité calculée et auto-déclarée aux parcs et espaces verts. Cela a permis d'apporter un éclairage nouveau sur la relation entre ces types de mesures pour les parcs et espaces verts, peu d'études s'étant directement intéressées à cette relation. Cette étude a démontré la différence entre les relations de chaque mesure d'accessibilité calculée et l'accessibilité auto-déclarée et donc a mis en valeur l'importance de considérer les attributs des parcs dans les mesures d'accessibilité calculée. Plus spécifiquement, l'étude a permis de jeter un éclairage nouveau sur les limites des mesures couramment utilisées, en particulier les mesures du nombre de parcs accessibles.

8.3 Limites

Ce projet de recherche présente néanmoins certaines limites. Tout d'abord, les mesures d'accessibilité calculée sont susceptibles de contenir des données erronées ou manquantes. En raison du nombre élevé de bases de données et ceci en particulier pour l'indice CIPQAY, il n'a pas été possible de faire une validation approfondie de chaque base de données. De plus, le seuil de 1000 mètres en distance réseau à la marche pour l'accessibilité aux parcs est un choix basé sur la distance moyenne parcourue par les Montréalais (Lachapelle et al., 2020). Toutefois, ce seuil pourrait possiblement surestimer l'accès aux parcs, particulièrement pour certains groupes d'individus, comme par exemple les personnes âgées, les enfants ou les personnes à mobilité réduite. Plus encore, si la qualité des parcs a été prise en considération, les mesures calculées ont été générées pour tous les types de parcs combinés. Une étude montre que les types des parcs influencent l'accessibilité ainsi que les préférences et les habitudes de fréquentation des parcs (Wendel et al., 2012). En agrégeant tous les types de parcs en une seule mesure, il n'a pas été possible de s'intéresser à cet aspect différencié.

En ce qui concerne spécifiquement l'indice CIPQAY, en complément des limites liées à la qualité des données utilisées, plusieurs hypothèses ont été faites pour adapter les types de notes et seuils. L'absence de lignes directrices normatives et de standards exige que certains choix arbitraires soient faits. Dans le cadre de cette étude, ces choix sont largement basés sur le contexte montréalais. Par exemple, le score binaire pour plusieurs variables (ex. : piscine publique, jardin communautaire, etc.) a été choisi en fonction du contexte dans cette étude. Cependant, cela ne signifie pas obligatoirement que le fait d'avoir accès à au moins un attribut est raisonnable. Plus encore, l'indice CIPQAY n'a pas été validé par des experts, contrairement à l'indice de base (Rigolon & Németh, 2018) qui a été dûment validé par des experts. Enfin, l'indice développé l'a été pour un groupe d'âge spécifique, qui est les jeunes (2 à 18 ans). Quoique plusieurs résultats dans cette recherche avec cet indice ont été significatifs et que plusieurs variables présentes dans l'indice sont communes et valables pour les différents groupes d'âge, tirer des constats sur les attributs des parcs et l'accessibilité en général reste une limite.

En ce qui concerne les données du sondage, l'échantillon n'a pas été pondéré pour être représentatif de la population de la ville de Montréal. L'échantillon d'origine (1017 observations) a été obtenu relativement avec une segmentation par groupe d'âge et de genre tirée à partir des données du recensement 2016 (Statistics Canada, 2016). Pour des raisons d'éthique et de confidentialité, le lieu du domicile déclaré n'est pas le lieu exact. Les répondants avaient le choix entre de choisir l'intersection la plus proche à leur lieu de domicile ou de mentionner leur code postal. Ainsi, les trois mesures d'accessibilité calculée ont été associées à chaque répondant à partir du code postal. Les mesures alors ont été agrégées au niveau du code postal lors de leurs associations. Cependant, l'agrégation spatiale diminue la précision des résultats et mène à une surestimation ou sous-estimation de l'accessibilité pour une part des individus. Cette limite est présente dû aux données disponibles dans le cadre de cette étude. Ensuite, le sondage a été diffusé en novembre 2021 uniquement et le phénomène de saisonnalité et les conditions météorologiques ne sont pas pris en considération. Toutefois, il a été démontré que ces dernières ont une influence sur l'accessibilité auto-déclarée (Spinney & Millward, 2011).

Concernant l'étude de l'association entre les mesures d'accessibilité calculée et l'accessibilité auto-déclarée, cette dernière a été mesurée globalement alors que les mesures calculées sont spécifiques à la marche. De plus, le sondage a été conçu pour les adultes résidents de la ville de Montréal alors que l'indice CIQPAY est spécifique aux jeunes. Ces différences entre les deux types de mesures, calculée et auto-déclarée, présentent une limite majeure de l'étude. En ce qui concerne l'évaluation d'inadéquation, le seuil fixé pour catégoriser les mesures, qui est la moyenne des résultats d'accessibilité de l'échantillon, a été inspiré d'une étude récente (J. Ryan & Pereira, 2021). Toutefois, en absence de normes, ce seuil pourrait surestimer ou sous-estimer les résultats.

8.4 Perspectives de recherche

Plusieurs options s'offrent à une personne souhaitant poursuivre cette recherche. Par exemple, les mesures d'accessibilité peuvent être générées pour différents seuils en fonction des caractéristiques individuelles, par exemple le groupe d'âge. Ces nouvelles mesures pourraient être comparées directement à l'accessibilité auto-déclarée du groupe concerné. Cela permettrait de mieux comprendre les associations ainsi que les divergences, si elles sont présentes, pour les différentes caractéristiques individuelles et ainsi les groupes de la société. De plus, ces mesures d'accessibilité pourraient être testées pour les différents modes de transport avec leur seuil respectif, ainsi que pour les différents types de parcs.

Ensuite, il serait souhaitable de développer une mesure d'accessibilité tel que le CIPQAY qui considère les attributs des destinations, mais pour les adultes, afin de la comparer avec l'accessibilité auto-déclarée par les répondants du sondage. Pour ce faire, une évaluation approfondie avec un groupe d'experts des domaines concernés supporterait les analyses.

Les prochaines études pourraient aussi se pencher sur la segmentation de l'accessibilité auto-déclarée. En effet, l'accessibilité auto-déclarée par mode de transport et par type de parcs pourrait être considérée afin de développer une compréhension plus approfondie. De plus, ses différentes mesures d'accessibilité pourraient ensuite être comparées à des mesures calculées adaptées selon le mode et le type de parcs correspondant. Par ailleurs, d'autres sondages pourraient être lancés à différents moments de l'année afin de mieux comprendre l'effet des conditions météorologiques sur les perceptions.

Finalement, il est possible d'adapter la démarche proposée dans ce mémoire pour l'appliquer dans d'autres villes à travers le monde, notamment par exemple pour le CIPQAY afin de vérifier si cette étude est effectivement transférable. Pour ce faire, il est nécessaire d'avoir des données géospatiales présentant les parcs et leurs attributs ainsi que des données provenant d'un sondage pour mesurer l'accessibilité auto-déclarée et les différentes caractéristiques individuelles. La méthodologie permet d'obtenir des pistes de réflexion sur la façon dont la méthode de modélisation de l'accessibilité aux parcs peut influencer la planification de transport et d'aménagement du territoire dans les villes. Par ailleurs, il serait pertinent d'analyser la relation entre les mesures calculées et auto-déclarées dans d'autres contextes, afin d'identifier les éléments potentiellement transférables d'un contexte à l'autre, ainsi que les éléments qui sont davantage spécifiques au contexte. À cet effet, des analyses comparatives s'avéreraient tout indiquées.

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ANNEXES

ANNEXE A ANALYSES ADDITIONNELLES AU CHAPITRE 5

Cette annexe contient des informations complémentaires au Chapitre 5 de ce mémoire.

Le Tableau A-1 résume les manipulations faites qui se sont avérées nécessaires pour certaines bases de données afin de pouvoir opérationnaliser toutes les variables de l'index.

Tableau A- 1 Manipulation des bases de données pour certaines variables de l'index

Variable	Initial data	Manipulation	Final data
Walking/bike paths and hiking/horseback trail	Trails polygons	Add points along the polygons separated by a distance of 65m	Points separated by a distance of 65m
Shaded behavior settings: playgrounds	All playgrounds points	Add 30 radial lines of a length of 15m	Playground where 50% of the radial lines intersect tree canopy polygons
Shaded behavior settings: sport activities	All sport activities points	Add 30 radial lines of a length of 60m	Sport activities where 50% of the radial lines intersect tree canopy polygons
Distant views (waterfront)	All parks and green spaces polygons	Add a 100m buffer from perimeters of parks	Parks where their 100m buffer intersects with waterfront
Parks maintenance standards	All parks and green spaces polygons	Classify parks by their types	All parks and green spaces polygons with their appropriate maintenance score
Violent crime density	All criminal acts points	Extract points within 100m buffer and inside parks	Extracted criminal acts points

ANNEXE B ANALYSES ADDITIONNELLES AU CHAPITRE 6

Cette annexe contient des informations complémentaires au Chapitre 6 de ce mémoire.

ACCESSIBILITÉ CALCULÉE

Le Tableau B-1 présente les résultats du test de corrélation entre les trois variables d'accessibilité calculée.

Tableau B- 2 Résultats de corrélation entre les variables d'accessibilité calculée

	Number of parks accessible	**Accessible surface area**	**Index CIPQAY**
	Correlation (p-value)	Correlation (p-value)	Correlation (p-value)
Number of parks accessible	1	0.12 (0.0016)	0.18 (<0.001)
Accessible surface area		1	0.25 (0.001)
Index CIPQAY			1

ETUDE D'ASSOCIATION ENTRE ACCESSIBILITÉ AUTO-DÉCLARÉE ET CALCULÉE

Le Tableau B-2 présente la régression ordonnée logistique de l'accessibilité auto-déclarée en fonction des caractéristiques individuelles seulement. L'accessibilité auto-déclarée est alors la variable dépendante et les variables représentant les caractéristiques individuelles sont alors les variables indépendantes. Les résultats de cette régression présentent la même direction et significativité pour toutes les variables indépendantes présentes. Les résultats démontrent que l'accessibilité auto-déclarée varie en fonction des caractéristiques individuelles, nonobstant l'accessibilité calculée.

Tableau B- 3 Résultats de la régression ordonnée logistique de l'accessibilité auto-déclarée

Independent Variables	**Coefficient estimate**		**prob-value**
Age Group (ref: 18 – 34 years old)			
35 - 59 years old	-0.087		0.61
60 years and older	0.44	*	0.03
Gender (ref: Woman)	0.25	.	0.09
Number of cars	0.11	.	0.05
Number of children	-0.11	*	0.07
Income level (ref: high)			
Low	-0.61	**	<0.001
Medium	-0.31		0.14
No answer	-0.32		0.26
Mode used most to reach parks (ref: car)			
Walking	0.95	***	<0.001
Public transport	0.34		0.18
Cycling	0.15		0.57
Intercept			
None | Very low	-6.16		
Very low | Low	-3.49		
Low | Moderate	-2.39		
Moderate | High	-0.31		
High | Very High	1.63		
Signif. Codes: (***) 0 0.001; (**) 0.01; (*) 0.05; (.) 0.1			
Log-Likelihood	-840.12		
Number of observations	683		

Le Tableau B-3 résume la procédure utilisée afin de déterminer le *mismatching results* entre chaque mesure d'accessibilité calculée et l'accessibilité auto-déclarée pour chaque répondant.

Tableau B- 4 Procédure de détermination de la variable *mismatching results* entre chaque mesure d'accessibilité calculée et l'accessibilité auto-déclarée

Calculated measure	Mean	Categorical variable of calculated measure	Self-reported accessibility					
			None	Very low	Low	Moderate	High	Very high
Number of parks accessible	> 11.41	High accessibility	Mismatch overestimation	Mismatch overestimation	Mismatch overestimation	Mismatch overestimation	Match	Match
	<= 11.41	Low Accessibility	Match	Match	Match	Match	Mismatch underestimation	Mismatch underestimation
Accessible surface area (km^2)	> 0.44	High accessibility	Mismatch overestimation	Mismatch overestimation	Mismatch overestimation	Mismatch overestimation	Match	Match
	<= 0.44	Low Accessibility	Match	Match	Match	Match	Mismatch underestimation	Mismatch underestimation
CIPQAY index	> 13.18	High accessibility	Mismatch overestimation	Mismatch overestimation	Mismatch overestimation	Mismatch overestimation	Match	Match
	<= 13.18	Low Accessibility	Match	Match	Match	Match	Mismatch underestimation	Mismatch underestimation