SPATIAL ACCESSIBILITY OF PRIMARY HEALTHCARE IN RURAL POPULATION: A REVIEW

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https://doi.org/10.32827/ijphcs.5.6.1

ABSTRACT

Background: Access to healthcare can be defined as opportunity or ease for patients to come to the services, while accessibility can be defined as the potential or ease for certain health services or health facilities to be reach and utilized by the patients. Spatial accessibility is assessment of accessibility determinant which can be segregated according to geographical location. The aim of this manuscript is to identify spatial accessibility assessments methods used in the primary healthcare accessibility studies within rural population setting and integration with its determinants.

Materials and Methods: Scoping systematic review was done using public domain search engine. Keywords used for article search are Spatial Accessibility; Geographical Accessibility; Primary Health Care; Primary Care; Rural; Non-Urban and Remote. All articles within 15 years of publication were included with the exclusion criteria of review article, research methodology protocol and non-English articles. After screening, 10 final articles were eligible for qualitative synthesis. Content analysis was carried out, then synthesized into location of study, purpose of the study, method of spatial accessibility assessment and accessibility determinants.

Result: Most of the studies in this review used gravity method (floating catchment method), three studies using physician population ratio and one study used travel impedance. Travel impedance and physician population ratio were described descriptively, which later were correlated with utilization and mortality. Several aspatial factors were also been associated with spatial accessibility through correlation, integration through formula calculation, aggregation in index and overlaying through geographical information system.

Conclusion: Development of geographical information system has made more studies to use floating catchment method as a tool to assess spatial accessibility. Alteration to existing floating catchment method to allow researcher to address limitation for its predecessor. Recent development also integrates spatial accessibility with aspatial factor and its determinants. This knowledge will facilitate policy maker to improve the accessibility by overcoming the barriers.
Keywords: Spatial Accessibility; Primary Health Care; Rural Population

1.0 Introduction

Definition of accessibility varies and each carries different interpretation. Generally, access to healthcare can be defined as the opportunity or ease for patients to come to the services, healthcare providers or facilities (Guagliardo, 2004). Accessibility can defined as the potential or ease for certain health services or health facilities to be reached and utilized by the patients (Guagliardo, 2004; Salkever, 1976).

Health care accessibility is one of the important components towards adequate and equitable health system. It is also widely accept a key goal towards realizing human right of having healthy life (Pillay, 2008). Ensuring a healthcare system which is accessible to the population has been a continuous concern of public health policy makers, providers and academicians (Dewulf, Neutens, De Weerdt, & Van de Weghe, 2013).

One of the effective strategy in achieving accessible healthcare is through an effective primary healthcare system (Dewulf et al., 2013). The spirit of establishment of a primary healthcare system from the first declaration of Alma Alta is ensuring a reachable, acceptable and affordable first level of contact to the population (Walley et al., 2008).

1.1 Spatial Accessibility

Spatial accessibility is an assessment of accessibility determinant which can be aggregated into geographical location (Guagliardo, 2004). Several methods have been used either by public health researchers and health geographers in order to come out with the assessment. Guagliardo (2004) classified these methods of spatial accessibility assessment of primary healthcare to either; (1) provider-population ratio, (2) travel impedance, or (3) gravity model. Provider-population ratio and travel impedance are two of the earliest methods of spatial accessibility assessment. Recent review done on accessibility has shown that most researchers used these two methods to measure accessibility as it is easy to calculate and interpreted both among the researchers and policy makers (Neutens, 2015).

Provider- population ratio is calculated by the ratio of provider in specific administrative area to the number of the population within the area (Dewulf et al., 2013). This method has been used by the World Health Organization to compare the health workforce among countries in order to come out with a standard for number of each profession needed per population (WHO, 2017). Despite its popular usage, this method is highly criticized due to its focus on the availability of health personnel, not taking into consideration the aspect of demand that is the number of population and the boundary where it is been calculated (Dewulf et al., 2013; Guagliardo, 2004; Neutens, 2015).

Travel impedance on the other hand, is assessed via the distance calculated from the population to the nearest provider (Guagliardo, 2004). Similar to provider-population ratio, it is easy to calculate and require minimum skills on spatial analysis. However, its main limitation lies on its characteristic which does not include supply and demands elements (Bissonnette, Wilson, Bell, & Shah, 2012). This method also only capture proximity, does not taking into account overlapping catchment area of health services and does not consider competition between the providers and bypassing the nearest health services in a condition.
where there are multiple health providers (McGrail, 2012). Gravity-type accessibility models is a trade-off between destination attractiveness and spatial separation through travel time or travel distance (Guagliardo, 2004; F. Wang & Luo, 2005; L. Wang & Tormala, 2014). Recent development of geographical information has allowed floating catchment method to emerge as the variation of gravity method overcoming the limitation imposed by provider-population ratio and travel impedance (Luo, 2004). Floating catchment method’s main advantage is its characteristic that consider the limitation of provider-population ratio and travel impedance; it takes into account the supply (provider or services) and demand (population needs) elements and consider the competition between the provider (Neutens, 2015). Method on how the floating catchment area been calculated will be further elaborated in the result and discussion part.

However despite further improvement on spatial accessibility assessment, these methods are not without any limitation. Spatial accessibility is still a static accessibility assessment, it does not allow time variation (Neutens, 2015) giving rise to a term called uncertain geographical context (UGOP). It explains the uncertainty of spatial accessibility assessment to time, duration and area of context (social, environment) in the population. Another limitation is the modified areal unit problem (MAUP) which is the statistical bias due to empirical result difference based on the choice of analysis unit and area of data aggregation (Guagliardo, 2004; McGrail & Humphreys, 2009a; Neutens, 2015). Several attempts has been made to address these two main limitations however due their complexity in analysis and interpretation, their application has yet been widespread especially in policy planning and implementation context (Neutens, 2015).

1.2 Determinants of spatial accessibility

Five determinants of accessibility which usually discussed are proximity, availability, affordability, acceptance and accommodation (Aday & Andersen, 1981). This determinant also been describe as the barrier to accessibility (Penchansky & Thomas, 1981). This determinants can be further classified into spatial factor which will include proximity and availability and aspatial factors in which the determinant that cannot be segregated to geographical location such as availability, affordability and accommodation (Guagliardo, 2004). Availability refers to number of services or provider available to the population while proximity refers to the distance that the population need to take or travel in order to receive the services (Guagliardo, Ronzio, Cheung, Chacko, & Joseph, 2004). While some literature explore both this separately, some of the researchers describe them in a combination which give rise to the term of spatial accessibility (Guagliardo, 2004). This is the spatial accessibility which is now gaining favor among the literature (Luo, 2004; F. Wang & Luo, 2005). In fact, both of spatial factor of accessibility and aspatial factor of accessibility affect health status and health utilization differently thus recent development has shown that many researcher attempt to combine and integrate both factor in many ways (F. Wang & Luo, 2005; L. Wang & Tormala, 2014).

This scoping systematic review aims to identify spatial accessibility assessment methods frequently used in the primary healthcare accessibility studies within rural population setting and integration with its determinants.
2.0 Materials and Methods

Scoping systematic review was carried out using public domain search engine such as Pubmed, Medline and Google Scholar. Keywords used for article search are Spatial Accessibility; Geographical Accessibility; Primary Health Care; Primary Care; Rural; Non-Urban and Remote. All articles within 15 years of publication were included with the exclusion criteria of review article, research methodology protocol and non-English articles. As the review focuses on the spatial accessibility to primary healthcare as a healthcare system, all articles which discuss about specific diseases and condition were excluded. Preliminary search using the keyword come out with 130 articles. After removing duplicating articles, 120 articles remained. These articles’s title then were screened according to their criteria. Afterward, 48 articles were identified from the abstract screening. Nineteen articles were eligible for full text review which result for ten final articles eligible for qualitative synthesis. Figure 1 further illustrate the flow of the article search and screening according to PRISMA flow diagram. Through qualitative synthesis, content of the articles was then further synthesized into location of study, purpose of the study, method of spatial accessibility assessment and aspatial factors which involve as accessibility determinants.

![Prisma Flow Diagram of article search and screening](image_url)

**Figure 1:** Prisma Flow Diagram of article search and screening
3.0 Results and Discussion

Content analysis all the articles are presented through several subtopic namely the method of measuring healthcare spatial accessibility, discussion about the methods, the accessibility determinant and integration between spatial accessibility with accessibility determinants.

3.1 Method of Measuring Healthcare Spatial Accessibility

Most of studies in this review were done in developed countries. Only one study was done in developing countries which is in India (Vadrevu & Kanjilal, 2016). All the studies included using geographical information software for the analysis. Title of the article, the location where the study being held and characteristic of the study area whether it involved rural, urban or both were listed in Table 1. Out of ten articles, four of them study spatial accessibility specifically in rural population while rest of the them were done with a combination of urban and rural population.

<table>
<thead>
<tr>
<th>Table 1: Study title, author, location and setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
</tr>
<tr>
<td>Using a GIS-based floating catchment method to assess areas with shortage of physicians</td>
</tr>
<tr>
<td>Assessing spatial and nonspatial factors for healthcare access: Towards an integrated approach to defining health professional shortage areas</td>
</tr>
<tr>
<td>Measuring spatial accessibility to primary care in rural areas: Improving the effectiveness of the two-step floating catchment area method</td>
</tr>
<tr>
<td>The index of rural access: an innovative integrated approach for measuring primary care access</td>
</tr>
<tr>
<td>Accessibility to primary health care in Belgium: an evaluation of policies awarding financial assistance in shortage areas</td>
</tr>
</tbody>
</table>
Integrating Spatial and Aspatial Factors in Measuring Accessibility to Primary Health Care Physicians: A Case Study of Aboriginal Population in Sudbury, Canada

Measuring spatial equity and access to maternal health services using enhanced two step floating catchment area method (E2SFCA) – a case study of the Indian Sundarbans

Spatial Accessibility of Primary Care in England: A Cross-Sectional Study Using a Floating Catchment Area Method

Measuring geographical accessibility to rural and remote health care services: Challenges and considerations

Most of the studies in the review used gravity method in the form of floating catchment method to determine spatial accessibility of the population. Three studies using physician population ratio (Dewulf et al., 2013; Shah et al., 2017; Todd et al., 2015). One of the studies used travel impedance as a method spatial accessibility assessment. Dewulf et al. (2015) and Shah et al. (2017) used several methods to compare outcome in spatial accessibility across all the methods while Todd et al. (2015) used solely the percentage of population that lived within specific catchment area but the study mapped the result along with deprivation decile nationwide. Table 2 list all the method that was used to determine spatial accessibility of rural population in the study.

**Table 2: Spatial Accessibility method**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Spatial Accessibility Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luo, 2004</td>
<td>Floating catchment method</td>
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<tr>
<td>Wang &amp; Luo, 2005</td>
<td>2 step floating catchment method</td>
</tr>
<tr>
<td>McGrail &amp; Humphreys, 2009a</td>
<td>2 step floating catchment method</td>
</tr>
<tr>
<td>McGrail &amp; Humphreys, 2009b</td>
<td>2 step floating catchment method</td>
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</table>
Traditionally, several methods have been used as spatial accessibility measurements. One of the way is by taking the average travel impedance from the population centroid to the health facility. Several metric that has been used were either distance time, straight line distance and network distance (Dewulf et al., 2013). This method has several shortcomings. First, it depends very much on the origin of the population, hence the calculation of travel impedance from residential area might differs if it come from working area (Dewulf et al., 2013). Secondly, it does not take into account of cross border patient. If the population and the facilities are confined within a designated boundary, it will assume that patient will only seek the facilities within that boundary while in real life situation, patient will cross border to seek a rather nearer facility (Guagliardo, 2004).

Travel impedance also can be an indicator for proximity as accessibility determinants. Most of the studies describe descriptively travel impedance to indicate proximity of the population to the health facilities (Dewulf et al., 2013). However, it also can be correlated with other outcome such as mortality. A study in Ethiopia postulated that children who live more than 1.5 hour from health facilities have two to three times for mortality than those who live less than 1.5 hour (Okwaraji, Cousens, Berhane, Mulholland, & Edmond, 2012).

Another way to calculate spatial accessibility is by implementing cumulative opportunity either through provider population ratio (Dewulf et al., 2013; Shah et al., 2017) or by calculation of the population percentage that live with a predefined specific distance area (Todd et al., 2015). Among other methods, this measurement is mostly use as it is highly intuitive, data is readily available and less dependent to spatial analysis skill and expertise (Guagliardo, 2004). However, it also poses several limitations. First, it does not take into account border crossing patient (Todd et al., 2015). It also did not taking into account the catchment area of the clinic (Todd et al., 2015). While it is good to be compared among different administrative area, this method of assessment assumed that the ability of patient to assess is uniformly similar within the predefined area (Dewulf et al., 2013).

### 3.2 Travel Impedance as proximity and provider population ratio as availability

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Method Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dewulf, Neutens, Weerdt &amp; Weghe, 2013</td>
<td>Provider-population ratio, distance close to physician, floating catchment method</td>
</tr>
<tr>
<td>Todd et al, 2015</td>
<td>Percentage of population lived within specific catchment area within each deprivation decile</td>
</tr>
<tr>
<td>Wang &amp; Tormala, 2014</td>
<td>Enhanced 2 step floating catchment method</td>
</tr>
<tr>
<td>Vadrevu &amp; Kanjilal, 2016</td>
<td>Enhanced 2 step floating catchment method</td>
</tr>
<tr>
<td>Bauer, Muller, Bruggmann &amp; Groneberg, 2017</td>
<td>Integrated floating catchment method</td>
</tr>
<tr>
<td>Shah, Milosavljevic, &amp; Bath, 2017</td>
<td>3 step floating catchment method, provider population ratio</td>
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</tbody>
</table>
Similar to travel impedance, provider population ratio can also be associated with other outcome like the study in Paris which stated that availability have a positive association with the health care utilization (Brondeel, Weill, Thomas, & Chaix, 2014).

### 3.3 Innovation through Floating Catchment Method

Floating catchment method is a method of spatial accessibility assessment classified under gravity method (Guagliardo, 2004). Basic concept of floating catchment method calculate provider population ratio within a specific catchment area determined by a predetermined radius with the centroid of the population become the center of the population area (Luo, 2004). Several variation floating method has been developed with one method tried to address limitation of another. Among the concern that deems modification to method are the variation of access within the catchment area (Luo, 2004), distance decay within the catchment area (L. Wang & Tormala, 2014) and realistic approximation of the catchment area (Vadrevu & Kanjilal, 2016).

2-step-floating-catchment method repeats the step for floating catchment twice using the location of population and provider become the center of the catchment area radius (F. Wang & Luo, 2005). The first step of calculation of provider population ratio will take location of provider as the center of catchment area radius while the second step will involve the aggregation of all provider population ratio within a catchment area with the population coordinate as the center of the radius (F. Wang & Luo, 2005).

Enhanced 2-step-floating-catchment method put different weightage to specific travel distance within the catchment area of 2-step-floating-catchment method (L. Wang & Tormala, 2014). As Wang & Tormala (2014) stated in their study this method would use impedance function to create weights for opportunities within specific catchment area. Different spatial accessibility result then would be derived depending on the area of travel zone and weightage put on each zone for example in every 5km or 10km travel distance (L. Wang & Tormala, 2014).

Integrated floating catchment method combine several variations of floating catchment method including enhanced 2-step-floating-catchment method and modified 2 step floating catchment method (Bauer et al., 2017). Through this variation several catchment areas were introduced, distance decay is applied within the catchment area and competition parameter which demands along with available physician (Bauer et al., 2017).

3-step floating catchment method is an extension of 2-step-floating catchment method. After calculation of 2-step catchment method, the third step will involve calculation of the average physician population ratio average within specific unit of spatial analysis such as census consolidated subdivision, or census subdivision (Shah et al., 2017). The spatial accessibility measurement would come out as ratio per unit of spatial analysis.

### 3.4 Accessibility Determinant through aspatial factor

Very few studies of spatial accessibility integrate spatial accessibility with aspatial factor. Other than the complexity of spatial accessibility, researcher need to be able to aggregate aspatial factor of accessibility and finally combine them with the measurement of spatial
accessibility (F. Wang & Luo, 2005). Table 3 list the aspatial factors which were studied among the articles reviewed.

**Table 3: Aspatial factor within spatial accessibility study**

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Aspatial factor studied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wang &amp; Luo, 2005</td>
<td>Socio-economic disadvantages: <em>female headed households</em>, <em>population in poverty</em>, <em>non-white minorities</em>, <em>household without vehicle</em>, <em>home ownership</em>, <em>housing unit lack of basic amenities</em>. Socio-cultural barriers: <em>households with linguistic isolation</em>, <em>households with more than 1 person per room</em>, <em>population without high school diploma</em>. High health needs: <em>population with high needs</em>, <em>median income</em></td>
</tr>
<tr>
<td>McGrail &amp; Humphreys, 2009</td>
<td>Health needs: <em>significant variable from advantages-disadvantages index from regression model towards DALY</em>. Mobility: <em>household without cars</em>, <em>low mobility individual</em>, <em>public transport availability</em></td>
</tr>
<tr>
<td>Todd et al, 2015</td>
<td>Deprivation deciles: <em>income</em>, <em>employment</em>, <em>health</em>, <em>crime</em>, <em>housing services</em>, <em>living environment</em>. Urban-rural classification</td>
</tr>
<tr>
<td>Wang &amp; Tormala, 2014</td>
<td>Distribution of aboriginal population within a census block</td>
</tr>
<tr>
<td>Bauer, Muller, Bruggmann &amp; Groneberg, 2017</td>
<td>Social deprivation, geographic barrier, urbanization, general health, population size</td>
</tr>
<tr>
<td>Shah, Milosavljevic, &amp; Bath, 2017</td>
<td>Deprivation deciles. urban-rural classification</td>
</tr>
</tbody>
</table>

Factor analysis (F. Wang & Luo, 2005) and regression analysis (McGrail & Humphreys, 2009b) were used to determine aspatial factors which give significant contribution. Afterwards to integrate between aspatial factor with spatial accessibility, some studies analyze them using geospatial analysis, overlaying aspatial and spatial accessibility through GIS software (F. Wang & Luo, 2005; L. Wang & Tormala, 2014) or develop special criteria based on deviation of the data from median (Todd et al., 2015; F. Wang & Luo, 2005; L. Wang & Tormala, 2014). Another way to integrate between the two factor is through statistical analysis either generalized linear model (Todd et al., 2015) correlation and regression analysis (Bauer et al., 2017). Certain study also develop special index such index of rural access (McGrail & Humphreys, 2009b) or comparative descriptive analysis (Shah et al., 2017).
3.4.1 Acceptance through vulnerable population

Distribution of vulnerable population are shown to be dispersed through out the urban and also in rural area (F. Wang & Luo, 2005). Area with low accessibility to primary healthcare was associated with high number of vulnerable population. However, in another study done in Canada, majority of vulnerable population seems to live in an area with high accessibility (Shah et al., 2017). Minority population such as immigrant (68.9%) resides in places with high accessibility to primary healthcare (Shah et al., 2017). This is agreed with the study which stated that Area with high number of minorities such are African American (OR =58.95, p < .0001) and Hispanic (OR = 18.91, p < .0001) are more likely to live in low access area (Seymour, Polsky, Brown, Barbu, & Grande, 2017). In regards to aboriginal population, cumulatively most of aboriginal population reside in area with high accessibility to primary healthcare (Shah et al., 2017). However looking in the more discrete spatial unit, area that have high aboriginal population have low spatial accessibility to primary healthcare (L. Wang & Tormala, 2014).

3.4.2 Affordability through socio-economic status and income

A study in Australia postulated that area with low socio-economic status coincide with the area with low spatial accessibility with healthcare (McGrail & Humphreys, 2009b). However, study in Saskatchewan Canada showed contradict finding where majority of low income population (80.2%) live in area with high spatial accessibility (Shah et al., 2017). Most deprived area and least deprived area have significant non linear association with the spatial accessibility (Todd et al., 2015). As the value of deprived area went higher the spatial accessibility (β= 0.533, p <.001) also would go higher (Bauer et al., 2017).

3.4.3 Accommodation through Literacy

In United States of America, Population with low literacy concentrated among area with high number of minorities and this area have low spatial accessibility which is also spread through the suburbs and rural area (F. Wang & Luo, 2005). However in Canada, population with low literacy tends to reside in area with high spatial accessibility (Shah et al., 2017). Mother with no education are 1.5 more likely to live far more (RR=1.04, 95% CI: 1.01–1.09, p = 0.044) than mother with no education (Okwaraji et al., 2012).

4.0 Conclusion

Development of geographical information system has made more studies to use floating catchment method as a tool to assess spatial accessibility instead of only using provider physician availability and travel impedance. Innovation to floating catchment has allowed alteration to existing floating catchment method to allow researcher to address limitation for its predecessor. Recent development also has seen integration of spatial accessibility with aspatial factor and its determinants through statistical association, spatial analysis and
development of special index. Knowledge about spatial accessibility and its determinants will facilitate health planner and policy maker to understand the situation needs and improve the accessibility by overcoming the barriers.

5.0 Acknowledgement

This manuscript is part of requirement of Health Economic Evaluation course in Doctor of Public Health Program in the Department of Community, Health Faculty of Medicine and Health Sciences, Universiti Putra Malaysia. We would like to thank the Director General, Ministry of Health Malaysia for his approval to publish this manuscript (Please insert Ref letter No.).

6.0 Declaration

Author(s) declare that there is no conflict of interest with the publication of this article.

7.0 Authors contribution

Author 1: literature searching and drafting the manuscript
Author 2: manuscript review and editing
Author 3: initiation of idea, final manuscript review and editing

References


