

Review

Measures of Transport-Related Social Exclusion: A Critical Review of the Literature

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Academic Editor: Marc A. Rosen

Received: 22 March 2016; Accepted: 12 July 2016; Published: 20 July 2016

Abstract: Quantitative measures of transport disadvantage are reviewed in this paper from the perspective of their effectiveness to investigate social exclusion. The effectiveness is assessed using criteria derived through a review of the concepts of transport disadvantage and social exclusion and their operationalisation. The specified criteria are related to issues of spatial (e.g., urban accessibility, and public transport accessibility), temporal (e.g., public transport availability, and facility opening hours), and social attributes of travel and activity participation (e.g., personal mobility, and disability). Four groups of transport disadvantage measures are identified and evaluated. These include deprivation-based measures, mobility-based measures, accessibility-based measures, and activity-based measures. The review suggests that although the first three categories of measures have traditionally been used to identify transport disadvantage, they do not satisfy issues surrounding activity participation—the key outcome of social exclusion. The activity space concept is a way in which these issues can be incorporated, as it is a measure of the outcomes of activity participation and their associated travel to that activity. Participation in an activity means that an individual has overcome the spatial, temporal and social barriers of travel for that activity. The research using the activity space concept has, however, inadequately identified individual travel and activity participation. This has been due to a separate application of a range of different indicators to assess activity space size. These indicators are by their nature multidimensional—e.g., area visited, distance travelled, and number of activity sites visited. Although each indicator represents a specific qualitative/quantitative aspect of travel and activity participation, researchers have treated these indicators in an isolated manner to identify transport disadvantage and consequently transport-related social exclusion. This paper identifies the weaknesses and strengths associated with these measures; and methods are directed to overcome the limitations.

Keywords: transport-related social exclusion; transport disadvantage; social exclusion; activity participation; accessibility; mobility; activity spaces

1. Introduction

The reduction of social exclusion has been a focus of policy agenda for some time. This paper examines issues surrounding the transport dimension of social exclusion. Although social exclusion involves many issues in which transport dimension is peripheral (e.g., poverty, and politics), better transport overcomes many problems associated with social exclusion enabling people to reach essential opportunities [1–5]. A number of studies have demonstrated that a lack of access to transport results poor access to goods and services and consequently leads to social exclusion [2,6–11]. As a result, the focus of transport policy is to take into account the needs of those who are transport disadvantaged to reduce transport-related social exclusion.

Transport researchers in the developed world have identified the transport needs of the disadvantaged in different contexts. Needs are feelings of scarcity together with the action to overcome such feelings [12–14]. Becker and Gerike [12] also mentioned that transport policy initiatives aiming to satisfy human needs could be regarded as sustainable transport development. For example, the concessionary fares scheme for older and disabled people in the UK can be regarded as meeting basic needs (such as independence) and promoting travel by more sustainable transport [15,16]. In policy terms, the justification and appraisal of such policy interventions are challenging due to the variety and changeably human needs [17,18]. As a result, an important requirement is therefore to use the analysis of disaggregated data to identify the transport disadvantaged as well as their variation in needs to minimise transport-related social exclusion.

Traditionally, transport needs have been identified using a two-step process. The first step identifies the transport disadvantaged groups or individuals. The second step attempts to understand the needs of the disadvantaged by examining their experience of exclusion or non-participation. However, there does not exist a frame of reference in the literature based on which the transport disadvantaged can be identified despite numerous articles have been published on this topic following an influential report by the Social Exclusion Unit in 2003 (Making the connections: transport and social exclusion) [9]. A substantial variation exists among these publications in several aspects ranging from the conceptualisation of the problem to operational definitions to measurements. Although these variations enriched our knowledge on the topic, the research field surprisingly suffers from dearth of review studies that can inform the state-of-the-art on this topic. The UK Department for Transport [19] has reviewed different modelling techniques (e.g., 4-stage model) used in transport research to develop accessibility measure tool to identify transport disadvantage. This is inadequate because the lack of accessibility is just one aspect of transport-related causes of social exclusion. Priya and Uteng [20] have briefly presented different measures used to identify transport-related social exclusion but have not assessed their usability.

Again, social exclusion is often a misunderstood, poorly defined and poorly measured construct [21–23]. As a result, an operational and theoretically sound measure of transport disadvantage in assessing social exclusion is almost absent. Researchers have often identified the disadvantaged groups using ad-hoc methods and in turn have examined their exclusionary outcomes (e.g., loss of job). The risk of such an exercise is that if the disadvantaged groups are poorly identified, the needs of the truly disadvantaged groups and/or individuals will remain underrepresented. As a result, transport policy initiatives will be unable to satisfy their needs and thus will become an unsustainable policy [24]. Becker and Gerike [12] have mentioned that neither needs nor the degree of needs satisfaction can be determined without involving the affected individuals. This paper presents a review of transport disadvantage measures and operationalised examples in order to assess social exclusion. The limitations of such measures in identifying transport disadvantage are also discussed and methods are directed to overcome these limitations.

The paper is based on a structured review of articles published on the topic supplemented by authoritative books. This review differs from existing reviews, see for example [19,20] as discussed above, in the following ways. Firstly, quantitative measures of transport disadvantage are reviewed from the perspective of their effectiveness to examine social exclusion. Secondly, measures are examined using criteria derived through a review of the concepts of social exclusion and transport disadvantage in Section 3, where it also makes an operational distinction between social exclusion and other related concepts. Social exclusion, as distinct from other related concepts, was found to be associated with seven distinct attributes. Transport disadvantage measures aiming to assess social exclusion should therefore incorporate these attributes. The attributes are used as the review criteria, which are related to the ability of the measures to incorporate spatial (e.g., urban accessibility, and public transport accessibility), temporal (e.g., public transport availability, facility opening hours, and dynamics), and social (e.g., personal mobility, and disability) barriers of travel and activity participation (Section 4). Two groups of transport disadvantage measures are identified and reviewed including process-based measures and outcome-based measures in Section 5. Process-based measures

include deprivation-based measures, mobility-based measures (area mobility and personal transport options), and area accessibility-based measures. Outcome measures, on the other hand, are based on the concept of activity spaces and include individual accessibility measures, personal mobility measures, and participation-based measures. The operationalised examples of the different transport disadvantage measures are also assessed using the derive criteria in this section. The findings from the reviews are synthesised and the weaknesses of these measures are identified in Section 6. The section then proposes a way forward for further development using the activity-based measures. Section 7 concludes this research.

2. Methodology

The review materials for this paper are primarily derived from published journal articles. However, some of the key authored books and edited book chapters are also included in the review. Given that the paper also aims to identify key policy strategies to address transport-related social exclusion, search is extended to in practice review as well. Search strategies for the selection of relevant literature pieces are based on published research between 1950 and 2016 on the topic with the following quotes—“social exclusion”, “transport disadvantage” and “transport-related social exclusion”—contained in the publication title, abstract and keywords. Scopus, Science Direct, and Google Scholar databases are used to obtain relevant full-text literature pieces. The initial search provided in total of a highly large number of 1792 publications. Filtering books, book chapters and journal articles among this large pool, as well as relevance checks, left us with a selection of most relevant 336 publications. These are then screened through reading their abstracts, introduction and conclusion sections in order to determine whether the publication is appropriate to be included in the final review. This brought the selected literature number down to 189. These publications were further analysed to examine whether the concepts, methods, research coverage, and findings revealed theoretical understandings, best practices and policies, gaps and issues related to transport-related social exclusion. Including the relevant key policy documents, the final literature selection included 155 pieces, which are reviewed thoroughly in this paper.

3. Social Exclusion

3.1. Concept

Given the contested nature of the term, this paper clarifies the concept of social exclusion first before detailing the concept of transport-related social exclusion. The term social exclusion was introduced into the European policy domain during the 1990s [25]. A detailed account of the evolution of the term in the European policy context can be found in [26]. In Britain, it entered into the government’s policy process with the setting up of the interdepartmental Social Exclusion Unit (SEU) in 1997 [27–30]. A similar concept was introduced in the USA with the name ‘environmental justice’ through an official order of the then President Clinton in 1994 [19]. The assumption is therefore to expect an agreed understanding of the term exists given decades of common usage, though this is not the case [8,31]. As Atkinson [31] (p. 1039) indicated, “there are as many theories of social exclusion as there are writers on the subject, for anyone, or any group, that adopted a lifestyle at odds with mainstream society was deemed to be excluded.”

Despite varying theoretical developments, researchers agree that the term originated in the French literature in the 1970s [19,27,30,31], whereas Cebollada [32] noted the origin of this term dates back to 1965. At that time, the term was used to refer to individuals who “slipped” through the social insurance system; the socially excluded were those who were administratively excluded by the state [27,30]. Three decades later when the term gained in significance in the development of policy, Cass et al. [29] investigated the perceptions held by local authorities in the UK towards social exclusion and found somewhat inconsistent views; some authorities referred the term to specific groups (e.g., the poor), others used it to refer certain deprived areas. In the literature, the terms poverty, deprivation, and social exclusion have also often been used interchangeably [33–35].

Mernagh and Commins [36] highlighted the problems associated with misunderstanding new concepts like social exclusion because of its significant level of public usage and its importance to the development of policy in practice. It is important, therefore, at the outset to make a distinction between social exclusion and other related concepts. The term revisited as a practical alternative to the notion of old poverty at the European level because of the political reservation to use the term poverty [26]. Latter on a distinction has been made and poverty is generally understood as the lack of material resources such as income [8,34,35]. Although Brennan et al. [28] mentioned that social exclusion has largely been assumed to refer to poverty; Atkinson and Hills [37] have shown that people may be socially excluded without being poor. Therefore, social exclusion is not just a fashionable way of talking about poverty or even about simply a subset of the poor, but a broader concept [26,30]. Deprivation, in contrast, is a more diffuse concept related to the quality of life [35]. Townsend [38] (p. 125) defined deprivation as “a state of observable and demonstrable disadvantage relative to the local community or the wider society or nation to which an individual, family or group belongs”.

Deprivation, therefore, refers to a lack of particular attributes, including but not limited to income, that contribute to some degree of suffering or relative disadvantage [33]. Traditionally, the measures of deprivation have attempted to identify and assess these attributes [39]. These are often referred to as different dimensions (or domains) of deprivation such as economic, social, political, personal, living space, mobility impairment, and geographical isolation [8,29,40–44].

Social exclusion, in contrast, refers to the process whereby an individual becomes deprived [35]. As a result, poverty and deprivation have been conceptualised as the outcomes whilst social exclusion is seen to be a process [26,33,45]. Thus, social exclusion embraces a view of poverty and concerned with multiple aspects of deprivation [46]. This means that the excluded are the ones who are not only poor but who have also lost other essential qualities of life, such as ability to get a job [17]. Researchers have seen social exclusion as a dynamic process involving the interactions of various contributing factors over time [17,26,34]. On the one hand, Brennan et al. [28] (p. 145) clearly showed the impacts of interactions between different contributing factors by stating “low educational attainment reduces employability, which causes low incomes, which cause high benefit dependency, which reduces motivation and creates health problems, and all these have an adverse effect back on educational attainment, which affects crime levels, which reduces enterprise and jobs and incomes and so on”. On the other, Burchardt et al. [27] (p. 232) elaborated “dynamics as one of the distinctive features of the social exclusion literature”. As a result, deprivation is seen as a snapshot at a particular point in time of different aspects of the life situation, which may change due to the interaction of processes over time [28]. Table 1 shows the process and outcome relationships between social exclusion, deprivation, and poverty.

Table 1. Social exclusion outcome and process concepts (adapted from [26]).

Dynamic Process	Static Outcome	Indicator
Impoverishment	Poverty	Income
Social exclusion	Deprivation	Multidimensional

Commins [47] (p. 4) classified the following four systems that can trigger the social exclusion problem:

- The democratic and legal system, which promotes civic integration;
- The labour market, which promotes economic integration;
- The welfare system, promoting what may be called social integration; and
- The family and community system, which promotes interpersonal integration.

Therefore, it can be said that the failure of certain systems (one or more of the above) that promote civic, economic, social and interpersonal integration in mainstream society lead to social exclusion [31,48,49]. The system view of social exclusion later on conceptualised as agency view that is responsible for causing social exclusion [30,34]. Burchardt et al. [30] classified the agency concept into the following three groups:

- Individuals—blaming the socially excluded for their own plight;
- Institutions and systems—civil and economic institutions which constrain opportunities for some individuals and which are beyond the control of any individual; and
- Discrimination and lack of enforced rights—the exercise of agency by some, acting to protect their own interests, and exclude others.

Unlike poverty, social exclusion is generally agreed to be a relative concept [21,50,51]. A person cannot be judged to be socially excluded in isolation and needs to be considered in the wider context of the activities of others, unlike the measure of poverty where economists take no account of whether the respondents are living in the same street or neighbourhood [34]. Following the relativity concept, Burchardt et al. [27] (p. 230) proposed the following definition: “an individual is socially excluded if (a) he or she is geographically resident in a society and (b) he or she does not participate in the normal activities of citizens in that society”.

This statement is considered as one of the first quasi-operational definitions because earlier definitions are far too vague to form the basis of operational measurement (see [19,45] for a range of definitions of social exclusion). This definition refers to relativity to the place in question [51]. On the other, it refers to measurable entities such as “participation” [19]. However, Department for Transport [19] criticised this definition from two perspectives:

- It does not define what constitutes normal activities; and
- It does not define what level of engagement constitutes participation in these activities.

Nevertheless, Burchardt et al. [27] considered five types of activity as normal in their empirical treatment of the definition (e.g., consumption, savings, production, political, and social). In their subsequent study, Burchardt et al. [50] (p. 30) slightly modified the above definition of social exclusion to: “an individual is socially excluded if he or she does not participate in key activities of the society in which he or she lives”.

In their latter study, they have addressed the weaknesses identified by Department for Transport [19] in the following ways. First, key activities have been operationalised using four dimensions of activities: consumption, production, political engagement, and social interaction. Second, the level of engagement is measured by duration of participation. In both studies, Burchardt et al. [27,50] considered a lack of participation as a key outcome of social exclusion. They have explained that indicators used to measure deprivation (e.g., income and employment) are the causes or risk factors of social exclusion rather than the outcomes. They argued that none of these characteristics would be regarded as constituting social exclusion if the individual was able—perhaps against the odds—to participate in their identified dimensions. Consequently, a lack of participation in activities is adapted as the ultimate outcome of social exclusion by many researchers [7,50,52,53]. Pringle and Walsh [35] (p. 3) specified that “[social exclusion] can refer to a state which goes beyond deprivation by implying an inability to participate fully in social and economic activities, including those which influence decision making”.

In a similar way, Shortall [27] (p. 455) emphasized that “social inclusion means the participation, and the ability to participate, in political and social structures”. Therefore, it appears that social exclusion is both as a process and as an outcome [45,54]. However, if social exclusion is measured using participation as an indicator, a distinction must be made with other concepts that are also measured by participation. Shortall [25] pointed out that social exclusion, civic engagement, and social capital are often used interchangeably in the literature because the key measure of these concepts is based on participation though these concepts are not identical. This work argued that clarity is required prior to its usage which otherwise may mislead the identification of the socially excluded.

Social capital refers to the advantages an individual can gain from formal or informal social participation, in the form of civic engagement [6,46]. Typical indicators of social capital include participation in social organisations such as political parties, clubs, trade union, church, women’s organisations, membership in organisations, attendance in meetings, and so on [6,55]. Therefore,

a significant overlap can be identified between the measures of social exclusion and social capital using participation as an indicator. In summary, the understanding is that civic engagement refers to participation in only social and civic activities, whereas the term social inclusion is used to describe the ability to participate in all types of activities.

3.2. Measures of Social Exclusion

Measures used to identify social exclusion are therefore both process-oriented and outcome oriented. In relation to the process-oriented approach, for instance, a number of authors have investigated the nature of the labour market and its impacts on social exclusion (see [28,34,37,48]). Multiple deprivation measures, such as the intermediate outcomes, are the traditional approaches to identifying deprived neighbourhoods in the UK [39,56–58]. Table 2 shows the different dimensions of deprivation considered in the English Indices of Deprivation (EID), Northern Ireland Multiple Deprivation Measure (NIMDM), Scottish Index of Multiple Deprivation (SIMD), and Welsh Index of Multiple Deprivation (WIMD) measures. Wide ranges of indicators were used to measure deprivation in each dimension. The score (or rank) of each dimension was subsequently summed up (weighted summation or exponentially transformed) to form a composite deprivation index.

Table 2. Currently used domains of deprivation measures and their weights in the UK [39,56–58].

EID 2007 (England)	NIMDM 2005 (Northern Ireland)	SIMD 2006 (Scotland)	WIMD 2008 (Wales)
Income (22.5%)	Income (25%)	Income (28%)	Income (23.5%)
Employment (22.5%)	Employment (25%)	Employment (28%)	Employment (23.5%)
Health and disability (13.5%)	Health and disability (15%)	Health (14%)	Health (14%)
Education, skills and training (13.5%)	Education, skills and training (15%)	Education, skills and training (14%)	Education, skills and training (14%)
Barriers to housing and services (9.3%)	Proximity to Services (10%)	Geographic access to services (9%)	Access to services (10%)
Living environment (9.3%)	Living environment (5%)		Physical environment (5%)
Crime (9.3%)	Crime and disorder (5%)	Crime (5%)	Community safety (5%)
		Housing (2%)	Housing (5%)

Burchardt et al. [27,50], on the other hand, developed a set of disaggregated measures using indicators related to participation in order to identify individuals at risk of being excluded (Table 3). They have analysed cross-sectional and longitudinal participation in these dimensions using the British Household Panel Survey data for the period of 1991–1995. This work has shown that participation in consumption activity is the most common form of exclusion whereas social isolation is the least common form of exclusion. They have also reported that less than 1% of respondents are excluded in all dimensions, whereas 55% of respondents are not excluded in any dimension. In their subsequent study, Burchardt et al. [50] have extended the analysis for the period of 1991–1998 to examine the dynamics of exclusion. They have found that exclusion on a particular dimension has a much stronger association over time than the associations between different dimensions at a single point in time.

Although Burchardt et al. [27,50] have not found any specific groups that are socially excluded, a third aspect of social exclusion measures involved the identification of groups that are usually classified as socially excluded in related literature. For instance, Santana [59] has identified groups that are reported as socially excluded comprised of children in poverty, single parents, elderly in poverty, unemployed, immigrants, alcohol addicts, consumers of hard drugs, prisoners and ex-prisoners, and homeless. This work has investigated the health situation of these groups in Portugal and found that they are in greater risk of adverse health outcomes than that of the general population. Similarly, Shortall [25] has interviewed three groups viz. women, small farmers, and Protestants in Northern Ireland to explore their participation in rural development initiatives. These groups are typically referred to as socially excluded in rural development documents in Northern Ireland [25]. This work found that although the Protestants were active in civic engagement, they were reluctant to

participate in development initiatives for ideological and theological reasons. This work also found that in spite of having strong social networks (social capital) women are structurally excluded, while small farmers chose not to participate in rural development programs because they have seen these programs as competing with their farming.

Table 3. Indicators of participation [24].

Dimension	Indicator	Measures
Consumption activity	Low income	Income under half mean equalised household income
Savings activity	Low wealth	Not an owner-occupier, not contributing to or receiving an occupational or personal pension, and no savings over £2000
Production activity	Lacks production activity	Not in employment or self-employment, full time education or training, looking after children, ore retired over pensionable age
Political activity	Political unengaged	Did not vote in the 1992 general election and not member of political or campaigning organisation
Social activity	Socially isolated	In any one of five respects, lacks someone who will offer support (listen, help in crisis, can relax with, really appreciates you, can count on to comfort)

3.3. Transport Disadvantage and Social Exclusion

Lack of participation in activities has been identified as the key outcome of social exclusion [27,50]. Studies have found strong evidence to indicate that significant barriers to participation in key activities (e.g., job, education, health, and social) are either a lack of suitable transport or a lack of accessible opportunities or a combination of both [2,6–9]. The transport disadvantaged therefore are those who face these problems. As a result, policy is increasingly concerned with meeting the needs of these groups and individuals [13,60–64]. Stanley and Stanley [65] (p. 14) have defined transport disadvantage as “a situation where people experience a shortage of transport options, which restricts their mobility and hence their access to goods, services and relationships”.

However, the above definition is incomplete due to the fact that it has not considered urban accessibility issues. Several authors have mentioned that poor mobility may be compensated by the presence of good accessibility to opportunities (e.g., urban accessibility)—for instance, if local shops, employment and services are available and within reach [6,54]. Therefore, it is clear that transport disadvantage is a function of both access to opportunities (e.g., urban accessibility) and access to transport—both personal mobility and public transport accessibility. Using this concept, Hurni [66] (p. 1) has first provided an operational definition of transport disadvantage as “a situation where disadvantaged groups of people live in transport disadvantaged areas”. Transport disadvantaged areas were referred to as locations with poor public transport accessibility and low levels of urban accessibility whereas specific populations with similar mobility (personal) constraints were regarded as transport disadvantaged groups.

As a result, transport researchers have highlighted to establish the “mobility rights” and “accessibility rights” of citizen to combat social exclusion [29,67,68]. A just society ensures participation in society to its entire members and is therefore an inclusive society [52]. An important element of social inclusion is, therefore, a matter of overcoming the constraints—constraints on the ability to travel—to gain access to the opportunities [2,55,69]. Casas [67] has mentioned that when the access rights are not secured, population is at a disadvantage and social exclusion occurs. Preston and Rajé [54] have indicated that social exclusion is not due to a lack of social opportunities to participate in but a lack of access to those opportunities. On the other hand, Cass et al. [29] (p. 539) have highlighted the need to establish the mobility rights of citizenship stating: “Exclusion results from some combination of distance, inadequate transport and limited ways of communicating; that these exclusions are unfair or discriminatory; and that local and national government should reduce such socio-spatial exclusion.

This implies that citizenship is no longer confined . . . to civil, political and social rights, but that there are also what we might term mobility rights.”

Accessibility and mobility are referred here as the “ease of reaching” and the “ease of moving” respectively [54,70]. Mobility is the measure of the means of transport and their level of efficiency [71]. In transportation, these are reflected on the ability of the transport system to provide the same level of access to different opportunities to all members of a society [67]. Those who are unable to engage in physical travel (whatever the reason) will be unable to participate and be socially excluded [29]. Transport is clearly a key element in achieving social inclusion [6,61]. From this point of view, greater social inclusion requires greater mobility and/or greater accessibility [2,52]. This link between transport and social exclusion has been referred to as transport related social exclusion. Kenyon et al. [8] (pp. 210–211) have defined transport related social exclusion as “the process by which people are prevented from participating in the economic, political and social life of the community because of reduced accessibility to opportunities, services and social networks, due in whole or in part to insufficient mobility in a society and environment built around the assumption of high mobility”.

4. Criteria for the Review of Transport Disadvantage Measures

A number of attributes of social exclusion can be identified from the conceptual and operational reviews of social exclusion in Section 3. The findings from the reviews are summarised in this section to use as criteria in order to review the operationalised transport disadvantage measures. Social exclusion is seen to be a process; a process which is largely considered to be related to societal systems and/or agencies—such as labour market, transport, legal system [25,30,31,34,35,47,48]. The processes are dynamic in nature and interact with each other [16,26,28,34]. As a result, individuals face deprivation in multiple dimensions including poverty at a particular point in time—as an intermediate outcome [33,38,46]. The different dimensions of deprivation (e.g., income, employment, and living environment) again act as processes which individually or together (interaction) prevent individuals from participating in activities—such as job, social [8,27,29,50]. Therefore, unlike civic engagement and social capital, which measure participation in social activities, a lack of participation in any types of activities is considered as the ultimate outcome of social exclusion [6,25,46,55]. In addition, unlike poverty, social exclusion is generally agreed to be a relative concept—relative to the places where individuals live [34,50]. Measures of transport disadvantage aiming to assess social exclusion should incorporate these attributes.

When relating these attributes (e.g., individual level phenomenon, geographical relativity, dynamics of different causal factors, interactions between different causal factors, and lack of participation in all types of activities) to measures of transport disadvantage, it is therefore important to identify transport disadvantage using a disaggregated approach [54,72]. A number of studies [19,73] have highlighted that disaggregation is required at the socioeconomic, spatial, and temporal level to be able to identify the differential impacts of transport policies. Socioeconomic disaggregation helps to identify socioeconomic differences (e.g., income, employment, and disability) in accessing goods and services. Spatial disaggregation helps in the evaluation of whether a transport system is accessible to all members of a society spatially or whether it provides access to all types of opportunities. Burchardt et al. [50] have noted that an evaluation of the nature of participation is important because a lack of participation in any type of activity is sufficient for social exclusion to exist. Temporal disaggregation allows assessment of the dynamics in terms of temporal availability of mobility options (e.g., public transport service) and/or opportunities. Disaggregation is also required to take into account the relativity of the measures [21,51]. In transport terms, this relativity means that the levels of accessibility and mobility of others living in the same area need to be considered to identify transport disadvantage, particularly when the analysis is concerned with the differential levels of area accessibility and area mobility. For instance, a shorter travel distance of an individual living in a highly accessible area does not necessarily mean that the individual is mobility impaired when compared to an individual living in an inaccessible area. Social exclusion is not just due to the main effects of different causal factors such as income and employment but rather the interactions between these different factors, as a result, transport disadvantage measures should be based on

the interactions between different explanatory factors in addition to modelling their main effects. For instance, Gray et al. [74] found that despite owning cars by both groups, high-income individuals made more trips and travelled longer distances using the car than their low-income counterparts in rural Scotland. Delbosc and Currie [22] have indicated that an identification of transport disadvantage without involving interactions between different factors is overly prescriptive and simplistic.

Based on the above discussion, the following seven criteria were derived to assess the effectiveness of existing transport disadvantage measures:

- Does the measure use a socio-economic disaggregated approach (disaggregation of socio-demographics)?
- Does the measure assess accessibility of different types of opportunities (spatial accessibility)?
- Does the measure assess accessibility of opportunities temporally (temporal accessibility)?
- Does the measure assess accessibility of transport spatially (spatial mobility)?
- Does the measure assess accessibility of transport temporally (temporal mobility)?
- Does the measure model interactions between different causal factors (interaction)?
- Does the measure take into account the activities of others living in the same area (relativity)?

5. Measures of Transport-Related Social Exclusion: A Review

Despite transport-related social exclusion is conceptually different from transport disadvantage, previous studies assume that these are identical concepts; and consequently, the indicators used to define transport disadvantage (e.g., lack of mobility/accessibility) are equally used to refer transport-related social exclusion [62,75]. Measures to quantify transport disadvantage can broadly be classified into, firstly, an assessment of the availability of mobility tools (e.g., personal mobility and/or public transport accessibility); secondly, an assessment of accessibility to opportunities (urban accessibility/potential accessibility); and thirdly, an assessment of various indicators reflecting travel-activity behaviour. The third measures are a relatively recent development in this field and are often referred to as activity-based measures. This measure uses activity space concept to measure actual accessibility—a measure of opportunities that actually are reached—in contrast to potential accessibility that measures the opportunities that could be reached [12,76]. Table 4 shows the measures (indicators) used in several research studies aiming to identify transport disadvantage in different contexts. Despite the variety of transport disadvantage measures that have been operationalised in different contexts, Table 4 highlights that like the measures used to identify social exclusion, quantitative measures used to identify transport disadvantage can also be broadly classified into either process-based or outcome-based.

Process-based measures evaluate the performance of transport and/or land use systems that potentially facilitate participation in activities in order to identify transport disadvantaged areas and include multiple deprivation-based measures (e.g., distance to essential opportunities from an area), area accessibility measures (e.g., number of opportunities located within a certain travel time from an area), and area mobility measures (e.g., distance to public transport services such as bus stops and train stations). The area mobility measures and area accessibility measures have also been referred to as a category approach and spatial approach respectively in the literature [17,67]. On the other hand, the outcome measures, based on the concept of activity spaces, assess the outcome of these systems by examining actual (or realised) activity-travel patterns of individuals. As a result, the outcome measures are also referred to as activity-based measures in the literature [19]. The outcome measures assess the levels of: personal mobility (e.g., distance travelled), individual accessibility (e.g., opportunities accessible within the limit of personal mobility level), and participation in activities (e.g., opportunities that actually are participated in) in order to identify the disadvantaged individuals or groups. Although the availability of personal mobility tools (e.g., car-ownership) is the characteristics of individuals rather than an area, it only indicates individuals potential to travel rather than actual travelling. As a result, this type of indicators (e.g., car-ownership, and driver's license) are categorised as process-based measure and analysed together with the area mobility measures in this paper.

Table 4. Measures used to identify transport-related social exclusion in research studies.

Reference	Context	Measures Used or Proposed	Identified Disadvantaged
Department for Transport [77]	England	Qualitative (e.g., focus groups, interviews)	Unemployed people, families with young children, young people, older people, low-income
Social Exclusion Unit [9]	England	Qualitative (public consultation and in-depth interviews to assess area accessibility and area mobility)	-
Department for Transport [19]	England	Mobility (area mobility and car ownership), area accessibility	Users of public transport
Department for Communities and Local Government [56]	England	Deprivation indices (distance to essential opportunities)	Output areas
Preston and Rajé [54]	England	Area mobility, area accessibility, personal mobility	-
Welsh Assembly Government [58]	Wales	Deprivation indices (distance to essential opportunities)	Output areas
Hine and Mitchell [2,7]	Scotland	Area accessibility, personal mobility (distance travelled, travel time), participation frequency (number of trip per week) and qualitative measures	Low incomes, women, elderly, disabled, children
Scottish Executive [57]	Scotland	Deprivation indices (distance to essential opportunities)	Data zones
Wu and Hine [78]	Northern Ireland	Area mobility, car-ownership	Households with no car and living in areas with no public transport services
NISRA [39]	Northern Ireland	Deprivation indices (distance to essential opportunities)	Output areas
Kamruzzaman et al. [41]	Northern Ireland	Participation (number of unique locations visited), participation duration (average daily activity duration), personal mobility (average daily distance travelled)	Students who live away from a demand responsive transport service
McDonagh [18]	Ireland	Qualitative (Policy review)	Rural areas
Currie et al. [79]	Australia	Area mobility, car ownership, number of trips, average trip length	Outer Melbourne area, individuals who are structurally dependent on the car, non-car individuals who live away from a city centre
Hurni [66]	Australia	Area mobility, area accessibility, car-ownership	Western Sydney region
Battellino et al. [80]	Australia	Area mobility, personal mobility	Disabled people living within the public transport accessible areas
Currie and Delbosc [63] Delbosc and Currie [22]	Australia	Multi-dimensional qualitative indicators were grouped into four dimensional measures of disadvantaged (e.g., transport, transit, impaired, rely on others)	Busy working adults, low-income, poor health, unemployed
Dodson et al. [81]	Australia	Area mobility, area accessibility	Suburban areas around Nerang, Worongary and Mudgeeraba
Casas [67]	USA	Personal mobility (the longest distance travelled from home), individual accessibility (cumulative opportunity)	Disabled
Casas et al. [82]	USA	Deprivation indices, personal mobility, individual accessibility (cumulative opportunity and space-time accessibility of opportunities)	Children in households with no employed member
McCray and Brais [83]	Canada	Area generated based on the locations of visited activity (standard distance circle)	Non-car owner, women with small children, women who live away from transit route
Schönfelder and Axhausen [84]	Germany	Area generated based on the locations of visited activity (e.g., standard deviational ellipse), participation (number of unique locations visited, number of trips)	No groups have been identified as disadvantaged
Priya and Uteng [20]	Norway	Car-ownership (driver's license)	Low incomes
Cebollada [32]	Spain	Area mobility, car-ownership (driver's license)	Women, young adults, immigrants

5.1. Deprivation-Based Measures

Multiple deprivation measures focus on the characteristics of a geographical area and measure the levels of deprivation in several dimensions (or domains). The basis for using these measures as an indicator of transport disadvantage has not been considered until recently. Although studies have shown that deprived areas are also deprived in terms of both access to transport and access to opportunities, earlier versions of these indices are criticised for not incorporating transport domains into the measures [17,33]. For instance, Wu and Hine [78] have mapped Public Transport Accessibility Levels (PTAL) index against the deprivation index for Belfast in Northern Ireland and found that the deprived wards were located within the “very poor/poor” PTAL zones. Subsequently, these indices included a transport dimension by incorporating a measure of accessibility to opportunities, which provided the basis to use these as a measure of transport disadvantage. These measures evaluate the levels of accessibility of an area by calculating road distance to essential services (e.g., doctors, post office, school, and super market).

A major weakness of these measures is, therefore, the unit of aggregation. It is not necessarily the case that all individuals in those areas can or should be defined as disadvantaged on the one hand [17,19,77,85]. On the other, the level of geographical access to opportunities is considered constant for all individuals living in an area. However, this might not be the case and varies depending on the levels of personal mobility. Casas et al. [82] used household level data to identify transport-excluded children in Erie and Niagara counties, New York. This work used a cumulative opportunity measure to determine accessibility level of each child and found that children from higher-income households have a lower deprivation index.

Since the score of the geographical access dimension is based on the road distance to different types of activities, a higher score in this dimension indicates that different types of activities are available to participate in and they are also located close by. Although the deprivation indices are the static outcome of social exclusion, by measuring these outcomes at certain time intervals would allow the analyst to examine changes in different dimensions over the periods (e.g., the UK case). However, because of the nature of the data used to derive the score for the geographical access dimension, this measure lacks the ability to examine whether transport is available both spatially and temporally to reach the available opportunities. Existence of an opportunity does not necessarily mean that transport (both private and public) is available to reach this opportunity. Similarly, despite taking into account the spatial distribution of different types of opportunities, these measures do not assess their temporal distribution (e.g., opening hours).

Current methods used to measure deprivation in the UK lack the ability of being able to make comparisons with other areas and therefore should not be used as a relative measure. Although the ranking of areas provides a basis for comparison, this however does not tell us how “good/bad” an area is when compared to others. In addition, the different dimensional measures (e.g., income and employment) are also not comparable to each other within an area. The Northern Ireland Multiple Deprivation Measure [39] (p. 30) underlines that “the scores should not be compared between domains as they have different minimum and maximum values and ranges. To compare between domains, the ranks should be used . . . because of the exponential distribution, it is not possible to say, for example, that an SOA [super output area] with a score of 40 is twice as deprived as an SOA with a score of 20”.

5.2. Area Mobility-Based Measures

Mobility-based measures identify individuals, groups, or areas with reduced mobility options by examining indicators such as car-ownership, driver’s licence, distance from the centroids of traffic analysis zones to public transport services such as bus stop, train station [86,87]. These measures then can be classified into an assessment of: personal mobility tools, and public transport accessibility (area mobility). Studies have found that car availability is the most significant indicator of personal mobility and consequently their ability to participate in activities [88]. Hine and Mitchell [2,7] have identified groups that are most likely to possess a lower level of access to a car. These are: low incomes, women,

elderly, disabled, and children by analysing data collected from questionnaires, travel diaries, focus groups, and interviews from Edinburgh, Glasgow, and North Lanarkshire.

Higgs and White [33] have, however, mentioned that a lack of car ownership would not be a problem if public transport services are available and within reach. Friends of the Earth [11] have shown that a significant number of non-car owning households do not have access to bus services in Bradford. In a similar way, using PTALs and ACCMAP tools, Wu and Hine [78] have identified public transport disadvantaged areas in Belfast and have found that more than 15% of households within these areas do not own a car. Dodson et al. [81] have mapped the spatio-temporal coverage level of public transport services in a GIS environment by generating a buffer distance of 400 m from bus stops and train stations and using frequency of these services at different times in a day and at different days in a week in Gold Coast City. The generated map was overlaid on Census Collectors District and the work found that the suburban areas such as Nerang, Worongary and Mudgeeraba were poorly served by public transport services during the morning peak hours. Using a similar approach like Wu and Hine [78], this work found that less than 17%-deprived households had no services at all during all periods. Currie et al. [79] (also see [4,89,90]) have developed a GIS-based public transport service level measure in Melbourne using buffer distances of 400 m from bus and tram stops, and 800 m from rail stations and frequency of these services. This service level has been compared with a transport need index and it has been found that overall 8.2% of Melbourne residents have very high needs but a zero or a low level of public transport supply.

Consequently, studies have adopted both car ownership and accessibility to public transport services as the main indicators by which it is possible to identify transport disadvantage. For instance, Cebollada [32] has generated distance buffers of 250 m, 500 m, and 750 m from urban bus stops, inter-urban bus stops, and local train stations, respectively, and has identified public transport disadvantaged areas in the Barcelona Metropolitan Region. From these areas, three groups were identified as transport disadvantaged including those who do not hold a driver's licence. The identified groups included women, young adults, and immigrants. By interviewing these groups, this study reported that many of the respondents had lower job opportunities due to their mobility limitations.

It appears that recent studies using mobility-based measures used disaggregated data to assess personal mobility options (see also [91]). However, the level of public transport accessibility has been measured in an aggregated way (as area mobility options). Access to public transport services within an area can be differentiated between groups (such as socioeconomic disaggregation). This means that what is accessible for one group (e.g., adult) might be inaccessible for another group (e.g., elderly). For instance, Battellino et al. [80] have identified pockets of transport-disadvantaged groups within public transport accessible areas in the inner city of Sydney. This study has reported that despite high levels of public transport accessibility, physical mobility problems (e.g., disability) can often prevent access to the public transport. Therefore, these measures require addressing socioeconomic disaggregation in order to assess public transport accessibility levels and identify the extent of transport disadvantage. Currie and Delbosc [64] and Delbosc and Currie [22] have generated a composite measure of transport disadvantage using 18 different types of difficulties that individuals reported in a household interview survey. Using a factor analysis of the 18 reported difficulties, they derived four-dimensional measures of disadvantage (e.g., transport disadvantage, transit disadvantage, vulnerable/impaired, and rely on others).

The mobility-based measures do not take into account the types of opportunities available to participate in and also their temporal availability. Stanley and Stanley [65] have mentioned that even a person with a high level of mobility (such as an able-bodied car driver) may have poor access to shops and services because of the residential locations in which they live. As a result, these measures are also not effective in evaluating whether mobility options are providing access to different types of opportunities. In addition, despite owning a car, groups may still face transport-related social exclusion particularly when they are forced to own cars (as structural dependence) [18]. This issue has been investigated recently by Currie et al. [79]. This work identified forced car ownership by selecting

low-income households who live outside of the public transport corridor in Melbourne but who own more than two cars. In this study, it was found that forced car ownership households make less trips and travel shorter distances than average 2+ car households living in outer Melbourne.

Personal mobility tools (e.g., car) are considered available at all times (if it is not shared with other members of a household) to participate in activities. The works of Wu and Hine [78] and Dodson et al. [81] have also taken into account the dynamics criterion in the measurement of public transport accessibility levels. These studies have shown that a significant spatial variation to public transport accessibility level can be found between peak and off-peak hours of a day. This means that those non-car owning individuals, who are not transport disadvantaged at certain times of day, might be disadvantaged at different times of the day. However, as these measures are spatially aggregated in nature, these studies therefore lack the ability to identify transport disadvantage at the level of socioeconomic disaggregation. The mobility-based measures also do not take into account the relativity of the area where an individual lives in terms of opportunities available [92–94]. For instance, Currie et al. [79] have reported that non-car owning households have made a significant number of walk trips because they live close to the local city centre. The implication of this finding is that low income families without access to a car may have poor mobility but good accessibility to opportunities that would allow them to participate more fully in society. In addition, due to an aggregated nature of analysis, the area mobility-based measures are not capable of taking into account the interaction criterion.

5.3. Area Accessibility-Based Measures

Accessibility refers to the opportunities that are available within a certain distance or travel time [85,87,95,96]. Although different methods exist in the literature to derive levels of accessibility (see [97]), cumulative opportunity/isochrones measure has been used predominantly to identify transport disadvantage [19]. Accessibility planning (provision of opportunities or transport services) is now a key policy tool to reduce social exclusion within many local transport plans in the UK [6,29,54]. Different GIS-based accessibility planning tools have been developed over the years to underpin accessibility planning such as CAPITAL [17], ACCESSION [98], LUPTAI [99], and AMELIA [1]. These tools have been used to identify areas where accessibility is poor [6,88]. Despite the usability of these measures, several weaknesses can also be identified. Farrington [100] (p. 320) has stated that: “A place is not just ‘more’ or ‘less’ accessible, but accessible relative to people in all their different circumstances: people experience more, or less, access to places.” Preston and Rajé [54] (p. 151) have stated that: “Although this initiative is not totally without merit, the resulting analysis may be too aggregate, both spatially and socially. The weakness of such an approach is that transport-related social exclusion is not always a socially and spatially concentrated process.”

Traditional accessibility planning needs to adopt a more socially and spatially disaggregated approach to identify transport advantage. Using an updated NATA (New Approach to Appraisal) framework, Department for Transport [19] has developed a socially disaggregated approach and investigated the opportunities available between car-owning and non-car owning individuals living in Sparkbrook (most deprived ward on the basis of Index of Deprivation 2000) using a multi-modal transport network. This work has generated 20, 40, and 60 min isochrones from the ward for public and private transport separately and overlaid on an opportunity maps (e.g., employment, health facilities, and shopping facilities). This study found that the calculated number of opportunities that can be reached by car is substantially greater than that which can be reached by public transport. However, this work has not considered spatio-temporal disaggregation in terms of accessing public transport services and the types of opportunities available between the groups. It has been assumed that the levels of personal mobility within the groups considered are identical and so does their levels of accessibility. Since this work demonstrated accessibility levels only between car-owning and non-car owning groups, it was not possible/required in this work to model interactions of these groups with other socioeconomic factors such as between low-income car-owners and high-income car-owners.

5.4. Activity-Based Measures

Although a combined measure of area accessibility and area mobility can complement each other [101,102], a major weakness of these process-oriented measures is the unit of aggregation. As a result, these measures are not suitable to take into account the interactions between different explanatory factors as well as the relativity of the measures. In addition, although the process-oriented measures are useful in evaluating the performance of transport and/or land use systems [103], they provide very little information about the effectiveness of policy options in terms of improving participation in activities—the outcome [21,88].

The activity-based measures have, however, overcome the above weaknesses through the application of the activity space concept. After reviewing various modelling techniques, Department for Transport [19] (p. 26) has stated that: “Conventional transport models tell us very little about the intensity, duration or frequency of individuals’ participation in different activities, all of which are potentially important issues from the perspective of social exclusion . . . The concepts of the activity-based approach in principle provide an attractive framework in which to understand how the spatial, temporal, financial and situational constraints [identified in the conceptual review] interact to influence the opportunities of individuals and households to participate in activities.” In their short review about activity-based measures of transport disadvantage, Priya and Uteng [20] (p. 133) have stated that: “Most likely, this approach will form the quantitative platform for assessing transport-related social exclusion and provide feedbacks to the transportation modelling process in future.”

Activities occur at specific locations for a certain time periods. Transportation resources (personal mobility and/or public transport accessibility) allow an individual to trade time for space, to travel and participate in activities at dispersed location [104]. Therefore, the size or spatial coverage of individuals’ participation in activities (activity spaces) varies depending on their personal circumstances (e.g., disability), exposure to travel opportunities (e.g., owning a car, introduction of new public transport services), and exposure to opportunities (e.g., opening of a new shopping centre) [29,55,67,105]. Miller [106] has mentioned that transport disadvantage can best be understood from the perspective of individual dynamic life trajectories, which operate within a particular socio-spatial context. This means that transport disadvantaged groups are excluded from certain parts of the environment [97]. As a result, personal use of space (activity spaces) over time has been used as an important indicator to measure transport disadvantage and consequently social exclusion [84].

5.4.1. Concept of Activity Spaces

Despite differences in operational definition, action spaces and activity spaces have often been used interchangeably in the literature [84,107]. Action spaces have been used to describe an individual’s total interaction with his/her environment and they contain all locations about which an individual is aware of or has some knowledge [108,109]. Action space has also been referred to as “awareness space” in the literature [110,111]. Jakle et al. [112] have divided the concept of action space into two meaningful components: movement and communication. Golledge and Stimson [109] have denoted the movement component of an action space as the activity space. This movement within an activity space has been characterised as: firstly, movement within and near the home; secondly, movement to and from regular activity locations such as journeys to work, to shop, to socialize, and so on; and thirdly, movement in and around the locations where those activities occur. Therefore, activity spaces have been considered as the subset of action spaces in which people have direct physical contact [108,109,111]. On the other hand, communication has been regarded as an indirect means (e.g., telephone, newspaper, magazines, radio, and television) of expanding one’s spatial knowledge [109].

Researchers’ efforts to conceptualise the movement patterns of individuals can be traced back to the mid 1960s. Since then two related themes have been progressed within the literature. One theme, influenced by the work of Wolpert [113] and Horton and Reynolds [114], looks for actual or observed movement patterns in space [109]. The other theme that has been progressed is based on Hägerstrand’s [115] time-geographic concept; this approach largely seeks to model potential

movement patterns of individuals subject to spatio-temporal constraints [116]. Due to data availability at the individual level and the advancement of computational technologies, research on both themes has intensified since the early 1990s [108,117]. A comprehensive list of research on both themes can be found elsewhere and is not discussed here (see [118]). In addition, two levels of activity spaces have been proposed in the literature including macro-level activity spaces, and micro-level activity spaces. White [111] has defined the macro-level activity spaces as the direct physical contacts of individuals in different cities (e.g., between different states in the US). However, the concept of micro-level activity spaces has received the most attention in the study of human travel behaviour. Micro-level activity spaces refer to the local area within which most of the individuals' movements occur during a specified time [119]. Direct contacts (activity spaces) shape an individual's territory [109]. Researchers in different fields have attempted to capture the spatial properties of the territory in an understandable manner. Activity locations have been represented spatially as points in these approaches and efforts have been made to measure the spatial properties of these points in order to identify individuals' levels of accessibility, mobility, and participation in activities as discussed in the following sub-sections.

5.4.2. Individual Accessibility-Based Measures

Different methods of deriving the boundary of activity spaces have been proposed in the literature including standard distance circle (SDC) [83,120], standard deviational ellipse (SDE) [84,120,121], minimum convex polygon (MCP) [120], polygonal generalised travel area [122], buffering along travelled routes [84], and area generated by using the furthest distance activity (FDA) location from the home [67,82]. In addition, although Rai et al. [119] have conceptually developed three additional measures associated with capturing the boundary of human activity spaces such as super-ellipse, cassini oval, and bean curve, the application of these concepts has not been reported in the literature.

Buliung and Kanaroglou [120] have generated a standard distance circle (SDC) using standard distance (SD) of activity locations as radius centred on the mean centre of activity locations (Figure 1). Using the SDC measure, they have shown that the size (area) of activity spaces for sub-urban households are more dispersed than urban households. A similar method has been used by McCray and Brais [83]. This found that women who own cars have a greater size of activity spaces than non-car owners. They have also reported that home location from transit route influenced the size (area) of the SDC for the non-car user. Although the SDC suggests a dispersed or clustered pattern of activity spaces with a measure of areal extent, it cannot be used to investigate orientation or shape of the activity spaces [118]. Buliung and Remmel [123] have indicated that individual activity spaces are likely to possess these properties due to heterogeneity in the spatio-temporal distribution of activity destinations, and the spatial structure of road networks.

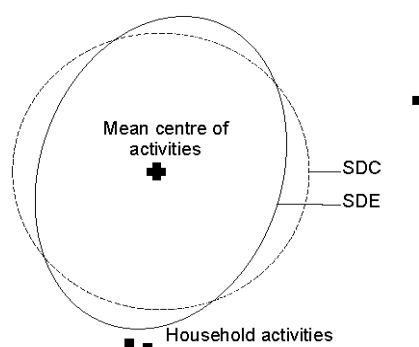


Figure 1. Standard distance circle and standard deviational ellipse measures (adapted from [118]).

Standard deviational ellipse (SDE) provides a unique approach to getting around this problem (Figure 1). It graphically represents the shape and direction of activity spaces on the one hand. On the other hand, the area of the ellipse represents the spatial extent of the activity spaces [121]. Ellipse-based

measures have been used to compare the dispersion between travellers [108]. Since the SDE is centred on a single point (the mean centre or any exogenously defined centre of gravity), much of the area inside an ellipse contains no activity points [123]. Schönfelder and Axhausen [84] have overcome the problem by creating and merging two ellipses centred on two pegs, such as home and office (Figure 2). However, the elliptical shape has been lost after merging the ellipses. Newsome et al. [121] have proposed a practical approach to overcome this problem. Instead of drawing two ellipses, they have drawn a single ellipse using the distance of the furthest activity location amongst the discretionary activities from the foci of the ellipse (Figure 3). The foci represent the pegs (e.g., home and work). Therefore, all other activities remain within the ellipse. The ellipse then represents an inner limit of potential opportunities over which an individual is able to engage in activities. They have quantified their ellipse construct in two ways. Firstly, the ratio of the minor to major axis indicates the fullness of the ellipse representing the relative extent to which the traveller is willing, able, or required to deviate from the main travel route. Secondly, the area of the ellipse represents the size of the activity spaces. They have linked the outcomes of these measures with travellers' characteristics and have found this potentially useful in understanding travel behaviour.

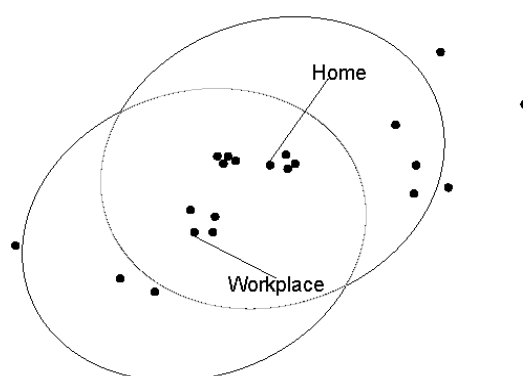


Figure 2. Merged ellipses (adapted from [84]).

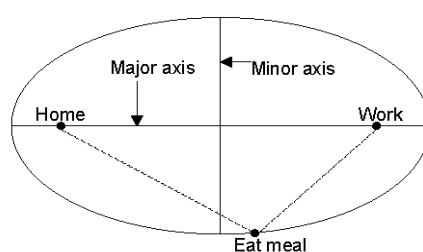


Figure 3. Ellipse drawn using the pegs and the furthest activity location (adapted from [121]).

Minimum convex polygon (MCP) based measure has recently been introduced into travel behaviour research (Figure 4) [118,120]. It was first introduced in the ecology literature in the late 1940s as an approach for measuring animal home-range [124]. With respect to human travel behaviour, the MCP is the smallest convex polygon containing all activity locations of an individual [108]. It provides a basic measure of the area or maximal geographical extent of the activity space on the one hand. Visually, on the other hand, the MCP provides a generalised depiction of the shape of activity spaces. Buliung et al. [108] have mentioned that the MCP is a supplementary measure of traditional area-based measures (e.g., ellipses), and have used the measure to explore weekday-to-weekend and day-to-day variation of travel behaviour. Using the MCP measure, Buliung and Kanaroglou [120] have shown that the size of activity spaces varies between CBD-based households and sub-urban households. Using a similar concept, Rogalsky [122] has created a polygonal generalised travel area using the origins and

destinations of all trips for working, poor, single mother living in Knoxville. This work found that individuals with mobility constraints had smaller sized of activity spaces than others.

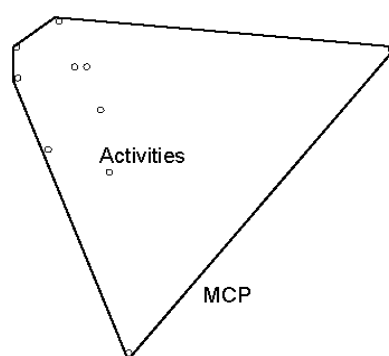


Figure 4. Minimum convex polygon measure (adapted from [123]).

Schönfelder and Axhausen [84] have mentioned that deriving activity space size in this way is a simplification of human behaviour and an overestimate of the potential contacts with activity locations. In reality, there could be locations within this area that are either inaccessible due to mobility constraints (e.g., a lack of bus routes for non-car owning individuals) or travellers would intentionally avoid due to ethnic reasons [78]. Golledge [125] has proposed an alternative measure mentioning that transport network structures shape the travellers' perception of potential activity locations as well as the knowledge of place and the spatial orientation. Using this alternative concept, Schönfelder and Axhausen [84] have measured activity space size by generating a 200 m buffer distance along the shortest path routes between origins and destinations.

The area (size) of activity spaces using the different measures discussed above has traditionally been used as an indicator of individual accessibility. As a continuous geometric space the area (size) generated by these measures is larger than the space in which activities are consumed and participated in. Miller [126] has highlighted that a large part of this area is useless for travel and activity participation because travel occurs along streets and activities occur at specific locations. As a result, he has discarded the planar form of the activity spaces and adopted only those discrete locations where activity could take place (e.g., street and buildings). After Miller [126], the network-based approach has widely been adopted to measure individual accessibility [127–134]. In relation to identifying transport disadvantage, Casas [67] and Casas et al. [82] have calculated distances from home to all destinations using a single weekday travel diary. The longest distance has been used as an indicator of mobility that delimits the size of activity spaces for an individual. This work has adopted a cumulative opportunity (accessibility) measure and counted the total number of opportunities available for an individual within the area generated, using the longest travel distance centred around the home placed over the network. The total number of opportunities has been used as an index of exclusion and has found a significant difference between the different groups (e.g., disabled and children).

This means that the methodology that presented by Casas [67] and Casas et al. [82] have overcome the identified weaknesses of traditional area accessibility measures (discussed in Section 5.3). These works have used the levels of personal mobility (longest distance travelled from home) to assess the levels and types of accessibility (as spatial disaggregation, e.g., shops) between different groups (as socioeconomic disaggregation, e.g., disabled). The work of Schönfelder and Axhausen [85] was conducted in three German cities with differential levels of opportunities. This study used general linear model (GLM) and investigated the variations associated with the size of activity spaces for different social groups separately for each area. This is one way of maintaining the spatial relativity concept in the measure. However, the weakness of this approach is that the spatial heterogeneity of the different areas was not modelled due to separating the analyses by areas. Research has indicated that the contexts of living areas influence travel behaviour, which cannot be captured by traditional

explanatory variables (e.g., age, income) and often referred to as latent influence [135]. A number of techniques have been used in the travel behaviour research to capture the contextual variations such as the market segmentation, use of dummy variables, expansion method, multi-level models, geographically weighted regression, multivariate regression with spatially expanded coefficients, and use of latent variable [135–139].

A number of studies, such as Casas [67], and Buliung and Kanaroglou [120], have taken into account the spatial heterogeneity aspects by incorporating a dummy living form variable (e.g., urban, sub-urban, and rural) into the measure. However, these studies lack the ability to model the relativity concept. Interestingly, none of these studies used interactions between different explanatory variables in order to identify disadvantaged groups. As a result, the modelling techniques used in these studies (e.g., regression analysis) derived a coefficient that described the main effects of each of the explanatory variables (e.g., income and living area) on the levels of accessibility without making reference to other explanatory variables in the model (interaction effect). This means that, for instance, the model assumes that car-ownership is invariant to other variables, which implies that, other things being equal, all car-owning individuals have similar levels of accessibility regardless of where they live or their income level [137]. However, this might not be the case, as Gray et al. [74] found that despite owning cars, high-income individuals made more trips and travelled longer distances using the car than low-income individuals in rural Scotland. Garson [140] has noted that a main effect is the direct effect of an explanatory variable on the dependent variable (e.g., accessibility) whereas an interaction effect is the joint effect of two or more explanatory variables on the dependent variable.

5.4.3. Personal Mobility-Based Measures

Mobility refers to an individual's ability to move [70,141]. Although car-ownership has frequently been used to refer to this ability, studies have shown that car-ownership does not always reflect actual mobility patterns of individuals particularly in rural areas because in rural areas it happens that individuals are forced to own a car [18,142]. As a result, researchers have used the activity space concept (movement) as a practical alternative of getting around the problem associated with using car-ownership as an indicator of personal mobility.

Using the activity space concept to measure mobility, Schönfelder [105] has used total distance travelled by an individual. This work found that the amount of travel is influenced by the occupational characteristics of travellers (socioeconomic disaggregation) on the one hand, and on the other hand, that the personal mobility also varies over time (dynamics). Unlike Schönfelder [105], Buliung and Kanaroglou [120] have used total daily household kilometres travelled (DHKT) as an indicator of household mobility. They have used Euclidean distance between successive activities to measure the DHKT and found that the DHKT varies with household structure (number of employed householders). This work used a location variable (dummy) to measure the contextual variations between travellers. The DHKT does not take into account the underlying friction (e.g., travel time, congestion) of travelling over the network. As a result, network-based distance has been adopted as an indicator of mobility (Figure 5). Wyllie and Smith [143] have reported that the mean travel distance for discretionary activities is higher for female than male extroverts. Kawase [144] has used mean travel distance (expressed in minutes) to measure the size of commuting mobility in a suburb of Tokyo. This work has found that the commuting distance is shorter for married women than married men and the mobility is relatively stable over time for married women who are in higher paid jobs (interaction between gender and employment). Kamruzzaman et al. [41] have used average daily distance travelled as a measure of student mobility and found that students who live outside of the limits of a demand responsive service have a significantly higher level of mobility (as spatial disaggregation).

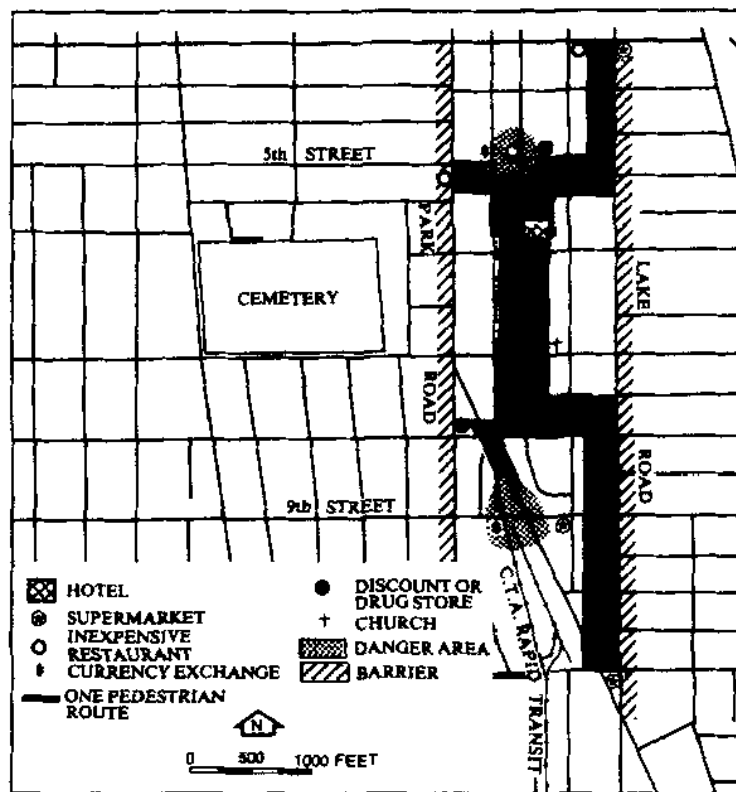


Figure 5. Traces of movement over the road networks [145].

Therefore, it appears that the operationalised examples of personal mobility-based measures using the concept of activity spaces overcome some of the identified weaknesses of the traditional mobility-based measures such as socioeconomic (e.g., male, female, disabled, and children) disaggregation, and spatio-temporal disaggregation of the availability/use of transport services. However, none of the operationalised examples have taken into account the spatial relativity criterion. In addition, like the traditional mobility-based measures, the personal mobility measures also do not take into account the types of opportunities available to participate in and also their temporal availability. This suggests that the personal mobility-based measures and the individual accessibility-based measures needs to be operationalised together to identify transport disadvantaged groups or individuals.

5.4.4. Participation-Based Measures

Researchers have recently attempted to measure actual participation in activities to identify transport disadvantage and their exclusionary outcome [84]. These measures have also been referred to as actual accessibility measures in the literature [12,76]. Becker and Gerike [76] have mentioned that actual accessibility measures, measure the opportunities that are actually reached—in contrast to potential accessibility, which measures the opportunities that could be reached. Different dimensional indicators have been used in the literature to measure participation in activities including count (e.g., number of trips, number of unique activity locations visited) [41,84,146,147], frequency of participation (e.g., number of trips per week or per day) [7,143,148], duration of participation (activity duration) [41,121,148], and types of opportunities participated in [41,148].

Using count-based measures, although the number of trips is frequently used as an indicator of participation in society [147], Schönfelder and Axhausen [84] have mentioned that much of the individuals trips are associated with one or few locations and can act only as a proxy measure. As a result, the number of unique activity locations visited by an individual has been used as an indicator of

participation in activities [41,84]. Wyllie and Smith [143] have found a positive correlation between the level of extroversion and the number of activity sites visited by adolescents (i.e., female aged 13–16 and male aged 14–16). Rollinson [145] (p. 457) has adapted the definition of everyday geography provided by Seamon [149] (p. 16) as “the sum total of a person’s first-hand involvements with the geographical world in which he or she typically lives” as a measure of participation in society. This study counted the number of places visited by elderly tenants living in single-room-occupancy hotels and concluded that the everyday geography of elderly men and women is highly constrained due to poverty and the barriers imposed on them by their neighbourhood environment such as street crime. Goldhaber and Schnell [146] have studied the relationship between ethnicity and the level of segregation using the concept of activity spaces. They have derived a ratio of visited activities to the total number of activity locations present in a region as an index of participation.

Wyllie and Smith [143] have also used the total number of trips per person per week (frequency) to activity sites as an indicator of participation and found a positive effect to the level of extroversion. Farber and Páez [148] have shown that the frequency of participation in out of home amusement activities is significantly lower for auto reliant individuals, being retired, older in age, living in urban core, and with a lower level of household income than their respective counterparts. This work used a geographic stratum variable (urban core, sub-urban satellite towns) of the individuals as a dummy variable to model the spatial heterogeneity. Farber and Páez [148] have also used average daily activity duration as a measure of magnitude of participation in activities and investigated the differences between different groups by taking into account the interactions between auto reliance variable and other explanatory variables. This work found that auto dependent individuals spent more time in social activities on weekends than on weekdays (dynamics) when compared to mixed mode user. Using activity duration as a measure of participation in activities, Newsome et al. [121] have shown that significant differences exist between different socioeconomic groups (e.g., age and race) as well as between different areas (e.g., home type: downtown, central city, suburb). Kamruzzaman et al. [41] have evaluated the levels of participation in activities using average daily activity duration of students and found that the average activity duration of low-income students is significantly lower. Using student activity-travel diary data, this work has not found any spatial differences in terms of the type of activities participated in (e.g., social, shopping, and educational) by different groups (e.g., low-income and high-income). However, this work has reported that students who live outside of the limits of a demand responsive service for them are temporally excluded from certain type of facilities (e.g., shopping).

The above examples suggest that participation-based measures meet four of the criteria used for the review: socioeconomic disaggregation (e.g., car ownership, and income), spatial disaggregation (e.g., downtown, types of opportunities participated in), dynamics of activity participation (temporal exclusion from certain activities for some groups), and interactions between different explanatory variables. However, the relativity criterion has not been addressed in these studies despite each of the studies was conducted using data from different contexts. In addition, these studies used four-dimensional indicators to measure participation in activities (count, frequency, types, and duration of participation) and each of these indicators represents a different qualitative aspect of travel and activity participation [19]. The following section highlights the importance of all these indicators to identify transport disadvantage.

6. Synthesis of Discussion on Measures/Indicators

Table 5 summarises the advantages and disadvantages associated with different measures used to identify transport disadvantage and consequently social exclusion. The review of the different measures has shown that both deprivation-based measures and area accessibility measures lack the ability to address the spatio-temporal aspects of access to transport whereas area mobility-based measures lack the ability to incorporate the spatio-temporal aspects of access to opportunities. In addition, these measures lack the ability to take into account the spatial relativity and interaction

criteria. On the other hand, a gradual incorporation of the different criteria was evident in the outcome-based measures, although none of the studies incorporated all the criteria together (Table 5). In addition, the relativity criterion has rarely been addressed in different studies. As a result, therefore, the identified transport disadvantaged groups have only been partially identified.

The review also shows that multidimensional indicators have been used to measure participation in activities. These dimensions are: count (e.g., number of unique activity locations visited) [41,84,143,145,150]; types of activity participated in [41,82]; frequency of participation [143,148]; and duration of participation—e.g., activity duration [41,121,148]. Researchers have investigated these indicators separately to identify transport disadvantage although each represents a different qualitative aspect of travel and activity participation. Based on [44], the following scenarios indicate the importance of each dimension to the measurement of transport-related social exclusion.

Scenario 1: Two individuals live in a city centre. Both of them have visited many activities located close by. But one of them has visited these activities once a week whereas the other individual has visited these activities twice in a week. The count-based measure (number of unique locations visited) will indicate an equal level of participation in activities for both individuals although one of them possesses a better ability to travel and participate in activities. A frequency-based measure will, therefore, complement the count-based measure.

Scenario 2: A person has visited several widely dispersed shopping locations by bus in a city. In this scenario, the count-based measure will indicate a higher level of participation in activities though the person has participated in only one type of activity. This measure, however, does not indicate whether the individual is able (or if public transport is available) to participate in all of his required activities.

Scenario 3: Two persons live in the same area. They have both visited the same places twice in a week. However, one person has spent more time in these activities. Both the count and the frequency-based measures will indicate an equal level of participation in activities for both individuals, even though one of them has potentially a greater opportunity to extend his participation in society.

Scenario 4: A person cannot be considered transport disadvantaged if s/he is able to travel long distances daily and if different types of opportunities are located within the boundary of their activity spaces in spite of their participation in a lower number of activities. This suggests that in addition to analysing the levels of participation in activities, an operationalisation of both the individual accessibility-based measures and the personal mobility-based measures are required to identify transport-related social exclusion.

Therefore, a single indicator cannot clearly capture evidence as to whether a person is at risk of being excluded due to their lack of participation in activities. As a result, a unique approach to the measurement of participation in activities is necessary, which combines the various dimensions of the different indicators used to measure participation (outcome). In addition to operationalising the participation-based measure in order to identify transport disadvantage and consequently social exclusion, the above scenarios indicate that it is also important to operationalise the individual accessibility-based measures and the personal mobility-based measures to identify transport disadvantage. This is due to the fact that transport disadvantage is a function of a lack of access to both transport (mobility) and opportunities (accessibility); and despite not being mobility and/or accessibility disadvantaged, the participation-based measures could identify an individual as participation disadvantaged as shown by Shortall [25].

7. Conclusions

This paper reviews quantitative measures used to objectively identify transport disadvantage and consequently the ability of the measures to identify transport-related social exclusion. The argument put forward in this paper is that transport-related social exclusion can only be identified with confidence if the underlying search procedure is robust. The search procedure in this case refers to the methodology used to identify transport disadvantaged groups, as they are the people who are susceptible to transport-related social exclusion. In other words, transport-related social exclusion does not exist if there is no transport disadvantaged in a society. This does not necessarily mean that all transport disadvantaged groups are socially excluded [151]. However, they are at risk of being excluded due to their lack of ability to travel/access and to participate in activities.

This paper reviewed quantitative measures of transport disadvantage. Church et al. [17] have indicated that in the absence of an objective assessment of access to key activities, the application of qualitative measure at the individual level of analysis will provide only a limited appreciation of travel experience. Quantitative measures used to identify transport disadvantage were shown to be either process-based or outcome-based. Process-based measures identify a lack of transport and/or land use arrangements that potentially facilitate participation in activities. These types of measures also include the more widely used deprivation-based measures, area mobility-based measures, and area accessibility-based measures. On the other hand, outcome-based measures, in particular activity-based measures using the concept of activity spaces, evaluate the levels of actual travel and activity participation. Although the outcome measures also evaluate potential accessibility but take into account individuals actual mobility levels (as outcome) to assess individuals' accessibility levels. As a result, these measures take into account the differential abilities of the individuals to assess levels of accessibility. Therefore, the individual accessibility-based measures and the personal mobility-based measures are also useful to indicate the performance of the transport/land use systems. As a result, the outcome measures can also inform the development of system specific policy responses. Farber and Páez [148] (p. 217) have stated that "if these individual effects are extant and measurable, they are of interest for their potential influence on aggregate outcomes".

Participation-based measures not only identify transport disadvantage by assessing the levels of participation in different activities but also helps in identifying the exclusionary outcomes such as a lack of participation in certain types of activities [41]. In addition, the two measures, individual accessibility and participation in activities, together facilitate a link for investigation between the types of opportunities available and the types of opportunities participated in. This discussion therefore suggests operationalising all three measures associated with the activity-based measures (e.g., individual accessibility, personal mobility, and participation in activities). Despite intensive application in the travel behaviour research and also having a good potential, the application of activity-based measures to identify transport-related social exclusion is fairly limited [19,20].

However, although the outcome measures reflect the performance of transport/land use systems, it, however, cannot be assumed that a lower level of mobility/accessibility for certain groups is due to a non-existence of transport/land use systems. This suggests the need of extending the analysis to include process-based investigation (e.g., existing transport and/or land use arrangements). Lyons [103] has indicated that process-based measures assist in the development of system specific policy responses whereas the outcome-based measures (e.g., individual accessibility and personal mobility) are more suitable for delivering symptom specific interventions. Therefore, both process-based measures and outcome-based measures are important in order to portray a complete picture of transport disadvantage. A major weakness of the quantitative process-based measures was found to be their unit of aggregation. A number of studies have, however, overcome this problem by operationalising qualitative process-based measures (e.g., focus groups, interviews, Q-methodology, and discourse analysis) [7,9,45,77,152–154]. Røe [153] has mentioned that the best way to deal with the problems associated with quantitative process-based measures is to adopt a qualitative approach. However, this work has also highlighted the necessity of quantitative modelling

approaches. As a result, a combined analysis of qualitative process-based measures and a quantitative outcome-based measures complement the identification of transport-related social exclusion. Røe [153] (p. 102) has stated that “these types of studies [disaggregated quantitative analysis], while giving important information about statistical correlations between individual background data and social events, do not capture the nature of social systems and structures, and do not necessarily enhance the understanding of causal mechanisms. To achieve this the quantitative techniques need to be combined with qualitative research”.

Acknowledgments: Authors wish to acknowledge the support of Queensland University of Technology and University of Ulster for the research upon which this paper is based. Authors are grateful to the anonymous reviewers, who provided constructive comments on an earlier version of the paper.

Author Contributions: This paper represents a result of teamwork. The first author (Md. Kamruzzaman) drafted the manuscript. The second author (Tan Yigitcanlar) revised the manuscript. All authors jointly designed the research, and reviewed the literature. All four authors read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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