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DEVELOPING A TAXONOMY OF THE BUILT ENVIRONMENT FOR DISABILITY STUDIES. METHODOLOGICAL INSIGHTS

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***Abstract*:** For a city to be inclusive, its physical environment must be identified, characterized and assessed prior carrying out any transformations or improvements. Indeed, such identification is a necessary first step to enhance the impact of appropriate policies for citizens with impairments and functional limitations. The objective of this research was to develop a comprehensive and applicable vocabulary set, for the description of the physical environment in support of the implementation of the United Nations Convention on the rights of persons with disabilities to Quebec City's context, which can, in turn, be applied to other cities and environments. We developed a taxonomy based on the Human Development Model – Disability Creation Process (HDM-DCP). We reviewed documents containing nomenclatures with respect to the specific case of Quebec

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City's physical environment in order to develop a comprehensive taxonomy that could be replicated in other contexts with other datasets. We organized the information under the original taxa of the HDM-DCP; this was carried out via an iterative process where elements of similar type were organized into a common level within one hierarchical branch under more general categories. When categories linking objects to broader subcategories were not already identified, we expanded the structure by creating new sub-categories or hybrids. The applicability of the developed taxonomy was tested through field analyses (photos of street sections) to determine whether all relevant objects and infrastructures in the city were included. The resulting taxonomy was found to be useful in identifying/mapping elements of the physical environment. Both at the individual and collective level, it allows the identification of the elements that play a role in mobility, resulting in enhanced social participation and the reduction of disabling situations for people with disabilities.

Keywords: Taxonomy, politics, disability, mobility, physical environment.

Introduction

The United Nations Convention on the rights of persons with disabilities (CRPD) has its foundation the principles of equality and non-discrimination. It informs signatory states, public and private actors of their responsibilities regarding aspects such as the implementation of policies, services, and infrastructures to ensure all people can access regardless of their disabilities (Fougeyrollas, 2010; Lang, 2009; Mégret, 2008; Shakespeare, 2015; United Nations, 2006). The Convention likewise frames disability in the language of human rights, marking a further move away from biomedical explanations, as the social model had done before, by placing the burden of disability on society and translating the phenomenon into a deficit of rights. Inversely, in an inclusive society respectful of the rights of its members, despite their differences and as defined in the supranational sphere, social and physical barriers within the national space are to be addressed and removed to facilitate social participation and the exercise of

these rights. The implementation of the CRPD at the international level relies on the existence of guiding principles alongside existing and modified national legislative and normative frameworks. However, the CRPD does not offer a precise description or categorization of objects in support of these principles (Lang, Kett, Groce, & Trani, 2011; Quinn, 2008). For a city to be rendered inclusive, its physical environment needs to be identified, characterized and assessed prior to being transformed and improved. In addition, such identification is a necessary first step to ensure the development of policies dealing with what is acceptable or not for citizens with impairments and functional limitations.

The tools currently used to assess accessibility focus on various environmental components as well as descriptors and norms or recommendations (Americans with disabilities act [ADA], 1995; Brownson et al., 2004; Kentucky Cabinet for Education and Workforce Development, 2012; McClain, Lutz, Salmans, & Wright, 1999; Measuring up program-2010 Legacies Now- Accessible Tourism Strategy, 2008; Rimmer, Riley, Wang, & Rauworth, 2004; Rivano-Fischer, 2004; Saelens, Sallis, Black, & Chen, 2003). The absence of taxonomical uniformity renders the identification of factors of the physical environment, their analysis as well as the way bodies interact with them very complex. Most existing tools are based on norms and not on a comprehensive conceptual model providing a specific vocabulary to describe environmental elements. An exhaustive taxonomy of the physical environment is required to implement, in a structured and efficient way, the provision and evaluation of accessible built infrastructures for all professionals and individuals who might be concerned with the improvement of accessibility of the built environment. Many persons with disabilities experience disabling situations (Fougeyrollas, Cloutier, et al., 1999) in their community due to obstacles found in the physical environment (Clifton, Smith, & Rodriguez, 2007; Gray, Hollingsworth, Stark, & Morgan, 2008; Hoehner, Ivy, Ramirez, Handy, & Brownson, 2007; Kirchner, Gerber, & Smith, 2008; Lee, Tudor-Locke, & Burns, 2008; Millington et al., 2009; Spivock, Gauvin, & Brodeur, 2007). This then entails important social and societal costs (Cooper, Cohen, & Hasselkus, 1991; Deliot-Lefevre, 2006; Law, 1991; McClain, Medrano, Marcum, & Schukar, 2000;

Shumway-Cook et al., 2005; Tranter, Slater, & Vaughan, 1991). Thus, to implement the guiding principles of the CRPD and limit the occurrences of such disabling situations, there is a need for the identification as well as the assessment of the diverse components of the built environments, such as objects or infrastructures, as well as their transformations in accordance with the CRPD.

The Centre interdisciplinaire de recherche en réadaptation et intégration sociale (CIRRIS)' research program *Right to equality and Inclusive Cities*, which we are a part of, grounds itself in Henry Lefebvre's (Lefebvre, 1968) radical notion of right to the city which entails the right of people, regardless of their capacities, to inhabit and enjoy the materiality of the city and to participate in its public affairs so as to reshape the processes of urbanization (Harvey, 2008). The CIRRIS program seeks ways through which public actors, community groups, and researchers can come together to improve quality and measurement of access (Fougeyrollas, Boucher, & Charrier, 2017) in order to eliminate environmental obstacles and make cities more inclusive for people with disabilities. In support to these activities, our team sought initially to develop a tool that could be used by all to identify the environmental components (physical and social) of the city and to qualify these as being either facilitators or obstacles to the social participation for people with disabilities. This research was built upon the research experiences of the co-authors as well as the experiences of various people with disabilities who acted as collaborators in the project. Indeed, people with disabilities are experts on what elements in an urban environment favor or hinder their mobility, and their concerns and knowledge need to be considered. For example, an ongoing research project aiming at developing design guidelines for accessible pedestrian infrastructures with municipalities consulted with individuals with motor, visual and hearing disabilities in order to better understand their needs in this regard (Gamache, Routhier, Morales, Vandersmissen, Boucher, et al., 2017; Gamache, Routhier, Morales, Vandersmissen, Leblond, et al., 2017). Many community partners are involved in the *Right to equality and Inclusive Cities* research team and helped generate ideas for this research.

A strong universal and systemic taxonomy of the physical environment built upon an interactionist perspective of disability ensures a common language usable by actors in different stages of the process of making cities more inclusive: from the identification of objects and infrastructures to their assessment and modification in order to improve access to the city.

The objective of this research was to develop a comprehensive and applicable set of information for the description of the physical environment in support of the CRPD. The methodology used for the development of the taxonomy could be adapted and expanded to any context of use. This paper offers insight into the methodological steps that our team underwent in the creation of a taxonomy of the physical environment that contains both particular objects and infrastructures and which is informed by the material reality of Quebec City. It could, however, be applied to other northern countries or other contexts. Furthermore, it should to be pointed that although this paper focuses on the physical environment, broader efforts must be undertaken to integrate the social dimension of the environment. In the ongoing works of our Inclusive Cities research team (Fougeyrollas, 2010; Fougeyrollas et al., 2017), such broader initiatives are also under development.

Scientific classifications and taxonomies

Taxonomies are the result of the process of classification of terms such as species, organisms, and economic activities (Gregg, 1954), and, in this case, physical elements of human dwelling spaces. A taxonomy is composed of taxa, categories, and elements, organized hierarchically as sub-groups or sets of elements going from the most general level of a classification to more specific ones (Gregg, 1954). Under a controlled vocabulary, each level of the taxonomy is created by grouping elements together in categories (Gregg, 1954). For example, a taxonomy of the physical environment of cities organizes elements (e.g. objects and infrastructures) into groups under headings such as “developed environment” which apply to a broad range of concepts (buildings, transportation infrastructure, technologies, etc.), or “natural environment” which refers to

weather, rock formations, topography, etc. (Fougeyrollas, Cloutier, et al., 1999). As used in disability studies, a taxonomy of the physical environment provides a background index of objects and infrastructures that serve to identify and define the elements implicated in a disabling situation. A scientific classification is based upon a conceptual framework, meaning a model identifying concepts and their relations, conceptual definitions, and one or more taxonomies, as previously defined, which allow the identification (via descriptors) of elements as they occur in reality (Badley, 2008; Fougeyrollas, 2010). Qualifiers are then used to encapsulate qualitative and quantitative judgements of the characteristics and properties of an element, for the measurement and evaluation of what can be found in a taxonomy. Before identifying qualifiers; however, a taxonomy must be created to provide a common vocabulary for collaborative work and the application of corrective measures and interventions. In addition, the development of a taxonomy can be done in many different ways, and consequently these various results that might not all be global, holistic and functional for the context of outdoor mobility. Note that a taxonomy is limited in its application (Badley, 2008) as it does not allow for the description of relations between elements within the taxonomy. It is the role of conceptual models to identify and describe the relations between the body and the environment as well as between elements of the environment. Nonetheless, a taxonomy constitutes a fundamental part of any scientific classification aiming at explaining the ecology of a phenomenon (as a whole and via its part), whether this be related to the human development or to how disabling situations emerge.

Situational aspects of disability

The creation of a comprehensive taxonomy of factors of the physical environment leads to the identification of environmental elements such as objects and infrastructures that play a role in the disability creation process. Disability, indeed, is fundamentally situational “i.e., it is through the interaction of a person who has impairments and functional limitations, with elements of the physical environment that do not allow for the realization of socially defined

activities, that disability is created" (Fougeyrollas, 1995; Fougeyrollas & Beauregard, 2001). For example, while a set of stairs could facilitate mobility for one person, it can prove to be difficult to use or become an absolute obstacle for others. This ecological understanding of human development (Bronfenbrenner, 1977, 1979; Fougeyrollas, 2010) requires the consideration of factors of the physical environment as agents in the disability creation process and how they intervene both at the individual and population level. This leads to the necessity of identifying the elements and relations at play within the "interlocked plurality of modes" (Whitehead, 1967, p. 70) of entities at a systemic level; where bodily, personal and environmental factors act upon one another simultaneously, creating possibilities or restrictions of social activity.

As of now, there is no comprehensive taxonomy of the physical components of the environment that is precise and exhaustive enough to be used as a general repertoire from which we could identify, document and report factors of the physical environment in specific contexts; nor does such a taxonomy exist to support the measurement and assessment of properties of the built environment so as to plan modifications that favor the social participation of people with disabilities. However, as previously mentioned, taxonomies are part of scientific classifications, and existing taxonomies should be considered either as a starting point for their expansion or at least as being complementary.

Disability models

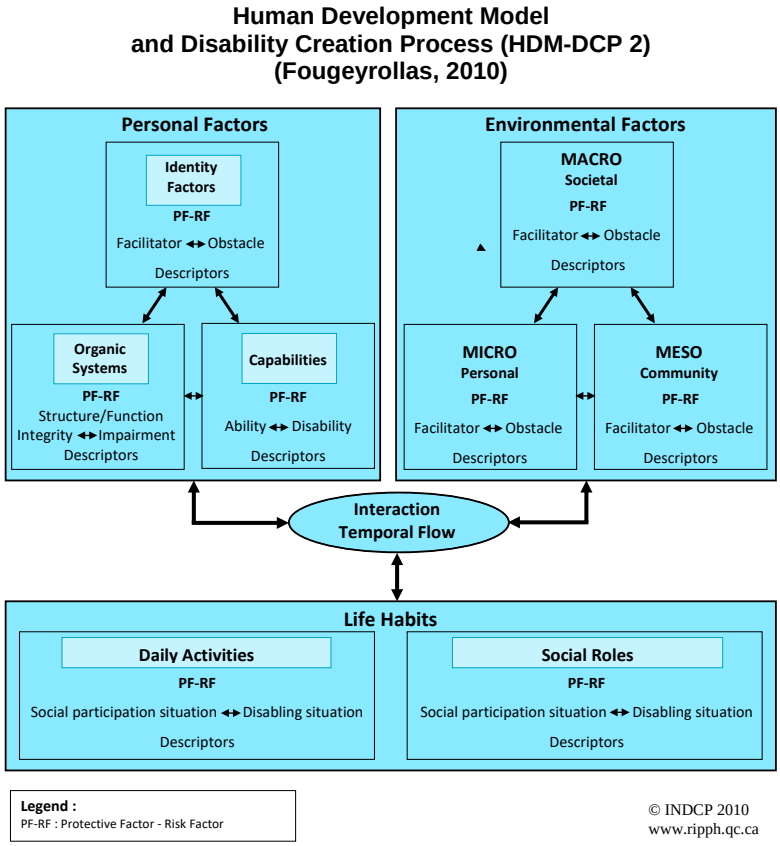
As mentioned earlier, a taxonomy alone does not usually provide the links between different elements of the taxonomy. It should be the task of disability models to explain the links between individual and environmental dimensions as well as social activities in a structured and holistic manner as they occur in disabling situations (Fougeyrollas, Cloutier, et al., 1999). Moreover, the implementation of accessibility practices is an interdisciplinary task which could be applied easily under guidance from appropriate use of disability models.

Contemporary disability models emphasize the role of the environment in the disability creation process (Edwards et al., 2014; Masala & Petretto, 2008; Masala & Petretto, 2010; Shakespeare, 2015). The recognition of the environment as generating sets of factors that influence the development of disability has been enshrined in political models such as that used in the elaboration of the CRPD, the social model (Oliver, 1990; Shakespeare & Watson, 2001), but also in the International Classification of Functioning, Disability and Health (ICF) (Organisation mondiale de la Santé, 2000), and the Human Development Model – Disability Creation Process (HDM-DCP) (Badley, 2008; Fougeyrollas, Cloutier, et al., 1999). Both the ICF and the HDM-DCP have defined taxonomies with broad environmental categories, but none of them have yet been detailed enough to include infrastructures and objects. They are limited in their scope, and their environmental taxonomies have not more than a few hierarchical levels, leaving the specific reality of the world "i.e., its objects and infrastructures, unclassified". However, the ICF and the HDM-DCP are composed of conceptual domains which are used to detail taxonomies regarding the person, his/her environment as well as the life habits he/she performs. This allows a better understanding of disability through the identification of the elements at play in disabling situations. The recognition of the importance of the environment in the process of disability creation in both the ICF and the HDM-DCP has had an substantial impact in the manner we understand disability (Barnes, 2011; Schneidert, Hurst, Miller, & Üstün, 2003; Tøssebro, 2004) and elaborate disability measurements (Palmer & Harley, 2012; Üstün, Chatterji, Bickenbach, Kostanjsek, & Schneider, 2003).

Both classifications provide a strong basis for the development of a more detailed and exhaustive taxonomy of the built environment in order to implement the CRPD and inclusive policies in urban contexts as well as to accommodate the new Sustainable Development Goal encapsulating disability issues (United Nations, 2015). Indeed, initial attempts to address this latter issue for the HDM-DCP have already been begun (Edwards, 2017). The specificities of the HDM-DCP in the province of Quebec where our research team works are more relevant for the

task at hand. The HDM-DCP conceptual model was adopted as the reference framework for the development of the province of Quebec's governmental disability policies (Office des personnes handicapées [OPHQ], 2009) and has served to create new laws that aim to promote the exercise of equality of rights since the end of the 1990's. Municipalities of 15,000 citizens or more, as well as public organizations employing more than 50 people, must prepare each year an action plan that identifies obstacles to the integration of people with disabilities as well as actions undertaken concerning the content of the previous action plan (Governement of Quebec, 2004). Across 25 years of development and use, the HDM-DCP model finds part of its robustness and usefulness in its recognition of environmental elements which are distributed across both social and physical factors. This model is furthermore widely used in clinical practice within the province (Ministère de la santé et des services sociaux, 2003) and has been utilized for the development of tools that help enhance social participation and of the access to the environment (Fougeyrollas, Cloutier, et al., 1999), such as the Measurement tool of the Quality of Environmental Factors (MQE) (Fougeyrollas, Noreau, St-Michel, & Boschen, 1999; Gray et al., 2008; Levasseur, Desrosiers, & St-Cyr, 2008; Noreau, Fougeyrollas, & Boschen, 2002; Whiteneck & Dijkers, 2009) and the Assessment of Life Habits Scale (LIFE-H) (Desrosiers et al., 2004; Fougeyrollas et al., 1998). The HDM-DCP is particularly useful in operationalizing social participation as an outcome, as it considers the temporal dimension in which the interaction between personal and environmental factors takes place. It provides mutually exclusive conceptual domains and dimensions regarding the realm of personal factors including organic systems, capabilities and identity factors that are associated with daily life activities and social roles (see Figure 1). The issue of mutual exclusivity between activities and participation is presently not resolved in the ICF (Badley, 2008; Imrie, 2004; Levasseur, Desrosiers, & St-Cyr, 2007; Whiteneck & Dijkers, 2009). Even though the HDM-DCP's taxonomy of environmental factors is currently limited in terms of content, it possesses a great potential for expansion. This model is directly applicable to Quebec's context to begin with, but could easily be applied to other cities and environments.

Figure 1. . Human Development Model – Disability Creation Process (HDM-DCP). Source: (Fougeyrollas, 2010)



Reference : FOUGEYROLLAS, Patrick (2010). *La funambule, le fil et la toile. Transformations réciproques du sens du handicap.* Quebec : Les Presses de l'Université Laval, 315 p.

The HDM-DCP defines environmental factors as follows: "An environmental factor is a physical or social dimension that determines a society's organisation and context" (Fougeyrollas, Cloutier, et al., 1999, p. 111). As presented in Table 1, in the HDM-DCP's taxonomy, there are four taxa or broad conceptual categories. The first level of categorization divides the model into *Physical factors*, which are: "the artificial and natural elements of the environment" (Fougeyrollas, Cloutier, et al., 1999, p. 119) and social factors, which are "elements of the environment's political, economic, social and cultural systems" (Fougeyrollas, Cloutier, et al., 1999, p. 113). A second level within the category of physical factors subdivides it into a *Nature* taxon, "the biotic and abiotic elements that surround and act upon human beings and who are acted upon in interaction

(sic)." (Fougeyrollas, Cloutier, et al., 1999, p. 119) and a Development taxon, "the elements created, transformed or organised by human beings that influence their environment." (Fougeyrollas, Cloutier, et al., 1999, p. 120). The Development taxon then divides into an Architecture, National and Regional Development taxon and a Technology taxon (see Table 1 for the definition of each term). In this research, we focused our attention on the category Development. The label 2.2.2.1 Urban Development at the lowest level of the original taxonomy is the one we wanted to develop further.

Table 1. HDM-DCP physical factors – development. Source: Fougeyrollas, P., Cloutier, R., Bergeron, H., St-Michel, G., Côté, J., Côté, M., Rémillard, M.-B. (1999). The Quebec classification: Disability creation process: Québec RIPPH/SCCIDIH.

Item	Description
2	**Physical factors: The artificial and natural elements of the environment**
2.2	Development: The elements created, transformed or organized by human beings that influence their environment
2.2.1	Architecture: "Buildings and their components erected by human beings (excluding technology)"
2.2.1.1	Residential Buildings
2.2.1.2	Public Buildings
2.2.1.3	Industrial Buildings

Item	Description
2.2.2	National and Regional Development: "The elements and their components resulting from the transformation and adaptation of geographically limited space according to the needs of human beings. (excluding architecture)"
2.2.2.1	Urban Development: The elements and their components resulting from the transformation and adaptation of space occupied by cities and their suburbs, such as public places, urban parks, urban road networks, etc.
2.2.2.2	Rural Development
2.2.2.3	Reservations and National Parks
2.2.2.4	Circulation Routes
2.2.2.5	Other Land Developments
2.2.3	Technology: "The products of the transformation of matter (excluding architecture)"

It should be noted that the expanded taxonomy could also be integrated into other classifications of factors of the physical environment, such as the ICF, taking into consideration the different conceptual segmentations that such alternative schema would entail. This classificatory process remains a collaborative, gradual and ongoing effort due to the ever-changing contexts of human development, including both the knowledge and the cultural understandings of the world we are trying to describe. The global approach of the HDM-DCP and the ICF and their compatibility with the CRDP and disability studies make them compatible with the taxonomy we developed.

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Methodology and Results

Expansion of the taxonomy

Starting from the original taxonomy of the HDM-DCP, which considers the elements of the environment as factors which can be either qualified as obstacles and facilitators, we developed the taxa to include both objects and infrastructures. We expanded the 2.2.2.1 Urban Development category, allowing us to organize elements in a hierarchical tree to identify environmental components of urban areas with regard to disability. In order to develop an overview of relevant terminology, we examined several existing documents. We began by reviewing documents containing nomenclatures concerning Quebec City's physical environment, including open data from the municipality of Quebec City (database - http://donnees.ville.quebec.qc.ca/donne_details.aspx?jdid=18), the GeoIndex (database - http://geoindex-plus.bibl.ulaval.ca/), the Guide pratique d'accessibilité universelle de la Ville de Québec (Service de l'aménagement du territoire de la Ville de Québec, 2010) (design guidelines to ensure accessibility of urban infrastructures for all), and the Measure of accessibility of urban infrastructures for adults with physical disabilities (MAUAP) (Gamache, Vincent, Routhier, McFadyen, Beauregard, et al., 2016; Gamache, Vincent, Routhier, McFadyen, Routhier, et al., 2016) (tool to assess the level of accessibility of urban infrastructures for adults with physical disabilities) (see the Appendix which describes the constitutive information of these documents). For example, in the Guide pratique d'accessibilité universelle de la Ville de Québec (Service de l'aménagement du territoire de la Ville de Québec, 2010), we found terms such as ramps, signage, stairs, sidewalks, pedestrian paths, crosswalks, paths. We then proceeded to combine the content of these documents into a common repertoire which acts as a general pool containing all of the information from existing nomenclatures of both objects and infrastructures of the city. We organized the information under the original taxa of the HDM-DCP. This step allowed for the identification of duplicates and synonyms, which were eliminated. The remaining elements were merged into simplified conceptual

categories. During this process, objects and infrastructures were grouped under newly created intermediate categories. Elements have been grouped and organized in relation to the properties of the taxa. For example, to classify the object curb cut, two higher-ranking categories were identified, Urban Road Networks and Pedestrian Network and were used to complete the link between the broader categories and the object. The same procedure was followed with the object sidewalk which was classified into the same category since it shared several of the same characteristics as the higher level taxa. The integration of each element was carried out via an iterative process where elements of similar type were organized into a common level of one hierarchical branch (example: sidewalk, curb cut) under general categories (Pedestrian Networks). Likewise, when categories linking objects to broader subcategories were not already identified or were missing, we expanded the structure of the HDM-DCP by creating new sub-categories or hybrids such as Urban Road Networks. In this particular case, the category Urban Road Network was not part of the original taxonomy but was readily found under the definition of Urban Development. The sub-category Pedestrian Network then had to be generated under Urban Road Network to organize elements such as the curb cut and the sidewalk. This allowed for a first expansion and then the linking of the different levels from the pre-existing macro categories to the objects.

In order to classify each element, we answered the following questions: 1- What are the characteristics that are specific to each category and each subcategory? 2- What makes categories mutually exclusive? 3- Does the element share enough characteristics to fit under a category? The validation process allowed us to organize the elements and create subcategories. This is where we differentiated objects, viewed as single elements, from infrastructures, which are structured groups of objects, in order to correctly hierarchize the different taxonomical levels of the physical environment. For an example of the developed taxonomy, see Table 2. The validation process also provided us with the opportunity to differentiate objects from their properties, the latter being related either to design choices or materials entering into the composition of objects. Even though

properties are not part of the taxonomy of the physical environment since the latter only includes objects, some properties can be found in the taxonomy of technology, for example, materials. This issue will be clarified in the discussion section.

Table 2. Example of the developed taxonomy for 2.2- Development, 2.2.2- National and Regional Development, 2.2.2.1- Urban Development, 2.2.2.1.1.3- Urban Road Networks

Level 1	Level 2	Level 3	Level 4
Roads	Street		
	Alley		
	Highway		
	Boulevard		
Physical transportation infrastructure	Juction		
	Section		
	Median		
	Crossing		
	Intersection	Intersection with an angle different from 90°	
		Roundabout	
		T or unaligned crossroad	
		Junction branch block	
		Crossroad with median	
		Crossroad with large radius	
		Crossroad with special traffic patterns	
	Upper passages		
	Bridge		
	Covered bridge		
	Rotating bridge		
	Ford		
	Culvert		
	Tunnel		
	Overpass		
Pedestrian network	Footbridge		
	Sidewalk	Raised sidewalk	
		Lowered sidewalk	
	Pedestrian path		
	Curb cut		

Level 1	Level 2	Level 3	Level 4
	Crosswalk		
	Path	Multi-purpose path	
		Natural path	
	Pedestrian network equipment	Gate	
		Bollard	
		Line	
		Radius	
	Projection		
	Covered walkway		
Cycling network	Cycling path/circuit		
	Cycling trail		
	Cycling segment		
	Cycling track		
	Cycling network equipment	Post	
		Retarder (délai)	
Transportation stops	Bus stop		
	Station		
	Metro station		
	Landing stage		
	Parking	Parking lot	
		Onstreet	
		Interior	
	Reserved parking space		
	Parking equipment	Parking meter	Button
			Slot
			Signage
		Ticket machine	
		Terminal	
		Toll station	
		Guard	
		Parking sticker	
	Signage	Pannel	
		Painting on the ground	
Road signage equipment	Road sign - speed	Epigraph	
	Lit signage	Commemorative plaque	
	Road marking		
Civic address	Postal address		

Level 1	Level 2	Level 3	Level 4
	Street name		
	Generic address		
	Link address		
	Building number		
	Civic number		
Traffic control device	Traffic light		
Pedestrian signage equipment	Optic/call button		
	Time count		
	Post		
	Audible signal		
	Tactile paving		
Surface	Pavement		
	Coating		
	Slab		
	Brick		
Public lighting	Lighting		
	Street light		
	Post		
Urban furniture	Bench		
	Trashcan		
	Bike rack		
	Piknik table		
	Water fountain		
	Anti-noise barrier		
	Retaining wall		

Evaluation of the extracted knowledge

The second phase of this research aimed to evaluate the applicability of the developed taxonomy. This phase consisted of field analyses and testing to determine whether the developed taxonomy included all objects and infrastructures observed in the city. To achieve this, street sections in Quebec City were studied (for an example see Figure 2). Photos of the physical elements were obtained for each road section. For each photo, the path was described using the taxonomy, and we identified missing elements. We found that all permanent public elements were included, but those private elements such as

houses, flower pots, or temporary objects such as a chain fence blocking the entrance to a park or garbage cans would need to be added to complete the taxonomy.

During field tests, concerns were raised regarding the manner in which objects act together in reality. It became apparent that properties of single objects taken alone were not sufficient to understand how these reacted within a disabling situation. Indeed, assemblages of objects can have different properties than those of individual objects. For example, a curb cut is never free-standing. It always exists in relation to its surrounding objects - it is integrated within the sidewalk and is adjusted to fit the contours of the street. The characteristics of each element affect the characteristics of surrounding elements, and their assemblage also acts on the characteristics of each individual element. When we try to assess either use or access to the physical environment, each object must be taken into account in relation to other objects in its surroundings. For example, the steepness of the road or the presence of a drainage grate in relation to the incline and the location of the curb cut might render the curb cut inaccessible due to the important energy expense required to overcome these combined obstacles and the inadequate angle of attack for wheelchair users to manoeuver safely. However, the curb cut in itself might not be inaccessible.

Figure 2. Example of a street section observed in Quebec City

DISCUSSION

The objective of this research was to develop a comprehensive and applicable information set for the description of the physical environment in support of the application of the CRPD and further the UN SGO's in relation to disability and urbanism (United Nations, 2015), but for which the methodology used for the development could be adapted to any context of use. We thus developed a taxonomy based on the HDM-DCP which is applicable in Quebec's context, but could also be applied elsewhere in northern climates. Furthermore, the methodology used to develop the taxonomy adopted a "disability studies" perspective aiming at the ensuring the respect of the CRDP and monitoring of its implementation so as to ensure equal rights for any citizen with disabilities. The

resulting taxonomy was found to be useful in identifying/mapping elements of the physical environment. Both at the individual and collective level, it allows the identification of items that interact with individuals, resulting in enhanced social participation or the reduction of disabling situations for people with disabilities. Some questions remain open, however. First, how should we address composite objects (i.e., objects composed of other objects, such as regular curb cuts vs. curb cuts with tactile paving)? For example, should the taxon Curb Cut be expanded into several subcategories identifying all types of curb cuts including curb cuts with tactile paving or should Tactile paving be placed in Technology as a separate object?

Secondly, the same question can be asked regarding materials entering the composition of objects. Should the object be subdivided into a typology reflecting the materials used or should materials have their own taxonomic section? Materials exist on their own, without necessarily being specific objects. For example, concrete can enter the composition of different objects: it can take the shape of a slab, which can then be a constituent of a sidewalk. Concrete, along with its subcategory concrete slab, was located in the taxonomical branch Technology. However, concrete slab can also be integrated within the taxonomical branch Built environment as a subcategory of Sidewalk, since it enters the composition of the object. When describing an object's materials and design characteristics, these could be regarded as the object's properties. Therefore, the definition of each element could contain an enumeration of its possible properties (materials and design characteristics) to make the taxonomy more operational and coherent without doubling the information content. Properties were a main concern in building the taxonomy since they allow for the identification of qualifiers of objects. For example, to fully describe a sidewalk, its properties need to be identified (i.e., slope) as well as qualifiers derived from observations, such as assessments from measurement scales (i.e., the slope's percentage). It is only through such qualifiers that the object can be judged as a function of its conformity to the functional requirements found in norms or

assessment tools. It is by measuring these qualifiers that one can propose a universal design or corrective intervention.

Another interesting question that arises is how the taxonomy would be used in an ontology of disability in the city – this is to say in the description of the relations between people with disabilities and objects as they happen in real life (Gharebaghi et al., 2017; Riddle, 2013; Vehmas & Makela, 2008). The taxonomy, when used as a background reference for an ontology of the city, leads to a knowledge base of objects, relations and processes of the city that have an effect on participatory or disabling situations. However, other branches of the taxonomy such as Technology, Architecture and the Social dimension, which include laws, policies, governmental agencies, private and public organizations, etc., remain to be developed to describe how the city really works. Since the taxonomy we are working on is a first attempt to structure the information about objects and infrastructure found in a city, these concerns should orient its development in order to answer the needs of actors, groups, stakeholders and governmental agencies with regard to disability and the development of inclusive cities. Additionally, taxonomies of individual and collective functional capabilities should be taken into consideration in the construction/description of an ontology. Scales could also be developed so as to evaluate objects and infrastructures from the perspectives of these different actors as a function of their own levels of expertise and intervention. For example, the scale of analysis at a population level requires the identification of a different set of objects, infrastructures, and relations than an intervention taking place at the individual level (Fougeyrollas, 2010).

The contribution of this study is anchored in the strategy used. More than one way of developing a taxonomy can be adopted, but the most appropriate way to develop a global, holistic and comprehensive taxonomy of the built environment focused on the task of outdoor mobility is not easily found. We proposed here a taxonomy applicable in northern countries, similar to the Quebec context in which this study was performed, but potentially expandable along similar rules to any urban context. The methodology used to develop the taxonomy can be

adapted to different contexts, according to the cultural data of the environment. It allows a contextual approach for the development of such a taxonomy to better analyze the necessary components for safe and efficient outside mobility that provides insight on the juxtaposition of assemblages and individual objects.

Limits

At the moment, the taxonomy of the physical environment developed here only represents the entities identified in the documents we consulted; it identifies only the objects found in Quebec City. Furthermore, the taxonomy only includes objects that were identified as being pertinent for the developers of these documents. To reach a higher degree of universality, documents from other cities and other sources should be considered. It is only through the compilation of data from a diversity of contexts that we can expect to reach a point of information saturation. Indeed, the taxonomy developed here has not yet been validated via different communities of practice (e.g. urbanists, engineers, occupational therapists) to ensure that it reflects different types of formal knowledge. Also, the testing phase led us to recognize that work needs to be done on other branches of the taxonomy, in particular on the technological taxonomy, and, more generally, on the social aspects. Only then would the taxonomy be sufficiently developed to ensure integration within appropriate ontologies allowing for the full identification of interactions between taxa. The taxonomy could also be completed with appropriate qualifiers, scales and assessment tools for tangible urban field applications.

Conclusions

This research involved the development of a comprehensive and applicable information set for the description of the physical environment in support of the application of the CRPD. The development of the taxonomical arborescence allowed further development of the HDM-DCP. Starting from pre-existing documents and taxonomies of the physical environment, we used an iterative approach to classify objects and infrastructures to create intermediate categories

which served to complete the taxonomic structure of the HDM-DCP. The results of this study are of two kinds, methodological and taxonomical. The methodological results consist of the organized integration of elements from documents into a structured taxonomy, the identification of concepts relative to objects and infrastructures at play in the disability creation process or in support of greater social participation, the differentiation of elements and their properties, and the recognition of other dimensions of the environment (such as social components and technology) that need to be developed to complete a realistic description of the urban space. Moreover, to ensure the universal character of the taxonomy, a further methodological step would involve the integration of documents from different geographical and cultural contexts. The taxonomical results consist of a full taxonomy of the physical environment, the identification of missing categories and subcategories of the HDM-DCP, the development of categories linking the general categories already found in the HDM-DCP with the objects and infrastructures found in diverse documents, and the finding that the taxonomy needs to be periodically updated to reflect the changes taking place in the real world.

From our perspective, organizing a city's environmental elements into a single taxonomy considerably increases the potential knowledge available to city actors (such as persons with disabilities, activists, stakeholders, and governments) and users of their own environment. Future studies should allow for the development of tools that are sensitive to cultural and legal contexts as well as normative goals and structural capacities. The latter would provide a common ground for academics and researchers to create national, regional or localized accessibility assessments based upon the developed taxonomy of factors of the physical environment. As stated previously, these tools should be universal enough to be used in different contexts but specific enough to engage the lived reality of persons with disabilities minimizing distortion from representations or interpretations.

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