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Résumé de l'article

La qualité de vie des personnes en situation de handicap dépend en grande partie de leur capacité à accéder aux espaces urbains et à mener leurs activités quotidiennes sans restriction. Malheureusement, il existe un écart considerable entre la planification urbaine traditionnelle et la manière dont les personnes en situation de handicap vivent en milieu urbain, ce qui limite significativement leur mobilité et leur participation sociale. Au cours des dernières années, plusieurs gouvernements et administrations ont publié des normes et des directives visant à garantir la création d'environnements accessibles pour faciliter la mobilité pour toutes les categories de la population. Toutefois, l'objectif et les moyens d'améliorer la mobilité des personnes en situation de handicap et l'accessibilité des espaces urbains demeurent peu compris par les autorités publiques et les acteurs impliqués. Afin d'aider les personnes en situation de handicap à surmonter les barrières environnementales qu'elles rencontrent, nous devons mieux comprendre comment elles perçoivent l'accessibilité d'un environnement urbain en tenant compte de l'hétérogénéité de leurs profils. Dans cet article, nous présentons le cadre théorique d'une nouvelle approche pour évaluer l'accessibilité des environnements urbains centrée sur la perception des usagers. Pour prendre en compte la diversité des profils des usagers, le cadre théorique proposé combine les principes du modèle du Processus de production du handicap (PPH) et le Design Cognitif. Ces deux paradigmes fournissent une base solide pour définir des protocoles expérimentaux permettant d'évaluer le niveau d'accessibilité d'espaces urbains contenant divers obstacles et facilitateurs. En outre, cet article illustre l'importance des technologies géospatiales pour la mise en oeuvre de tels protocoles.

Using Geospatial Technologies for Assessing Accessibility of Urban Spaces for People with Motor Disabilities: Theoretical Framework of an Approach Centered on Users' Perception

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Abstract

The quality of life of people with disabilities strongly depends on their ability to access urban spaces and conduct their daily activities without any restriction. Unfortunately, there is a significant gap between traditional urban design and the way people with disabilities live in urban environments, which significantly limits their mobility and hence their social participation. In recent years, several governments and administrations have issued norms and guidelines that aim to ensure the construction of environments that are accessible and barrier-free in order to facilitate the mobility of these people. However, the goal and the means to improve mobility and quality of access to urban environments are still misunderstood by the public authorities and the actors involved. In order to help people with disabilities overcome the existing environmental barriers, we need to better understand how they perceive the accessibility of an urban environment while taking into account the heterogeneity of their profiles. In this paper, we present a theoretical framework of a new approach to assess accessibility of urban environments centered on users' perception. To take into consideration the diversity of users' profiles, the proposed framework combines the principles of the Disability Creation Process model and 'Cognitive Design'. These two paradigms provide a solid background for the definition of experimental protocols for assessing the level of accessibility of urban spaces that may contain diverse obstacles and facilitators. In addition, this paper illustrates the importance of geospatial technologies for the implementation of such protocols.

Keywords: accessibility assessment, users' perception, geospatial technologies, wheelchair users

Résumé

La qualité de vie des personnes en situation de handicap dépend en grande partie de leur capacité à accéder aux espaces urbains et à mener leurs activités quotidiennes sans restriction. Malheureusement, il existe un écart considerable entre la planification urbaine traditionnelle et la manière dont les personnes en situation de handicap vivent en milieu urbain, ce qui limite significativement leur mobilité et leur participation sociale. Au cours des dernières années, plusieurs gouvernements et administrations ont publié des normes et des directives visant à garantir la création d'environnements accessibles pour faciliter la mobilité pour toutes les categories de la population. Toutefois, l'objectif et les moyens d'améliorer la mobilité des personnes en situation de handicap et l'accessibilité des espaces urbains demeurent peu compris par les autorités publiques et les acteurs impliqués. Afin d'aider les personnes en situation de handicap à surmonter les barrières environnementales qu'elles rencontrent, nous devons mieux comprendre comment elles perçoivent l'accessibilité d'un environnement urbain en tenant compte de l'hétérogénéité de leurs profils. Dans cet article, nous présentons le cadre théorique d'une nouvelle approche pour évaluer l'accessibilité des environnements urbains centrée sur la perception des usagers. Pour prendre en compte la diversité des profils des usagers, le cadre théorique proposé combine les principes du modèle du Processus de production du handicap (PPH) et le Design Cognitif. Ces deux paradigmes fournissent une base solide pour définir des protocoles expérimentaux permettant d'évaluer le niveau d'accessibilité d'espaces urbains contenant divers obstacles et facilitateurs. En outre, cet article illustre l'importance des technologies géospatiales pour la mise en œuvre de tels protocoles.

Mots-clés : Mobilité, évaluation de l'accessibilité, perception des usagers, technologies géospatiales, usagers de fauteuil roulant

1. Introduction

The quality of life of individuals within a society is strongly related to their ability to access spaces and conduct activities that are necessary for their happiness and well-being (Doi et al., 2008). Unfortunately, the contemporary urban landscape contains several obstacles that lead to various forms of social exclusion, especially for people with disabilities. This social exclusion is the result of a constraint-based process that hinders an active participation of individuals or groups in the normal activities of their society (Preston & Rajé, 2007).

This gap between traditional urban design and the way in which people live and interact in urban environments generates situations that may significantly limit the quality of social participation and the exercise of human rights (Alexander, 2013; Beck, 2001; Hall, 2005; Hall & Imrie, 1999; Hanson, 2004; Hastings & Thomas, 2005; Imrie & Kumar, 1998; Tessier & Tarabulsy, 1996, Quinn & Degener, 2002; Jain, 2012; Walsh, 2003). An inclusive city is one that allows the exercise of human rights equally by unrestricted access to urban spaces and services – a concern which is clearly announced by national and international organizations such as the Office for people with disabilities in Quebec (Office des Personnes Handicapées du Québec. (2009) and the United Nations (United Nations, 2006). However, the goal and the means to improve the quality of access to urban environments, and to ensure the exercise of rights and full participation of people with disabilities, are still misunderstood by the authorities and actors involved in the field (Sherman & Sherman, 2011). As a result, people with disabilities frequently face urban and social obstacles in their daily life. In addition, persistence of these obstacles generates social inequalities and exclusion for people with disabilities (Borioli & Laub, 2006; Campbell, 2012; Cass et al., 2005; Davis, 2002; Gleeson, 2001; Hanson, 2004; Hastings & Thomas, 2005; Imrie & Kumar, 1998; Wendell, 1996). In contrast, by developing services and infrastructures in response to the diverse needs of its population, an inclusive city tends to reduce exclusion of people with disabilities, which is an essential element for the achievement of their full social participation (Goltsman & Iacofano, 2008).

The inability to move independently and safely leads to various forms of social exclusion. Indeed, for people with motor impairments, the ability to move independently and safely is essential to efficient engagement in their social roles and the exercice of their daily activities such as working, studying, shopping, participating in community life, and so on (Noreau & Fougeyrollas, 2000). Thus, members of society and policy makers should make all the necessary efforts to design environments that meet the needs of all members of the community, including people with special needs.

The 'Universal Design' is an approach that aims to satisfy such an objective. It focuses on all users, to the greatest extent possible, without the need for adaptation or specialized design (Center for Universal Design, 1997). This approach draws on a philosophy of design that recognizes, respects, evaluates and attempts to accommodate the widest range of human abilities, requirements and preferences in the design process (Stephanidis, et al., 1998). By adopting this philosophy, Universal Design prevents the exclusion of people who are generally not considered as belonging to 'the normal population' because of their different abilities (Iwarsson & Stahl, 2003). Within the Universal Design approach, all users are considered as belonging to one population, comprised of individuals with heterogeneous characteristics and abilities (Iwarsson & Stahl, 2003).

In recent years, several governments and authorities have issued norms and guidelines that aim to ensure the construction of environments that are accessible and barrier-free (Institut de réadaptation en déficience physique de Québec, Ville de Québec, & Centre interdisciplinaire de recherche en réadaptation et intégration sociale, 2010; U.S. Department of Housing and Urban Development, 1994; U.S. Architectural and Transportation Barriers Compliance Board, 1988). These norms and guidelines have helped substantially reducing social exclusion caused by characteristics of the physical environment in which people with disabilities carry out their daily activities. Unfortunately, in spite of all these efforts, several public spaces still remain inaccessible or accessible with difficulty. This may be due to several reasons:

1) Norms and standards have not been respected when building the physical environment;
2) Norms and standards do not fully meet the needs and expectations of one or many population groups;
3) The Universal Design approach has failed to design a solution that equitably meets the expectations of all of the population because of the high heterogeneity of needs and abilities.

Aware of the current (in)accessibility condition of urban environments, persons with motor disabilities may take actions to avoid – or at least to reduce – the occurrence of handicap situations related to their mobility (Rochette et al., 2001). Indeed, the mobility of these persons is significantly constrained by their disabilities as well as by various types of obstacles in the environment where they perform their daily activities. According to Disability Creation Process (DCP) (in French: Processus de production du handicap - PPH) (Fougeyrollas et al., 1998), the quality of social participation of people with disabilities is the result of interactions between personal factors (such as identity, and physical and mental abilities) and the physical and social environments in which they live. Therefore, it remains necessary to ensure that individuals with disabilities have the necessary information about the accessibility of the environments (either indoor or outdoor) in which they need to circulate.

Quality of access to urban spaces is strongly related to the presence of obstacles or facilitators within the environment. Accurate information regarding the location and geometric characteristics (shape, dimension, slope, etc.) of these obstacles and facilitators would be of great usefulness for safe and efficient mobility of people with physical disabilities. Indeed, recent advances in geospatial and wireless communication technologies (Geographic Information Systems (GIS), Global Positioning Systems (GPS), Internet and mobile technologies) offer a great opportunity for the development of new assistive solutions to help people with disabilities in their mobility, thereby improving their security, health and social participation (Matthews et al., 2003; Beale et al., 2006; Mackett et al., 2008; Moussaoui et al., 2012; Krūminaitė & Zlatanova, 2014; Kostic & Scheider, 2015). In particular, these technologies provide a variety of features that allow performing advanced spatial analyses, which help people with disabilities overcome diverse obstacles in outdoor environments. These spatial analyses are mainly based on geospatial databases that are used to locate the main obstacles, facilitators and other environmental features that may influence the mobility of people with disabilities. In addition, to perform such types of analysis, the database must contain quantitative assessment (or measurement) of the accessibility of each obstacle or facilitator in order to calculate the most accessible path. Thus, the assessment of accessibility level can be considered as the basis of elaborating assistive navigation devices that respond to the needs and expectations of people with disabilities. The characteristics of the environment, the diversity of profiles of people with disabilities and the difference in these people's perceptions are the main challenges that one faces when assessing the accessibility of the environment (Matthews et al., 2003). Any efficient approach for assessing accessibility should take into consideration these three challenging aspects.

In this paper, we will present the theoretical framework of a new approach to assess the accessibility of urban environments centered on users' perception. The proposed framework takes into consideration the heterogeneity of users' profiles. This approach stems from the Disability Creation Process (DCP) model (Fougeyrollas et al., 1998) and 'Cognitive Design' principles (Yaagoubi & Edwards, 2008) which provide a solid background to develop experimental protocols that will be used to apprehend the perception of obstacles and facilitators among users with different profiles. In this paper, we will show how geospatial technologies will serve to implement such an approach. More specifically, we will focus on people moving with manual wheelchairs in outdoor environments. However, the proposed approach may be adapted and extended to other forms of disabilities.

The following sections of this paper are structured as follow; first, we will present a literature review on issues and approaches pertaining to accessibility measurement. We will then introduce the principles of the Disability Creation Process (DCP) model and 'Cognitive Design', in order to demonstrate how these two paradigms, help us define a theoretical framework that aims to understand how people with motor disabilities perceive and interact with various environmental barriers and facilitators. Then, we will highlight how geospatial technologies can be used to develop an experimentation protocol that integrates DCP and Cognitive Design principles. Lastly, we will detail how an experimental protocol is developed based on the proposed theoretical framework.

2. Previous work on Accessibility Measurement

In general, the measurement (or assessment) of accessibility can be defined as the estimation of the level of access relative to some type of activity from an origin location to one or multiple destinations of that activity. This level of access can be related to constraints such as travel mode, distance, time and cost (Church & Marston, 2003). According to Church and Marston (2003), the measurement of accessibility may be absolute or relative. The absolute measurement refers to the level of access of a group regardless of other groups of population. This type of accessibility assessment includes:

1) Opportunities of activities;
2) Total distances;
3) Closest available facility;
4) Gross interaction potential of a facility;
5) Probabilistic choice of a facility;
6) Net and maximum benefit, and finally;
7) Determination of whether accessible or not (Church & Marston, 2003).

On the other hand, the relative accessibility measurement allows comparing the level of access between two different groups. This type of measurement uses absolute methods for each category of population (using the same method for both groups), and then calculates a simple ratio (Church & Marston, 2003).

In the particular case of people moving with a wheelchair, some studies address the issue of accessibility from the perspective of an enumeration of obstacles and facilitators that exist in the environment (Meyers et al., 2002; Bennett et al., 2009; Welage & Liu, 2011). Other studies have addressed accessibility by focusing on skills developed by wheelchair users' in order to handle obstacles (Manoeuvring, Obstacle negotiating, Wheelie, Making transfers, …)

A third approach within the field of accessibility measurement draws on spatial analysis in Geographic Information Systems (GIS) in order to assess the level of accessibility (Matthews et al., 2003; Beale et al., 2006; Mackett et al., 2008; Sobek & Miller, 2006). These recent studies are informed by GIS spatial analysis functions and geospatial databases, i.e. assigning to each segment of the pedestrian network a value of accessibility based on the obstacles and facilitators that exist in this segment. Thereafter, the GIS solution is used to calculate the optimal route based on values of accessibility that are stored in the spatial database. The main difference among GIS solutions is the method by which the accessibility values of pedestrian segments are assessed before introducing them into the geospatial database. Note that the method of communicating accessibility information to wheelchair users is an essential issue (which is seldom addressed in the scientific literature), however it is beyond of the scope of this paper.

Concerning the existing solutions for accessibility assessment based on GIS, we can refer to three main assistive tools that are: AMELIA, U-ACCESS and MAGUS. These three assistive devices calculate an accessibility value for the proposed optimal route and allow mapping this optimal route on the interface of the GIS solution.

AMELIA (A Methodology for Enhancing Life by Increasing Accessibility) is a GIS solution that is particularly designed to consider elderly people and those moving with wheelchairs (Mackett et al., 2008). The AMELIA GIS database for accessibility was compiled based on three types of barriers:

1) Crossings without dropped kerbs;
2) Footways with an effective width of less than 1000mm;
3) Dropped kerbs with a gradient of more than 5°.

U-ACCESS is a web-based routing tool for pedestrians with different physical abilities (Sobek & Miller, 2006). This solution takes into consideration three levels of physical abilities; peripatetic, aided mobility and the use of a wheelchair. In terms of pedestrian network characteristics, U-ACCESS incorporates sidewalks (minimum width and step height), dropped kerbs (minimum width and step height), ramps (slope, width, turn radius), parking for people with disability (width) and entrance (door handle, minimum step height and width).

The third solution, named MAGUS (Modelling Access with GIS in Urban Systems), is a geographical information system that offers information about route accessibility for wheelchair users in urban areas (Matthews et al., 2003). The values of accessibility incorporated into the MAGUS database take into consideration three aspects: the needs, perceptions and experiences of the users. To do so, the conceptors have adopted an approach that combines questionnaires, focus groups and experiments. The objective of the questionnaire is to identify barriers that impede mobility of people using wheelchairs. Then, focus groups comprised of wheelchair users were accompanied to carry out on-site observations. Some experiments were also conducted in order to assess the rolling resistance of various surface types. In addition, the MAGUS system allows users to include details about their profile. For instance, it invites users to specify their wheelchair type (manual self-propelled, manual assisted and powered), their fitness level from 10% to 100% and their route preferences (shortest route, optimum route, fewest slopes, avoiding bad surfaces, only use crossing with lights and limiting road crossing) (Beale et al., 2006).

The assistive solutions for accessibility listed above are all based on an inventory of environmental obstacles and facilitators in order to incorporate them into each system's geospatial database. The completeness of such a database differs from one solution to another depending on their scopes and purposes (e.g. AMELIA takes into consideration only three types of obstacles, whereas MAGUS incorporates more categories of obstacles and facilitators). Nonetheless, for these three solutions, the value of access level corresponding to the incorporated obstacles and facilitators is calculated based on only two parameters, namely travel mode and the nature of obstacle or facilitator itself. Despite the importance of users' perception in the case of MAGUS, the conceptors' methodological approach doesn't demonstrate in which ways users' perception were taken into account in the assessment of accessibility and how these perceptions relate to different user profiles. Moreover, sending questionnaires by post to participants in order to simply identify the main barriers and facilitators should be deeply rethought. Indeed, some measurements may be perceived differently from one user to another, or even perceived incorrectly. For example, when asked to evaluate a 12% slope, some wheelchair users might not be able to properly construct a mental image of this slope in order to estimate the level of difficulty of such an obstacle. Furthermore, even if their mental image is fairly accurate, the necessary effort of accessing a path with a same slope (12%) depends on the length of the path itself: a path with a slope of 12% on 5m is much easier than another path with the same slope but on 20m.

Considering these limitations, we believe that in order to define a successful and suitable assessment of accessibility, we have to develop an experimental protocol that meets the following criteria:

1) Collecting enough information about the user's profile and his or her level of physical ability;
2) Including the social context in which the participants live and perform their daily activities;
3) Ensuring proper understanding among participants about the meaning of obstacles and facilitators as well as measurements that correspond to these elements;
4) Allowing participants not only to identify various obstacles and facilitators, but also to quote these elements based on their perception;
5) Providing an opportunity for participants to identify and quote obstacles and facilitators that may not be included on the list prepared by researchers who designed the experiment.

In this paper, we propose a theoretical framework for developing experimental protocols that aim to assess accessibility. Based on geospatial technologies, the proposed framework allows us to design an experiment that meets the criteria listed above. In the following section, we will demonstrate how the principles of Cognitive Design (Yaagoubi & Edwards, 2008) and Disability Creation Process (DCP) (Fougeyrollas et al., 1998) help achieve this purpose.

3. Users' perception centred approach for accessibility assessment of urban spaces

As previously mentioned, the measurement of accessibility is a fundamental step for a successful design of any assistive navigation device for people with disabilities. An efficient method of measuring the accessibility should take into account the following factors:

1) Obstacles and facilitators that are present in the environment of navigation;
2) The profile of the person;
3) His or her perception of the environment.

We believe that the Disability Creation Process (DCP) model and Cognitive Design are two approaches that offer a basis for building a robust framework to define a reliable experimentation for assessing the accessibility of the environment of navigation. DCP is a conceptual model that considers the occurrence of handicap situations as the result of the interaction between personal and environmental factors (Rochette et al., 2001). On the other hand, Cognitive Design constitutes a cognitively-informed engineering method for developing assistive technologies (Yaagoubi & Edwards, 2008). In the following, we will review the principles of Cognitive Design and DCP, after which we will highlight the expected strengths of our approach that combines DCP and Cognitive Design. Then, we will show how the proposed users' perception based approach will help us define the mains constraints that should be taken into consideration when elaborating the experimental protocol for assessing accessibility.

3.1 Cognitive Design

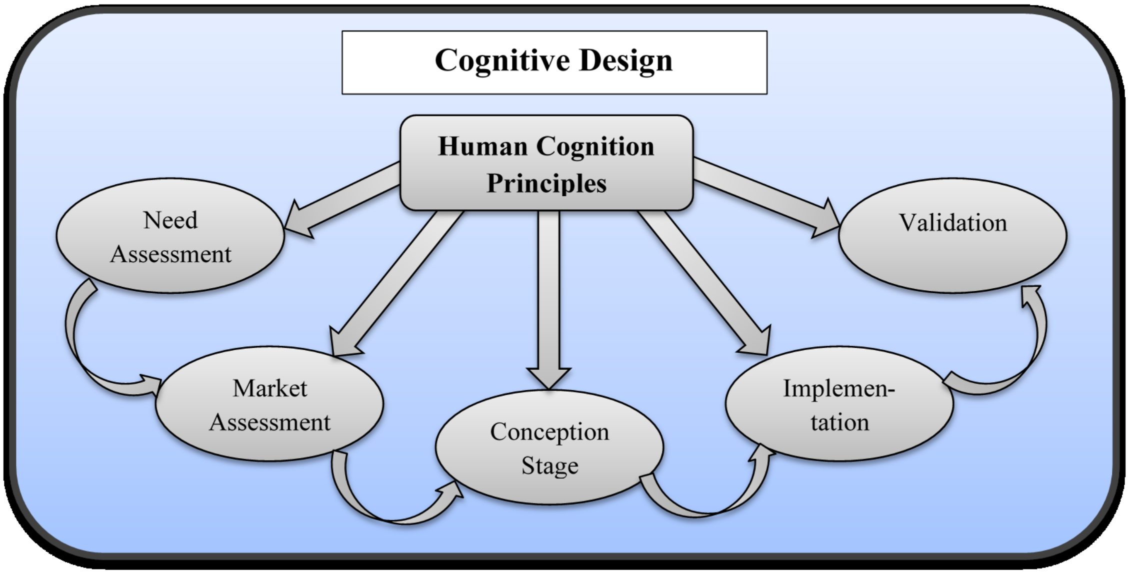
Cognitive Design is an approach that aims to integrate knowledge of human cognition and perceptual organisation into the design process in a systematic fashion (Yaagoubi & Edwards, 2008). This approach was originally developed to design cognitively informed assistive devices that seek to exploit what we know about human cognition to provide functional capabilities that may serve larger groups of individuals. Given that Cognitive Design follows an engineering framework, each phase of this framework has to be fully cognitively enriched. The main phases of Cognitive Design are:

1) Need assessment;
2) Market assessment;
3) Conception;
4) Elaboration and implemention of the solution;
5) Validation based on safety, reliability, reinforcement and preference criteria.

For more details about integrating cognitive principles into each stage, please refer to Yaagoubi & Edwards (2008).

The following figure recapitulates the main phases of Cognitive Design.

FIGURE 1: PRINCIPLES OF COGNITIVE DESIGN



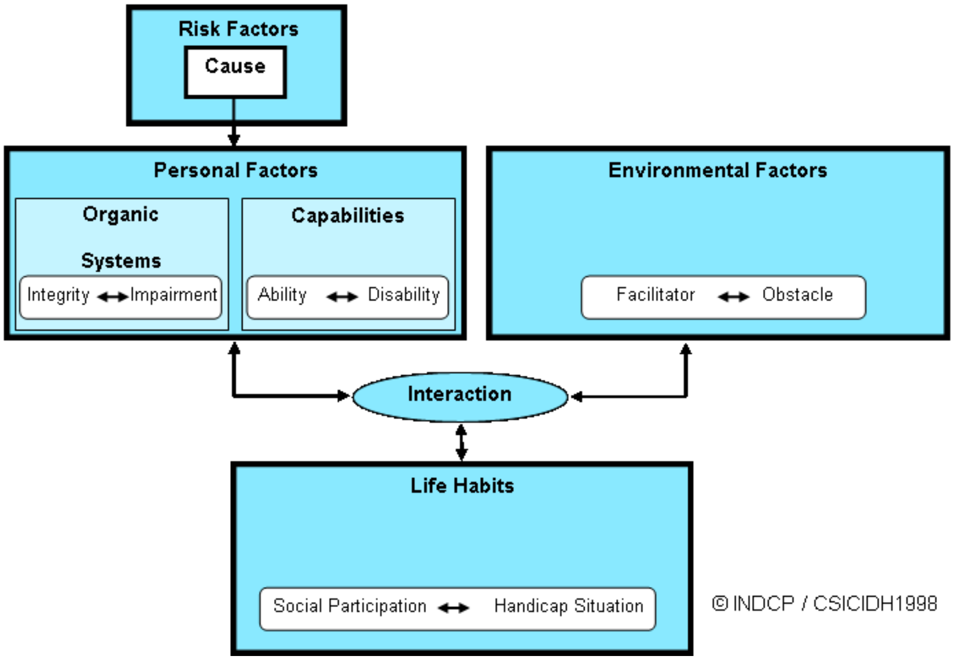
Given that one of the main objectives of accessibility assessment is to design an assistive solution that serves people with disabilities, we believe that adopting the same approach during all the stages of conception leads to suitable solutions that meet the needs and expectations of the users. Thus, in the following, we will emphasis on how Cognitive Design will help us elaborate an efficient experimentation for assessing accessibility for people moving with wheelchairs.

The first step of the Cogntivie Design process is the assessement of needs. This phase may be considered as the key to elaborating an appropriate assistive solution. It is also a very crucial and a complex stage in the Cognitive Design process. Indeed, instead of simply evaluating the functional problem to solve (e.g., assisting people moving with wheelchairs), the process of Cognitive Design requires taking into account the cognitive factors and processes involved in how the person attempts to solve their problem. Considering the contributions of the DCP model which includes elements of social context (Fougeyrollas et al., 1998), this assessment may also need to encompass social constraints. Furthermore, the need assessment stage in Cognitive Design is a dual task: we have to clearly identify functional needs related to carrying out navigational activities with a wheelchair, as well as how these needs are articulated in terms of what is known about cognitive functioning (i.e. how people perceive their own abilities, how they perceive various obstacles and facilitators in the environment, etc.).

3.2 Disability Creation Process

The Disability Creation Process (DCP) is a systemic model of human development which aims to explain the consequences of disease, trauma and other disorders. According to the DCP model, social participation is conceptualised as 'life habits', defined as 'daily activities and social roles that ensure the survival and development of a person in society throughout his or her life' (Hastings & Thomas, 2005). Social participation results from the interaction between individual characteristics (personal factors such as age, gender, impairments and disabilities) and components of his/her life milieu (environmental factors) that modulate the accomplishment of valued activities or social roles (see figure 2). An optimal social participation situation corresponds to full accomplishment of activities of daily living and social roles, whereas a handicap situation restricts the possibilities of these accomplishments.

FIGURE 2: DISABILITY CREATION PROCESS CONCEPTUAL SCHEME



In Figure 2, the "environmental factors" box is clearly delimited and includes all dimensions of the environment (social, cultural, political, physical, etc.) in which the person lives. The dynamic nature of the interactive process is symbolized by arrows in bold typeface. The point of central convergence, marked by the word "interaction", aims at naming the relationship and inter-influence of the three domains: personal factors, environmental factors, and life habits. The model's objective is to clarify the determining variables of the interactive process and to consider this interaction as being in a continuous flux. In the practice of rehabilitation or social integration, this conceptual framework is useful for identifying independent variables and dependent outcomes, measuring change, and knowing why change is occurring if one is able to control the variables in the systemic process. It is a tool for monitoring individual and societal change.

3.3 Main constraints in the experimentation

The elaboration of an experimentation that is based on the principles of Cognitive Design and the DCP allows taking into consideration:

1) The cognitive aspects related to the perception of obstacles and facilitators for people navigation with a wheelchair;
2) The diversity of user profiles related to physical characteristics of the persons;
3) The social and physical environments in which the person will carry out his or her daily activities of navigation.

These three elements strongly influence the mobility of people who use wheelchairs and, hence, the quality of their access to the environment.

Accordingly, we claim that to efficiently assess the accessibility of the environment of navigation, it is mandatory that the experimentation protocol respect the four following principles.

- **The profile of the wheelchair user**

The user's profile is an important factor that has an impact on the perception of accessibility and the way in which one interacts with the environment. For example, it is likely that two people with a similar form of disability but belonging to different age groups will interact differently with obstacles and facilitators. In addition, a person who has better physical fitness will perceive and interact in a different way with obstacles and facilitators than a user with who has lower physical fitness, even if they belong to the same age group (Routhier et al., 2003).

Therefore, the experimental protocol must provide an efficient method to classify wheelchair users into appropriate user profiles. This allows the sytem to assign to each obstacle and facilitator an accessibility level that depends on the profile of the wheelchair user.

- **The experience of the wheelchair user**

The level of experience of using a wheelchair is also an important factor that affects the accessibility of some environments. Indeed, the user's experience is strongly related to the mastering of some essential manoeuvres such as propulsion forward and backward, obstacle-negotiating and the wheelie (Fliess-Douer et al., 2010). The ability to perform these manoeuvres allows some persons using the wheelchair to overcome obstacles which may not be bypassed by less experienced users. Thus, it is important that the assessment allows associating the level of experience to the perception of accessibility.

- **The characteristics of the user's environment**

In order to adequately assess the accessibility of the environment, we mustn't be restricted to its physical characteristics. Although physical properties of the environment such as the width of the sidewalk, the existence of steps, the drop of kerbs, and the quality of pavements are important elements that help evaluate the accessibility of the environment, the social environment also plays a crucial role in quality of access. Indeed, politico-economic factors (e.g. access to employment for people with physical disabilities) and socio-cultural factors (e.g. the familial environment may be a facilitator in case of support or obstacle when overprotection) are important issues that strongly affect quality of access (Fougeyrollas et al., 1998).

Therefore, the experimental protocol should highlight the correlation between physical and social characteristics of the environment and the perception of accessibility among people navigating with a wheelchair.

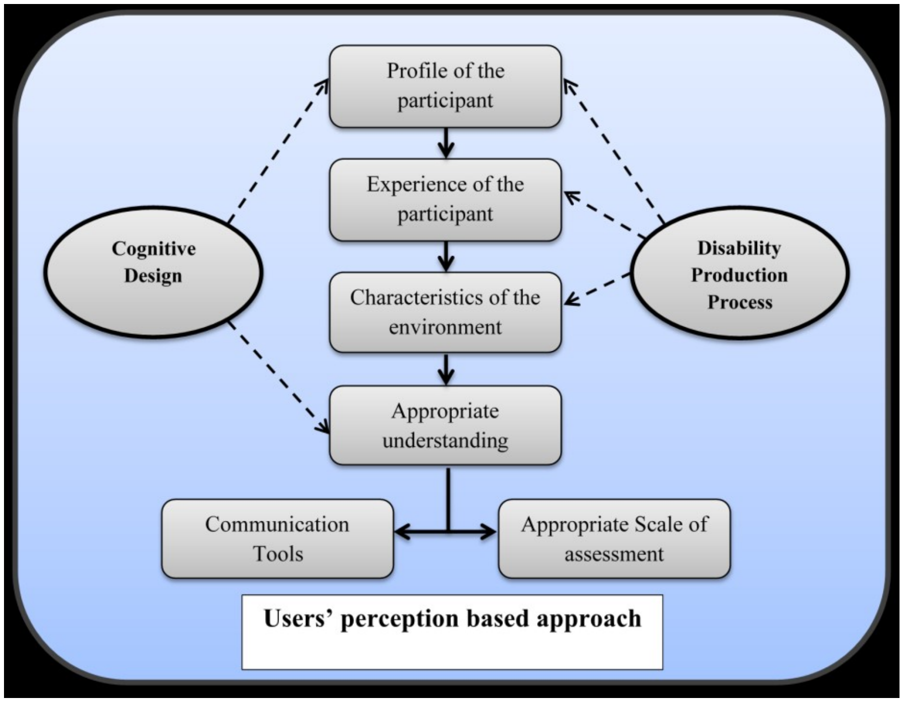
- **Appropriate understanding of the questions**

One of the major challenges of evaluating the perception of accessibility among wheelchair users is adequately identifying the meaning of some measurements that depict the physical characteristics of the environment. For example, examine the following question: 'do you consider a slope of 8% across a distance of 75 meter as a major obstacle?' This kind of question may be qualified as ambiguous or difficult to comprehend for two reasons: firstly, because the measurements may be understood differently (or even not understood) by the participants, thereby affecting the relevance of the assessment process. Secondly, the measurement scale of accessibility assessment is not clear at all in the previous question.

Therefore, in order to better assess the perception of accessibility among wheelchair users, it is necessary that questionnaires be supported by communication tools that facilitate the understanding of physical characteristics of the environment. In addition, the questions should include a measurement scale used to assess precisely and adequately the level of accessibility of obstacles and facilitators.

The following figure recapitulates the most important elements that should be taken into consideration while designing an experimental protocol to assess the perception of accessibility.

FIGURE 3: PRINCIPLES OF USERS' PERCEPTION CENTERED APPROACH



4. Development of an experimental protocol for accessibility assessment based on wheelchair users' perception

In this section, we will examine the particular case of assessing the perception of accessibility for people moving with a wheelchair in more detail. This case serves as an illustration of how our approach may help develop an experimental protocol for assessing the perception of accessibility whatever the type of motor disability or the means of mobility.

The objective of this protocol is to describe the users' daily experiences of mobility and their perceptions of obstacles and facilitators that are present in the environment of navigation. These obstacles and facilitators are mainly related to the outdoor environment, especially pedestrian route networks.

The two specific objectives of the proposed protocol are the following:

1) Identify the main obstacles and facilitators that determine the quality of access to urban areas;
2) Define the level of accessibility of obstacles and facilitators based on the perceptions and the experiences of wheelchair users who have heterogeneous profiles.

4.1 The main obstacles and facilitators in outdoor urban environment

Based on our scientific literature review, we identified the most important obstacles and facilitators that impact the mobility of people using wheelchairs. However, in the questionnaire that we will present later, participants are also given the possibility to add other obstacles or facilitators that may not have been included in our literature review.

In the following, we present the list of obstacles and facilitators that formed the basis for the development of our experimental protocol. This master list mainly draws on the work of Matthews et al. (2003), Mackett et al. (2008), and Bennett et al. (2009) and the practical guide of universal accessibility developed by Quebec City (2010).

Note that obstacles and facilitators mentioned below are mainly related to the accessibility of outdoor environment. The accessibility of buildings and other facilities are out of the scope of this paper.

▪ **Pavement surface**

The type of pavement surface is an important factor in the navigation of wheelchair users in outdoor environments. Each type of pavement may have a different impeding component. Hence, it is necessary to take into consideration the type of the pavement when assessing the accessibility of outdoor itineraries. The main types of pavement surface are: concrete, paving, tarmac, brick, grass and gravel.

▪ **Pedestrian path / Sidewalk**

The pedestrian path or sidewalk may contain the following obstacles or facilitators:

- Width: more than 2m, between 1m and 2m and less than 1m;
- Presence of street furniture;
- Slope of the pedestrian path: more than 1:16, less than 1:16;
- Slope signaling for steep gradient of pedestrian path;
- Pathway maintenance;
- Presence of manholes.

▪ **Crosswalk**

The presence of crosswalks is one of the key issues in the accessibility of outdoor urban environments. People navigating with wheelchairs often need to move from an elevated sidewalk to an intersecting crosswalk in order to safely cross the street (Bennett et al., 2009). The characteristics that help assess the accessibility of a crosswalk are the following:

- Presence of a curb ramp;
- Sidewalk elevation: more than 20 mm, between 10 and 20 mm and less than 10 mm;
- Slope of the curb ramp: more than 1:8, between 1:8 and 1:12 and less than 1:12;
- Presence of a gutter;
- Transition from the sidewalk to the crosswalk through the curb ramp along a distance more than 1.5 m or less than 1.5 m;
- Presence of a road hump.

▪ **Ramp**

A ramp is an installation for joining different levels in order to allow access. In general, ramps are used when stairs obstruct the mobility of individuals. They are often used to ensure access to the entrance of a building. However, they may also be present in outdoor environments such as parks. A ramp may be characterized by the following:

- Presence of steps;
- Slope more than 1:12, between 1:12 and 1:16 and less than 1:16;
- Width of the ramp: more than 1.75m, between 1.75m and 1m and less than 1m;
- Maximum length without landing: less than 9m and more than 9m;
- Length of landing: less than 1.2m or more than 1.2m.

4.2 The design of the experimentation protocol

The experimental protocol that we have developed to assess the perception of accessibility among people navigating with a wheelchair consists of three instruments of measurement:

1) ‘Wheelchair user profile’ questionnaire;
2) JAMAR Dynamometer to measure participants’ strenght;
3) Questionnaire on ‘the accessibility of three routes according to the perception of wheelchair users.

4.2.1 The questionnaire: ‘Wheelchair user profile’

The purpose of this questionnaire is to clearly define the profile of the wheelchair user in order to determine the correlation between the profile of the participant and his or her perception of accessibility.

The 'Wheelchair user profile' questionnaire includes the following elements:

- Socio-demographic and clinical data such as age, gender, type of residence, aerobic capacity, diagnostic and strength;
- Type of wheelchair and the number of years of using a wheelchair;
- Use of other mobility aids;
- Skills of manoeuvring with a wheelchair;
- Frequency of outdoor mobility with a wheelchair;
- Maximal distance to travel in one ride.

4.2.2 Hand strength of the wheelchair user

The second part of the experimental protocol is the measurement of the participant's hand strength. To do so, we use the JAMAR dynamometer which displays the grip strength from 0 to 200 pounds (90 kg).

FIGURE 4: JAMAR DYNAMOMETER
http://www.scriphessco.com/

In order to perform this test, we follow six steps:

1) Ask the participant to sit in a chair with good back support and feet on the ground. The shoulders should be in a position of abduction with a back support and fixed arm rests, the elbows fixed at 90 degrees, the forearms in a neutral position and the wrist between 0 and 30 degrees in dorsiflexion and between 0 and 15 degrees in ulnar deviation.
2) Adjust the dynamometer to fit the size of the participant's hand.
3) When the participant is properly seated, encourage the participant to strongly tighten the JAMAR dynamometer. After 3 seconds, the participant can release the device.
4) Record the maximum value displayed by the JAMAR dynamometer.
5) Repeat the test two more time with the same hand.
6) Repeat steps 1 to 5 with the other hand.

4.2.3 The questionnaire: 'the accessibility of three routes according to the perception of wheelchair users'

This questionnaire aims to assess the accessibility of three routes in Quebec City. The first path is proposed by the research team, while the two other paths are provided by the participants.

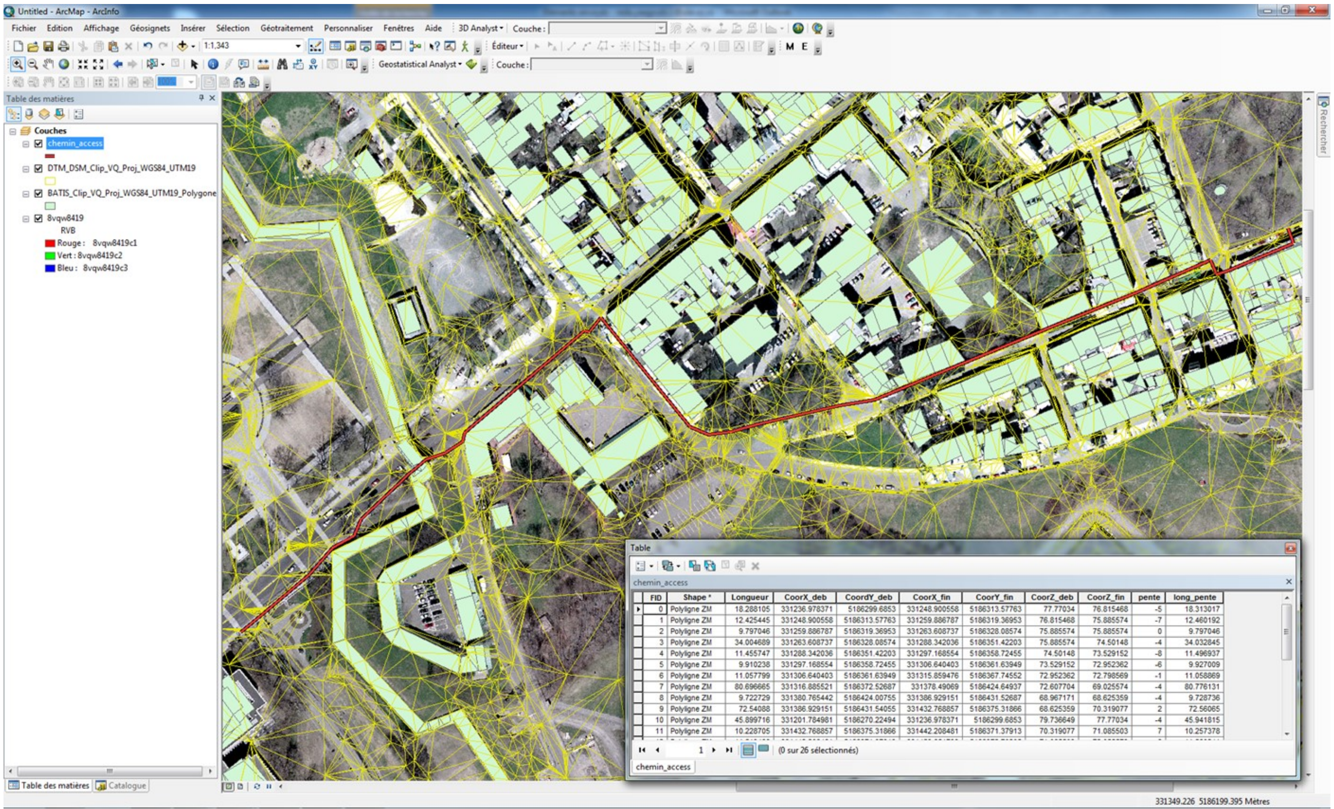
- **The path proposed by the research team**

The research team proposed an itinerary in the Old City of Quebec between 'Parc des Champs-de-Bataille' and 'le Jardin des Gouverneurs' (c.f. Figure 4). This route was chosen because the Old City of Quebec is a historical area which is frequently visited by the residents of Quebec City. In addition, this itinerary contains several obstacles and facilitators that have been identified in the scientific literature.

In order to analyse the proposed route, we used aerial images, Digital Surface Model (DSM) and images from Google Earth. Data was integrated to ArcGIS software, developed by the Environmental Systems Research Institute (ESRI), in order to perform spatial analyses to extract descriptive information such as: the slope of each route segment, the length of the route segment, the width of the sidewalk, the width of the crosswalk, the curb ramp, etc.

The following figure shows the aerial image of the proposed route analysed with ArcMAP, the DSM and the attribute table that contains the slope of each segment of this route.

FIGURE 5: THE PROPOSED ROUTE ANALYSED WITH ARCMAP, WITH THE AERIAL IMAGE, THE DSM AND THE ATTRIBUTE TABLE OF EACH SEGMENT OF THE ROUTE



The itinerary proposed by the research team was divided into 16 segments during the analysis. Each participant is asked to assess the obstacles and facilitators that are present in each segment of the route. The scale used is based on five levels which are:

1) Inaccessible;
2) Difficult;
3) No effect;
4) Quite easy;
5) Very easy.

Another appreciation ('I don't know') is added if the participant is unable to rate the identified obstacle or the facilitator. In addition, the participant can also add obstacles or facilitators for the same segment if they were not included in the questionnaire.

In order to facilitate the understanding of descriptions and measurements outlined in the questionnaire (such as type of pavement, level of the slope, length of the segment, etc.), we used a video-projector to show for each segment the corresponding 360° images from Google Street View (Figure 5) and suitably zommed aerial images.

We believe the use of such images is a powerful approach that helps visually support the information presented in the questionnaire. This leads to appropriate understanding by the participant and hence, accurate assessing of obstacles and facilitators by the wheelchair user.

The following figure illustrates an example of questions related to one segment in the proposed itinerary with the corresponding Google Street View and Google Maps images that are used to support the questionnaire.

FIGURE 6: EXAMPLE OF QUESTIONS RELATED TO ONE SEGMENT OF THE PROPOSED ITINERARY AND THE CORRESPONDING IMAGES FROM GOOGLE MAPS AND GOOGLE STREET VIEW

QUESTION 3: Segment 2: The right side pedestrian sidewalk from 'Grande Allée' towards 'Le Jardin des Gouverneurs' until the beginning of the Saint-Louis Road.

Could you assess the level of accessibility of the following elements?

- Sidewalk paved with concrete:

  ☐ Inaccessible; ☐ Difficult; ☐ No effect; ☐ Quite easy; ☐ Very easy

  ☐ I don't know

- Manhole cover:

  ☐ Inaccessible; ☐ Difficult; ☐ No effect; ☐ Quite easy; ☐ Very easy

  ☐ I don't know

- Slope gradient of the sidewalk at the crossing of Saint-Louis Road:

Taking into account that you are going straight and you will not cross the Saint-Louis Road, how do you assess the difference in height of the sidewalk at the intersection of Saint Louis Road and Honoré Mercier Avenue:

☐ Inaccessible; ☐ Difficult; ☐ No effect; ☐ Quite easy; ☐ Very easy

☐ I don't know

QUESTION 4: Segment 2: The right side pedestrian sidewalk from 'Grande Allée' towards 'Le Jardin des Gouverneurs' until the beginning of the Saint-Louis Road.

Do you think that there are other obstacles or facilitators to mention in this segment? If so, please list and assess them according to the same scale of measurement

☐ Inaccessible; ☐ Difficult; ☐ No effect; ☐ Quite easy; ☐ Very easy

☐ I don't know

- **The Two paths provided by the participants**

The objective of examining two routes provided by the participants is to assess their perception of accessibility according to their daily experience. By offering participants the possibility to propose routes to analyse, we minimize inaccuracy associated to the misunderstanding of questions related to the itineraries because the participant has already taken them in the reality. For both paths provided by the participant, the same approach as for the path proposed by the research team is adopted. This means that the two paths are analysed to extract the measurements related to existing obstacles and facilitators. Also, the images corresponding to each segment of these two well-known paths will be displayed through a video projector.

Participants are asked to provide a path that they consider easy and one that they perceive as more difficult. For example, a participant may propose a route from his home to the library, indicating the streets taken and the position of sidewalk (right or left). The aim of examining easy and difficult paths proposed by the participants is to extract facilitators or obstacles that may not appear in the itinerary provided by the research team. In addition, the analysis may inform us about how experience may influence participants' perception.

It is important to mention that in-situ observations to understand users' perception of accessibility are interesting. However, this kind of method requires much more time and perfect control of the environment to ensure participants' safety. Therefore, the integration of two well-know paths (easy and difficult) in the proposed experimental protocol is an interesting alternative to in-situ observations, because the risk of a misinterpretation of obstacles and facilitators corresponding to different segments is minimal. This is due to the fact that these two routes were taken several times by the participants.

The following table recapitulates the main parts of the proposed experimental protocol based on wheelchair users' perception of the environment of navigation.

TABLE 1: THE MAIN PARTS OF THE PROPOSED PROTOCOL

Experimental Protocol Parts		
Participant profile	Hand strength of the participant	Assessing accessibility of the environment of navigation
Socio-demographic data Clinical data User experience Frequency of using a wheelchair	Measuring strength of the right hand Measuring strength of the left hand	Proposed path by the researcher team Easy path well-known by the participant Difficult path well-known by the participant

5. Discussion and conclusions

In this paper, we presented a new theoretical framework for an approach based on users' perception for assessing the accessibility of urban spaces. To do so, we started by conducting a broad literature review on the methods for the measurement and assessment of accessibility of urban spaces for people with motor disabilities. We noticed that some of these studies address the issue of accessibility by simply enumerating obstacles and facilitators that exist in the environment. Other studies address accessibility by focusing on the wheelchair users' skills that are needed to get around obstacles (e.g. manoeuvring and basic daily living skills, obstacle negotiating skills, and etc.). Finally, some of the existing studies draw on new technologies such as Geographic Information Systems (GIS) and their advanced spatial analysis capabilities to assess the accessibility of urban spaces. In these methods, the level of accessibility with respect to various obstacles and facilitators in the environment is calculated based on two parameters, travel mode and the nature of the obstacle or facilitator. These methods don't consider the perception of users and their profiles in the accessibility assessment process.

The principles of Disability Creation Process (DCP) and Cognitive Design reveal the interest of a deeper reflection on the impact of social factors on the perception of diverse social and physical obstacles and facilitators in the environment. In addition, the diversity of the users' profiles is a critical factor that affects users' perception of the environment. Indeed, carrying out navigation activities in an environment is strongly related to the individual's perception of the obstacles and facilitators that exist therein. Based on this argumentation, we proposed a theoretical framework that incorporates these factors in an integrated approach for the measurement of the accessibility of urban spaces for the navigation of people with disabilities. DCP and Cognitive Design offer the necessary basis to build a robust framework for defining protocols for experiments that consider the perception of users and their profiles. Following the DCP model, we considered not only physical factors but also diverse social factors that affect the mobility of people with disabilities. Regarding the Cognitive Design approach, we described navigation tasks as twofold: on one hand, we clearly identified the functional needs when carrying out navigational activities with a wheelchair; on the other hand, we determined how these needs are articulated in terms of what is known about cognitive functioning (i.e. how people perceive their own abilities, how they perceive various obstacles and facilitators in the environment, etc.).

The use of geospatial technologies is of great interest for the design of experimental protocols that consider users' perceptions when assessing the accessibility of urban spaces. These technologies help capture geometric characteristics (shape, dimension, slope, etc.)

of obstacles and facilitators that may impede or favor the movement of individuals with physical impairments.

To develop an experimental protocol based on the proposed framework, the following factors should be taken into account:

1) The profile of the wheelchair user;
2) The experience of the wheelchair user;
3) The characteristics of the user's environment (i.e. both social and physical environments);
4) The user's perception and understanding of the exact meaning of the questions in the protocol.

With respect to these factors, we have included three instruments of measurement:

1) A 'Wheelchair user profile' questionnaire to collect information on socio-demographic and clinical data, type of wheelchair, user experience, skills, etc.;
2) A JAMAR Dynamometer to measure the strength of the participant;
3) A questionnaire to assess the accessibility of three routes according to the perception of wheelchair users based on geospatial technologies such as GIS, Google Maps and Google Street View.

In the questionnaire that assesses the accessibility of three routes, the first route is proposed by the research team and contains common obstacles and facilitators identified in the literature, while the two other routes are provided by participants to better capture their previous experience and perception of the environment.

The proposed framework presents several advantages. The first is the consideration of the diversity of profiles among people with disabilities, depending on their experiences, their wheelchair manoeuvring skills and their functional capacities. Most of the existing approaches propose an oversimplified measurement of these factors that fails to reflect the specific profiles of persons with motor disabilities. The second important advantage of our framework is the consideration of environmental factors, specifically the inclusion of social components of the environment in accordance with the principles of the DCP model which offers a more integrated representation of environmental factors affecting the mobility of people with disabilities. Finally, through the proposed framework, the users' perception of their environment can be assessed based on their daily experience from their own itineraries (which have different perceived levels of difficulties).

This work is part of an ongoing research project for the development of mobile geospatial assistive technologies adapted for the mobility of people with disabilities. The next phase of this project is to recruit participants to validate the proposed experimental protocol and to evaluate its efficiency. In addition, the consideration of social factors needs further work in order to better integrate economical, cultural, legal and other pertinent dimensions related to social aspect of environmental factors. Further investigations are also needed to capture the opinions and perceptions of people with disabilities on the questionnaire and the way it is formulated.

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References

ALEXANDER E. (2013). Values in planning and design: A process perspective on ethics in forming the built environment. In C. Basta & S. Moroni (Eds.), *Ethics, design and planning of the built environment* (pp. 3-22). Netherlands: Springer Netherlands.

BEALE, L., FIELD, K., BRIGGS, D., PICTON, P., & MATTHEWS, H. (2006). Mapping for wheelchair users: Route navigation in urban spaces. *The Cartographic Journal*, *43*(1), 68-81.

BECK, U. (2001). *La société du risque : sur la voie d'une autre modernité*. Paris : Flammarion.

BENNETT, S., KIRBY, R. L, & MACDONALD, B. (2009). Wheelchair accessibility: Descriptive survey of curb ramps in an urban area. *Disability and Rehabilitation: Assistive Technology*, *4*(1), 17-23.

BORIOLI, J., & LAUB, R. (2006). Le handicap entre nature et processus : applications au milieu urbain. *URBIA - Les Cahiers du développement urbain durable*, *1*(2), 83-93.

CAMPBELL, F. K. (2012). Inaccessible environments as inhumane and degrading: Deconstructing Price V United Kingdom (2001) Implications for (re)reading Sri Lankan Disability Law. *SSRN Electronic Journal*. 2012. Retrieved from https://ssrn.com/abstract=2084562.

CASS, N., SHOVE, E., & URRY J. (2005). Social exclusion, mobility and access. *Sociological Review*, *53*(3), 539-555.

CENTER FOR UNIVERSAL DESIGN. (1997). *The principles of universal design (version 2.0)*. Raleigh, NC: North Carolina State University. Retrieved from https://www.ncsu.edu/ncsu/design/cud/about_ud/udprinciples.htm

CHURCH, R. L. & MARSTON, J. R. (2003). Measuring accessibility for people with a disability. *Geographical Analysis, 35*(1), 83-96.

DAVIS, L. J. (2002). *Bending over backwards: Disability, dismodernism, and other difficult positions*. New York: New York University Press.

DOI, K., KII, M., & NAKANISHI, H. (2008). An integrated evaluation method of accessibility, quality of life, and social interaction. *Environment and Planning B: Planning and Design, 35,* 1098-1116.

FLIESS-DOUER, O., VANLANDEWIJCK, Y. C., MANOR, G. L., & VAN DER WOUDE, L. H.-V. (2010). A systematic review of wheelchair skills tests for manual wheelchair users with a spinal cord injury: towards a standardized outcome measure. *Clinical Rehabilitation*, *24*, 867-886.

FOUGEYROLLAS, P., CLOUTIER, R., BERGERON, H., COTE, J., & ST-MICHEL G. (1998). *Classification québécoise : Processus de production du handicap*. Lac St-Charles, Québec : Réseau international sur le Processus de production du handicap.

GLEESON, B. (2001). Disability and the open city. *Urban Studies*, *38*(2), 251-265.

GOLTSMAN, S., & IACOFANO, D. (2008). *The inclusive city: Design solutions for buildings, neighborhoods and urban spaces*. Berkeley, California: MIG Communications.

GOODLEY, D., & LAWTHOM, R. (2013). Hardt and Negri and the geo-political imagination: empire, multitude and critical disability studies. *Critical Sociology*, *39*(3), 369-384.

HALL, E. (2005). Social geographies of learning disability: narratives of exclusion and inclusion. *Area*, *36*(3), 298-306.

HALL, P., & IMRIE, R. (1999). Architectural practices and disabling design in the built environment. *Environment and Planning B: Planning and Design, 26*(3), 409-425.

HANSON, J. (2004, September). The inclusive city: delivering a more accessible urban environment through inclusive design. In *RICS Cobra 2004 International Construction Conference: responding to change.* York, UK.

HASTINGS, J., & THOMAS, H. (2005). Accessing the nation: Disability, political inclusion and built form. *Urban Studies*, *42*(3), 527-544.

IMRIE, R., & KUMAR, M. (1998). Focusing on disability and access in the built environment. *Disability & Society*, *13*(3), 357-374.

INSTITUT DE READAPTATION EN DEFICIENCE PHYSIQUE DE QUEBEC, VILLE DE QUEBEC, & CENTRE INTERDISCIPLINAIRE DE RECHERCHE EN READAPTATION ET INTEGRATION SOCIALE. (2010). Guide pratique d'accessibilité universelle – Manuel d'utilisation. Retrieved from http://www.ville.quebec.qc.ca/citoyens/propriete/docs/acces/acces_Manuel_utilisation_2010.pdf

IWARSSON, S., & STAHL, A. (2003). Accessibility, usability and universal design - positioning and definition of concepts describing person - environment relationships. *Disability and Rehabilitation*, *25*(2), 57-66.

JAIN, P. (2012). *Limited right to city: The changing meaning of public space*. Columbia University Academic Commons. Retrieved from http://hdl.handle.net/10022/AC:P:13286

KOSTIC, N., & SCHEIDER, S. (2015). Automated Generation of Indoor Accessibility Information for Mobility-Impaired Individuals. In *AGILE 2015* (pp. 235-252). Springer International Publishing.

KRŪMINAITĖ, M., & ZLATANOVA, S. (2014, November). Indoor space subdivision for indoor navigation. In *Proceedings of the Sixth ACM SIGSPATIAL International Workshop on Indoor Spatial Awareness* (pp. 25-31).

MACKETT, R. L., ACHUTHAN, K., & TITHERIDGE, H. (2008). AMELIA: making streets more accessible for people with mobility difficulties. *URBAN DESIGN International*, *13*, 80-89.

MATTHEWS, H., BEALE, L., PICTON, P., & BRIGGS, D. (2003). Modelling access with GIS in urban systems (MAGUS): capturing the experiences of wheelchair users. *Area*, *35*(1), 34-45.

MEYERS, A. R., ANDERSON, J. J., MILLER, D. R., SHIPP, K., & HOENIG, H. (2002). Barriers, facilitators, and access for wheelchair users: substantive and methodologic lessons from a pilot study of environmental effects. *Social Science & Medicine, 55*, 1435-1446.

MOUSSAOUI, A., PRUSKI, A., & MAAOUI, C. (2012). Virtual reality for accessibility assessment of a built environment for a wheelchair user. *Technology and Disability, 24,* 129-137.

NOREAU, L., & FOUGEYROLLAS, P. (2000). Long-term consequences of spinal cord injury on social participation: the occurrence of handicap situations. *Disability and Rehabilitation, 22*(4), 170-180.

OFFICE DES PERSONNES HANDICAPEES DU QUEBEC. (2009). *À part entière, pour un véritable exercice du droit à l'égalité des personnes handicapées*. Gouvernement du Québec.

ORGANISATION DES NATIONS UNIES. (2006). *Convention internationale relative aux droits des personnes handicapées*. New York.

POWELL, J. J. *(2013).* From ableism to accessibility in the universal design university*. Review of Disability Studies: An International Journal, 8*(4), Retrieved from http://www.rds.hawaii.edu/ojs/index.php/journal/article/view/80

PRESTON, J., & RAJÉ, F. (2007). Accessibility, mobility and transport-related social exclusion. *Journal of Transport Geography*, *15*, 151-160.

QUINN, G., & DEGENER, T. (2002). *Droits de l'homme et invalidité : l'utilisation actuelle et l'usage potentiel des instruments des Nations Unies relatifs aux droits de l'homme dans la perspective de l'invalidité*. Genève : Publication des Nations Unies.

ROCHETTE, A., DESROSIERS, J., & NOREAU, L. (2001). Association between personal and environmental factors and the occurrence of handicap situations following a stroke. *Disability and Rehabilitation*, *23*(13), 559-569.

ROUTHIER, F., VINCENT, C., DESROSIERS, J., & NADEAU, S. (2003). Mobility of wheelchair users: A proposed performance assessment framework. *Disability and rehabilitation*, *25*(1), 19-34.

SHERMAN, S., & SHERMAN, J. (2011). Design professionals and the built environment: encountering boundaries 20 years after the Americans with Disabilities Act. *Disability & Society*, *27*(1), 51-64.

SOBEK, A. D. & MILLER, H. J. (2006). U-Access: a web based system for routing pedestrians of differing abilities, *Journal of Geographical Systems*, *8*, 269-287.

STEPHANIDIS, C., AKOUMIANAKIS, D., SFYRAKIS, M., & PARAMYTHIS, A. (1998, October). Universal accessibility in HCI: process-oriented design guidelines and tool requirements. In C. Stephanidis & A. Waern (Eds.), *Proceedings of the 4th ERCIM Workshop on User Interfaces for All*. Stockholm, Sweden.

TESSIER, R. & TARABULSY, G. M. (1996). *Le modèle écologique dans l'étude du développement de l'enfant*. Sainte-Foy : Presses de l'Université du Québec.

U.S. ARCHITECTURAL AND TRANSPORTATION BARRIERS COMPLIANCE BOARD. (1988). *Uniform Federal Accessibility Standards.* Washington, DC: U.S. Government. Retrieved from https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-aba-standards/ufas

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT. (1994). Fair housing accessibility guidelines; Questions and answers; Supplement to notice. Washington, DC: U.S. Government. Retrieved from https://portal.hud.gov/hudportal/HUD?src=/program_offices/fair_housing_equal_opp/disabilities/fhefhasp

WALSH, P. N. (2003). Human rights, development and disability. *British Journal of Learning Disabilities*, *31*(3), 110-112.

WELAGE, N., & LIU, K. P. (2011). Wheelchair accessibility of public buildings: a review of the literature. *Disability and Rehabilitation: Assistive Technology*, 6(1), 1-9.

WENDELL, S. (1996). *The rejected body: Feminist philosophical reflections on disability*. New York: Routledge.

WOLBRING, G. (2012). Expanding ableism: Taking down the ghettoization of impact of disability studies scholars. *Societies*, *2*(3), 75-83.

YAAGOUBI, R., & EDWARDS, G. (2008). Cognitive design in action: developing assistive technology for situational awareness for persons who are blind. *Disability and Rehabilitation: Assistive Technology*, *3*(5), 241-252.