Catchment areas for public transport

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Abstract

In the planning of public transport the catchment areas of stops are often included to estimate the potential number of travellers. There are different approaches to GIS-based catchment area analyses depending on the desired level of detail. The Circular Buffer approach is the fundamental, but also the simplest approach. The Service Area approach is based on searches in road networks and represents the actual feeder routes and is thereby a more detailed approach. The Service Area approach can be refined by adding additional resistance to certain points in the road network, e.g. stairways.

Differences between the Circular Buffer approach and the Service Area approach are illustrated and a comparison between the sizes of the catchment areas is made. The strength of the Service Area approach and the impact on the catchment area when adding additional time resistance for the crossing of stairways is illustrated by a case example. Furthermore, a case example illustrates how the additional time resistance in stairways affects the catchment area of an underground station compared to a ground-level station. It is also illustrated how catchment area analyses can serve in the planning of stops on a new line by calculating travel potential along the line.

The article shows how the different approaches result in differences in the examined catchment areas. It shows how the Service Area approach prevents inaccessible areas from being included in the catchment area and how it allows for detours in feeder routes to/from stations. The article also shows how the refinement of the Service Area approach with additional time resistance results in smaller catchment areas when the feeder routes cross stairs.

It is concluded that GIS-based catchment area analyses are a multiple decision support tool for the planning of public transport where the level of detail can be suited to the purpose.

Keywords: catchment area, public transport, GIS, Service Area, network search, time resistance, accessibility.

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1 Introduction

A catchment area for public transport can be defined as the vicinity of a stop or station of a public transport line. Moreover, this area is where most of the non-transferring passengers at the particular stop or station come from. In that way the catchment area can be viewed as the customer base for public transport.

A Catchment area analysis usually consists of two phases. The first phase is the determination of the geographical catchment area. Often, this will be determined by willingness to walk criteria. The next phase is the implementation of information regarding travel demand to the geographical catchment area to determine the potential number of travellers. Such information could very well be the number of inhabitants and workplaces within the geographical area. The larger the catchment area is and the denser the population and workplaces are, the higher the travel potential will be.

Applied analyses of catchment areas for public transport can serve different purposes. Usually, it is used in the planning process of new public transport lines. However it is important that it is used as decision support and not as a conclusive solution. Other factors also influence the planning process. Transfers, general logic and knowledge of the conditions must also be incorporated. In the planning of public transport catchment area analyses can serve in the initial phase when the stop has to be placed on a new line. It can also serve when having two or more alternative alignment proposals to choose between. It can be used in the more advanced stage of the planning process by selecting and deselecting stops. Furthermore, it can serve as a rough estimate for dwelling times at the different stops of a new public transport line. More detailed catchment area analyses can be used to investigate improvement in accessibility to stations.

The practical execution of catchment area analyses is done through geographic information systems (GIS) that provide geographical data handling. In this article, focus will primarily be on the first phase of the catchment area analysis by analysing geographical catchment areas. Therefore, section 2 describes approaches to use GIS to analyse catchment areas. This forms the basis of more advanced catchment area analyses where walking resistance is included in section 3. Section 4 describes how catchment area analyses can be visualized by travel potential graphs. Section 5 describes the level of detail, before the conclusions are drawn in section 6.

2 Catchment area approaches

The simplest way to analyse the potential number of travellers for a stop is to consider the number of inhabitants and workplaces in a Euclidean distance from the stop. This kind of analyses can be conducted using GIS in two simple steps:

- Make a circular buffer around a stop
- Intersect the buffer with a map containing information about inhabitants and workplaces

In Denmark, this simple approach has been used the last years to examine and optimize stop locations for new railway and light rail lines (e.g. [1]). Often the level of detail in the method has been increased by dividing the catchment area into different buffer rings depending on the distance to the station (e.g. [1] and [2]).

The Circular Buffer approach is a fairly good way of examining the catchment areas for stops but it does not take the geographical surroundings into account. In most cases, the actual walking distance to/from the stop is longer than the Euclidean distance since there are natural barriers like rivers, buildings, rail tracks etc. This disadvantage is often coped with by applying a detour factor that reduces the buffer distance to compensate for the longer walking distance. However, in cases where the length of the detours varies considerably within the stop surroundings, this solution is not very precise. Furthermore, areas that are separated completely from the stop by e.g. rivers might still be considered as part of the stop's catchment area (see the ring buffers in figure 1).

To overcome the problem with varying detours, the Network Analyst Service Area tool for ArcGIS (other GIS software has similar functions) can be used (cf. [3] for detailed information about the methodology). This tool makes it possible to search a distance following the road and pathway network and then interpolate a buffer based on the actual distances referred to as a Service Area. In this way, only areas that are considered as part of the catchment area are included and areas isolated from the stop/station are not included cf. figure 1.

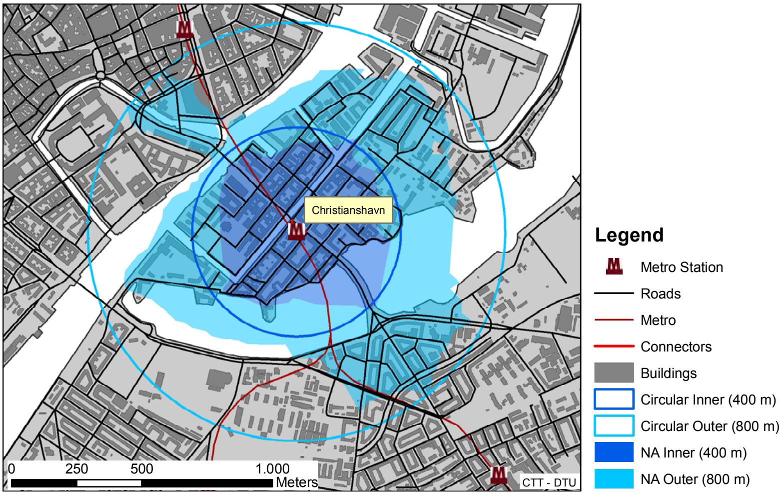

Figure 1: Catchment area of Christianshavn Metro Station in Copenhagen – Circular Buffer approach and Service Area approach [3].

2.1 Comparison between Circular Buffer and Service Area buffer

The Circular Buffer approach consistently overestimates the size of the catchment area, and thereby often also the potential number of travellers. This can partly be handled by applying a detour factor on the buffer distance of the circular buffers. However, the detour factor depends on the layout of the street and path network together with the geographical barriers in the stop's surroundings. The variation of the area of the two methods and the proportion is shown in table 1 (based on [3]).

Table 1: Proportions between the sizes of the catchment area calculated with Circular Buffers and Service Areas.

Station	Area (600m Circular Buffer)	Area (600m Service Area buffer)	Proportion
Bispebjerg	1,130,970 m^2	419,879 m^2	0.37
Charlottenlund	1,130,970 m^2	728,505 m^2	0.64
Christianshavn	1,130,970 m^2	663,117 m^2	0.59
Dybboelsbro	1,130,970 m^2	596,301 m^2	0.53
Hellerup	1,130,970 m^2	855,473 m^2	0.76
Jaegersborg	1,130,970 m^2	652,961 m^2	0.58
Noerrebro	1,130,970 m^2	842,050 m^2	0.74
Sjaeloer	1,130,970 m^2	715,351 m^2	0.63
Svanemoellen	1,130,970 m^2	703,817 m^2	0.62
Sydhavn	1,130,970 m^2	654,828 m^2	0.58

Table 1 shows that the proportion between catchment areas of the Circular Buffer approach and the Service Area approach varies from 0.37 to 0.76. This variation indicates that it is impossible to apply one general detour factor to improve the Circular Buffer approach (also [4] shows this tendency), why a method like the Service Area approach is reckoned to be more realistic.

3 Time resistance in catchment area analyses

In previous Service Area analyses the size and shape of the catchment area have been determined by distance to/from the stop. However, when using an average walking speed (here 80 meters/minute [4]), time can be implemented instead of distance as a resistance variable in the street and path network search.

Maps are (most often) 2-dimentional. This means that the catchment area analyses do not take the time it takes to climb stairs into account but "only" the 2D walking distance. In case of e.g. metro stations, the time to access the platform is significant (in Copenhagen it is measured to take about 1.5 minutes from street level to platform level 20 metres below although the 2D distance is zero or only few meters). This extra access time may be a large part of the total access time to the station, and should, therefore, be included in the analyses.

Using the Network Analyst Service Area tool for ArcGIS, additional time resistance can be added to nodes in the GIS map. This results in a smaller, but more realistic catchment area compared to both the Circular Buffer approach and the Service Area approach without additional time resistance.

3.1 Resistance in stairway crossings

Figure 2 illustrates how an additional time resistance variable, in the form of stairway crossing, applied to the network search impacts the catchment area. The case example is Nordhavn station on the suburban railway network in Copenhagen. The willingness to walk to/from the station is set to 5 minutes. When a new pedestrian bridge over the existing road and rail tracks was opened, it expanded the catchment area over Nordhavn station. This expansion can be investigated by using the Service Area approach, cf. left side of figure 2. However, using the new pedestrian bridge means crossings of stairway steps just as the entrance to the elevated station also means climbing stairs. When implementing an assumed time resistance of 15 seconds for crossing the stairways to the platform and the bridge, the catchment area is decreased as viewed in right side of figure 2.

A more favourable solution would have been to extend the southern end of the platform at Nordhavn station and then connect the pedestrian bridge directly to the platform. In this way, crossing of two stairways could be avoided and in

Figure 2: Catchment area of Nordhavn station without and with pedestrian bridge (left side), and with and without stairway resistance (right side).

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consequence of that obtaining a larger catchment area. Only by applying specific time resistance in nodes representing stairways is it possible to investigate the full effect of such an improvement of accessibility to stations.

3.2 Stairway resistance impact on the catchment area of an underground station

Due to the time resistance, the Service Area approach can be used to examine catchment areas of different alternatives for public means of transport more detailedly. E.g., it is possible to examine the difference in catchment area for an underground metro line and a light rail system at street level.

Figure 3 illustrates how the stairway resistance impacts the catchment area of an underground station compared to a ground-level station. The Case example is Noerrebro Runddel, a central place in Copenhagen where both an underground solution (Metro) and a ground-level solution (light rail) has been proposed [5]. Access time from street-level to platform level is set to 1.5 minutes for the underground station proposal. Whereas the ground-level station proposal does not have any access time applied since it is already at street level. This results in a larger catchment area for the ground-level station proposal.

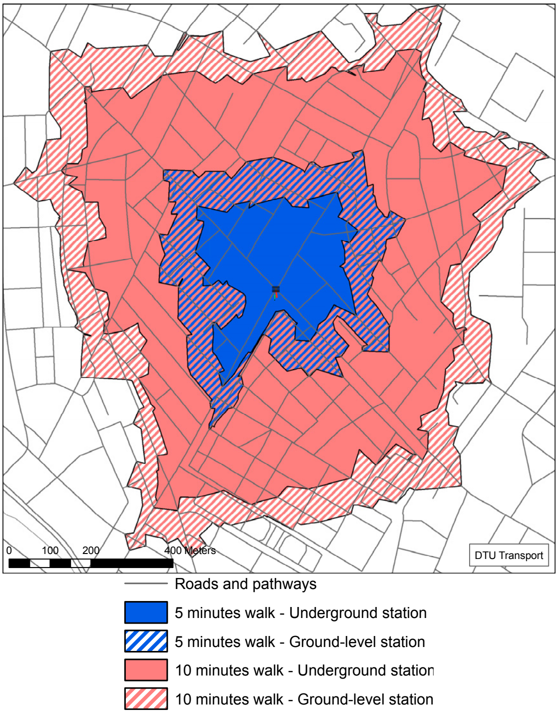

Figure 3: Catchment area of an underground station vs. a ground-level station – proposal at Noerrebro Runddel.

By applying different time resistances to the map, it is also possible to examine the catchment area for different groups of potential travellers – e.g. young people, elderly people and people with prams. In this way it is possible to evaluate whether it is favourable/necessary to improve the access to public transport for some groups of potential travellers. However, conducting this kind of analyses requires detailed data about both the infrastructure network and the time resistances of different access paths and entrance points – e.g. lifts and stairs.

In this analysis only measurable additional time use has been included. The time it takes to climb stairways depends on the number of steps and can relatively easy be measured and implemented. However, studies of walking often also include an experienced resistance due to the effort of climbing stairs that is an addition to the actual time use resistance (e.g. [6]). This experienced resistance might be correlated to the actual time resistance in a way that results in higher values for disabled, elderly people or people with prams. If experienced resistance was to be implemented in this study, the result would be even smaller catchment areas. Regarding the underground stations there might also be the psychological perception of already being in the public transport system as soon as entering the Metro entrance. In that way travellers to an underground public transport line can, more or less subconsciously, be willing to accept a longer access time, and thus increasing the catchment area.

It is also possible to implement other time resistance variables in the network search. This could be issues such as road crossings or other traffic conflict points. In cities with hilly terrain a resistance for crossing slopes could also be implemented, e.g. by adding an additional time resistance every time a network link crosses a contour line. All approaches are relatively easy to implement in GIS-based catchment area analyses.

4 Travel potential graph

The above described methods can be used to examine existing stops and/or to optimize the stop location for a new line. However, in case of a new line it is often desired to identify areas along the route where there is a large amount of potential travellers. This can be helpful in the initial placement of stops at the line. Such an analysis can be carried out using GIS too. The catchment area for a route of the new line can be examined for each X metres (e.g. 1, 10, 25, 50 or 100 metres depending on the desired level of detail). These analyses can then be plotted to a graph to visualize where the highest potential of travellers are located, cf. figure 4.

Based on figure 4, it is straightforward to identify the areas along the route that have the highest potential for travellers. However, the best location of the stops is not necessarily at the top of the peaks of the travel potential graph. To secure many passengers from the area around the public transport line, it is important to locate the stops where the travel potential is high. On the other hand, it is important to plan for short transfers to other public transport lines too to secure an attractive public transport network. Therefore, stops should not be decided solely based on the travel potential graph, but be combined with common sense and logic. Catchment areas used to calculate the travel potential graph can be composed of either circular buffers or service areas. However, the Service Area approach might be overkill for this purpose and also requires more detailed input of data.

5 Level of detail

No matter how precise a methodology is used to conduct the catchment area analyses, the results will not be better than the parameters and dataset used. When using the Service Area approach it is important with a detailed street and path network to ensure that all feeder routes are implemented. This also means that all roads that are not accessible for soft road users, like motorways, must be excluded from the network search. Furthermore, double digitized roads can cause unrealistic detours since they can not be crossed in a network search unless there are crossings connecting the one-way roads (see [3] for further details).

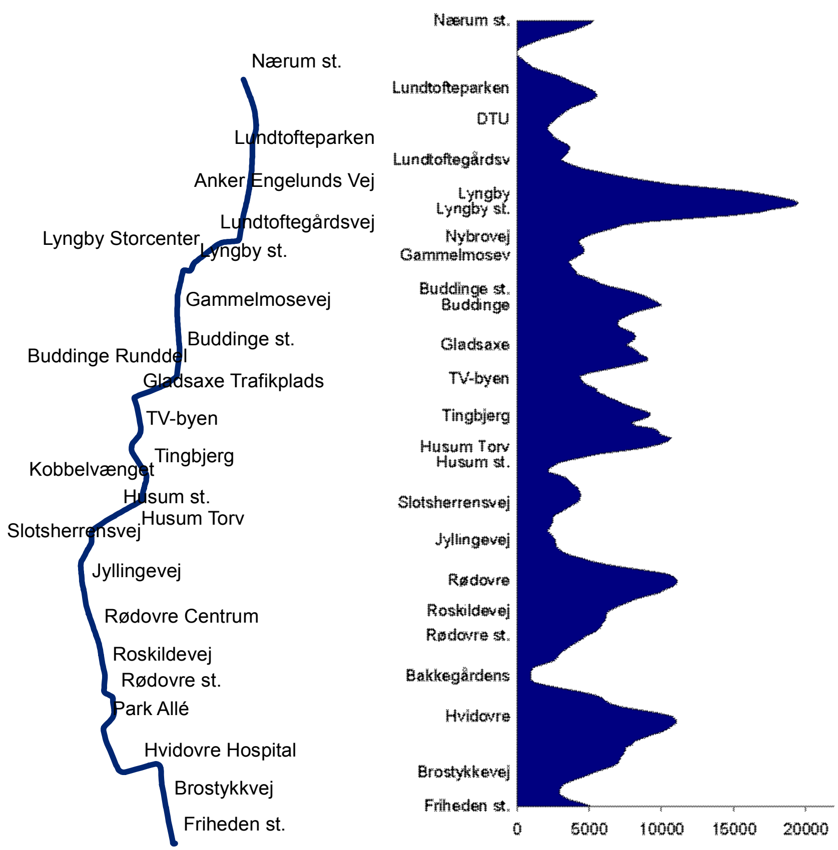

Figure 4: Travel potential graph.

Also the search distance or the willingness to walk criteria can vary depending on the mean of transport, length of total journey, walking environment etc. To handle this, a suitable value must be determined and then all subsequent calculations must be based on that value for comparability of the results.

When calculating the potential number of travellers for catchment areas, the data used for travel demand, e.g. population and workplaces, should be as detailed as possible. It could be based on land use or even buildings but the data can be difficult to obtain at such a disaggregated level. Furthermore, there are other sources to travel demand than population and workplaces but they are complex to implement because of their irregular impact. If the data for travel demand is not detailed enough, the approaches for improving the geographical catchment areas are unnecessary. The level of detail in the catchment area analysis must be commensurate with the level of detail of the applied datasets. But even so, catchment area analyses can not fully reflect reality and should only provide guidance in the planning process. As a rule, catchment area analyses should preferable be used as a comparative and/or change describing decision support rather than a measure of the absolute travel potential.

6 Conclusions

When using catchment area analyses the objective of the analysis and the desired level of detail must be the decisive factor for choosing the precise approach.

The Circular Buffer approach is a rough, but straightforward method to implement. It suits fine for investigations of whole public transport lines, alternative alignments and initial placement of stops. The Service Area approach provides more detailed catchment area analyses since it is based on the actual feeder routes to public transport. The approach is suitable for examination of changes in the streets and pathways surrounding stations, e.g. improving access paths to public transport. The Service Area approach can be refined by implementing additional time resistance in certain designated points of the network like stairways. This can be favourable for investigations in special conditions in connection with access paths and the actual entrances to the stations, e.g. the impact of crossing many stairs to get to the station platform.

GIS-based catchment area analyses are a multiple decision support tool for planning of public transport lines, stops and accessibility to stops. The level of detail can be very high if the datasets support it. However, it must never be used as more than decision support since other factors also come into play. But used together with logic and common sense it is a strong method to assist in the planning of public transport.

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