New perspective on the accessibility of railway transport for the vulnerable traveller

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Abstract. Vulnerable travellers experience various problems in the transport environment. These may reduce public travel confidence and consequently lead to decreased mobility. A goal of our research is to find out how to improve the accessibility to railway travelling, especially, for persons with functional limitations. By reducing barriers, the ability of travelling would be improved, and consequently allow for more flexible travel behaviors. In order to develop a model and a method of measurement for accessibility, we (a) constructed a reference group of representative *'typical older persons'* (65-85 years) from questionnaire data, and (b) developed an accessibility measure for persons with functional limitations. In this measure barriers have different weights for the different persons depending on their functional ability and travel behavior. This gives the probability of facing a certain barrier when travelling to a certain destination; that is, a measure of accessibility for the individual. The more weight placed on a certain barrier, the less probable it is that the particular journey will take place. These weights will be obtained in forthcoming research on the perception of a set of various travel scenarios representing barriers.

1. Introduction

An overall goal of our research is to find out how we may improve the accessibility to railway travelling for persons with functional limitations. For the group of "vulnerable travellers" different kinds of functional limitations lead to different problems in the transport environment; covering the whole trip, from start to arrival at the intended place of destination. Traditionally, transportation research has been conducted with "mainstream" travellers who are viewed as interchangeable. But, the experience of the travel environment and its impact will differ among individuals, depending on where and when travel takes place. For the group of "vulnerable travellers" different kinds of functional limitations will lead to various problems in the transport environment. For instance, persons with cognitive impairment, involving stroke, dementia and brain injuries, often face specific accessibility problems such as coping difficulties in an increasingly changing travel environment. Also the elderly may have problems with our computerized information society. This can reduce public travel confidence and consequently lead to decreased mobility. Moreover, the severity of each type of functional limitation as well as other factors such as earlier travel

experiences and factors related to personality, would certainly affect the interpretation of the travelling situation. Therefore, a focus on the individual with his/her specific or manifold of functional limitations would reveal needs that are disguised in the larger population. Moreover, it seems wise to include persons that are *not* travelling, because they already encountered insuperable barriers in travel environments. Without these would-be passengers, the most important factors might be missed among those that ought to be improved in the travelling system.

2. The concept of accessibility

There is no definition of accessibility that is uniform or generally accepted. Gould [1] describes it as "a slippery notion", that is a common concept widely used until faced with the problem of defining and measuring it. Accessibility research is found in i.a. geography, economics, occupational therapy and psychology, and its definition differs depending on the goal of the research. For example, in the United Kingdom [2], the concept of accessibility for persons with impairments is used in two different contexts: either to describe design characteristics that improve (or prohibit) the travelling or to describe the ease of reaching an intended destination. 'Accessibility' is used as a quantity in planning for measuring how the travel chain in a transport network performs for various groups of passengers. Even though its definition has not become uniform and generally accepted, the main distinction in recent definitions is that accessibility is an attribute of people *and* of places [3].

3. Accessibility measures

Not only are there many different definitions of accessibility, there are also many different ways of measuring it. Depending on scientific discipline, different ways of measuring accessibility have developed that capture different aspects or dimensions of the concept [4]. Thus, there is no consistent terminology for describing the various methods of measuring accessibility. However, it is fruitful to distinguish between two accessibility constructs: *place* accessibility and *individual* accessibility.
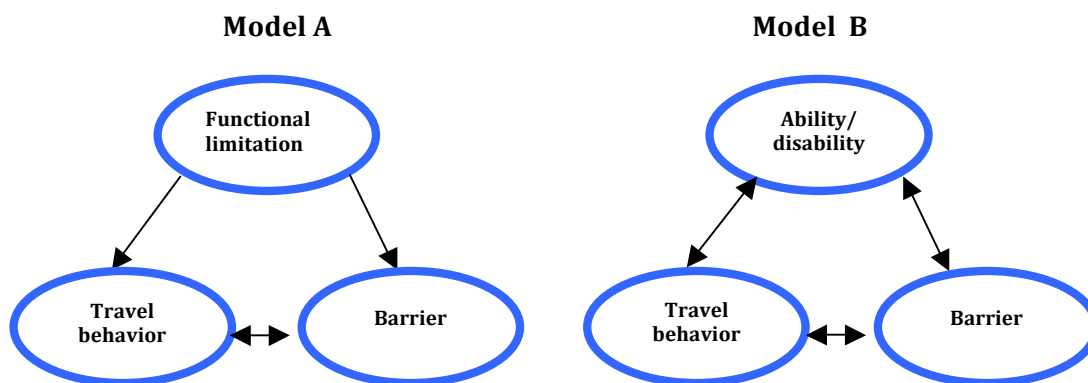

Figure 1. Accessibility may be modeled for travellers' functional limitations (Model A) or for travellers' abilities and/or disabilities (Model B). Please note that functional limitations are invariant relative to travel behavior and the barriers, whereas abilities/disabilities instead are variant owing to reciprocal interactions.

The measurement model for place accessibility is primarily based on various characteristics of the transport and geographical (physical) place, whereas individual accessibility is based on a set of features of each traveller in the transport system [2]. In our research, we focus on the measurement of *individual accessibility* (Figure 1).

A 'functional limitation' constitutes a physical, psychological or intellectual reduction in human function. It is a temporary or permanent condition in individuals. Alternatively, 'disability' is defined as the product of interactions among individual

features and environmental characteristics [5]. Disability may involve anything from inaccessible information to physical design characteristics like staircases or doorsteps and/or psychological features like attitudes of fellow passengers or staff. The same functional limitation may thus, in interaction with one environment, but not another, become a disability.

A 'barrier' constitutes i.a. a physical, psychological, social or economic constraint in the travel chain, experienced by the individual passenger. Examples of barriers are design deficiencies of stations, trains and time-table information as well as delays. Over time, the set of barriers will vary for one traveller as well as among travellers. For example, if one traveller has already encountered a barrier during a trip, a subsequent barrier (the same kind or a new one) might well be perceived even worse than the previous one.

In the present research context, 'travel behavior' refers to the way persons use different means of transport. Here, we focus mainly on travel frequency and travel mode. In Sweden and in many other countries, car is the most frequently used travel mode. Thus, measured as number of movements per day, the car stands for 38% (drivers) and 15% (passengers). Car use declines with increasing age as does mobility in general. Among the Swedish car users in the age group 65-84 years old, men and high-income earners have more often a driver's license and own a car. Only 0.7% of all journeys are by railway [6]; see also [7] and [8]. The most common reasons for old persons' travels are shopping, physical exercise and recreational activities [9].

Rimmer et al [10] developed the AIMFREE set of psychometric measuring instruments for persons with functional limitations. They developed and validated 16 survey instruments that measured accessibility to recreational and fitness environments. Interestingly, they utilized the Rash model for demonstrating good psychometric properties of their instrument. Also a Swedish research team has developed a supportive instrument, "The Travel Chain Enabler", for assessing urban public bus transportation accessibility for persons with functional limitations [11], [12].

4. Measurement model of accessibility

We propose a triangular model in which the accessibility to railway travelling results from interactive processes among three cornerstone constructs (Figure 1, Model A): travellers' functional limitations, barriers in the transport system, and overall travelling behavior. By replacing the invariant construct travellers' functional limitations (Model A) with the variant construct travellers' *abilities* or *disabilities* (Model B), our measurement model of accessibility will involve three reciprocal interactions instead of one. Thus, in Model B, each of the three constructs constitutes complex, multi-variable quantities (or patterns) among which reciprocal interaction outcomes are of paramount importance for measuring the quantity *accessibility*. Thus, it is fruitful to study the abilities of persons with functional limitations, rather than focusing on their disabilities. By reducing the barriers, the ability of travelling will be improved, and consequently allow for more flexible travel behaviors.

Emardson et al. [13] have defined an accessibility measure for persons with functional limitations in which barriers have different weights for the different persons depending on their functional ability and travel behavior. This gives the probability of facing a certain barrier when travelling to a certain destination; that is, a measure of accessibility for the individual. The more weight placed on a certain barrier, the less probable is the particular journey. Moreover, disability and functional limitation should be understood from the perspective of travellers' personal experience and interpretation, which may differ among individuals even if the functional limitations, and additional disabilities, are of the same kind and severity.

As said above, barriers can vary among individuals as well as for the same individual over time. For example, having encountered a barrier during a trip can result in an adverse perception of subsequent barrier. However, for simplicity we will not consider, in the following, that the perception of barriers is affected by previous situations. Using the approach of viewing barriers as constraints in the travel chain, Emardson et al. [13] modeled the accessibility reported by a person i with regard to destination j, A_{ij} as:

$$A_{ij}^{m} = \prod_{b}(1 - p_{jb}\psi_{i}(d_{b}))$$

(1)

where d_b is barrier number b and p_{jb} is the probability of facing barrier b when going to destination j and

$$\psi_{i}(d_{b}) = \phi_{i}(d_{b}) + \nu_{ib}$$

(2)

Here, we introduce an accessibility indicator, ϕ, which is a function operating on the set of barriers, and it is defined on a scale from 0 to 1 [14]. These scale values denote the perceived effort if facing a certain barrier, and it can be interpreted in terms of the probability of cancelling a journey. The function value 1 indicates 100% probability of cancelling the journey, and the value of 0 indicates a barrier causing no problem to the traveler. The symbol ν represents the measurement noise and is a random variable, which is normally distributed with a mean value u and a standard deviation, σ_{ν}. For a specific person and destination, the presented model is separable on the barriers. It is not additive however.

The measured accessibility for a group of travelers can then be modeled as:

$$A_{j}^{m} = \frac{1}{I}\sum_{i}\widehat{p}_{ij}\prod_{b}(1 - p_{jb}\psi_{i}(d_{b}))$$

(3)

Where I is the number of persons and $\widehat{p}_{ij}$ the probability that person i is aiming for destination j. The measured accessibility will hence be a number between 0 and 1. Simulations [10] indicate a measurement uncertainty of the accessibility around 0.03 given a situation with 20 barriers. In difference to the accessibility model for a specific person, this model is not separable on the barriers.

In our study, we will use a set of persons to grade identified barriers. Emardson *et al.* [13] showed, using Monte Carlo simulations, that in order to have a standard deviation of the measured accessibility of a size typically a tenth of the measured value; we need a group of about 40 persons grading the barriers.

In order to guarantee the validity of the accessibility measures, it is important that the barriers are scaled by a representative group of persons. To find these groups of persons, we conducted a questionnaire study on perceived accessibility in the railway system. We chose older persons as the target group because functional limitations are more common with older age. Moreover, the growing number of older persons in society poses challenges to the transport system as regards services to meet the special needs of this group. From the questionnaire data, we constructed a reference group of representative *'typical older persons'* (65-85 years). They are identified by a procedure involving two stages: Stage 1, persons are removed who are very dissimilar from the typical 'older train traveller' on the basis of binary coding of a large number of criterion variables. Stage 2, participants are selected on the basis of fuzzy resemblance of the typical 'older person' on the most important criteria (see further [15]).

With the reference group constituted and in place, individuals are recruited for an interview study. The research goal is to explore the range of barriers encountered in the railway system and how they are perceived. The respondents are selected based on inclusion criteria for the reference group (age, gender, travel frequency, travel mode, etc.). Thus, persons would be included who have various functional limitations and represent a wide range of travel behavior. We will explore the range of barriers encountered by them. The different kinds of barriers would be measured according to Eq. 1, which delivers *individual accessibility measures*. This is accomplished by putting a perceived-effort weight on each barrier for each individual. These weights will be obtained in forthcoming research on the perception of a set of various scenarios representing barriers.

Acknowledgments

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