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1 Abstract

The paper presents a method to examine the catchment areas for stops in high quality public transport systems based on the actual street network in the examined area. This is achieved by implementing the service area functions from the ArcGIS extension Network Analyst. The method is compared to a more simple method using only the Euclidean distance from the examined stop and the paper describes the differences in detail-level of the results. Furthermore, the paper describes how the Network Analyst method can be use to examine improvements in the catchment areas by adding extra entrances to stations or by making changes in the street network around the station. It is concluded that the Network Analyst method improves the detail-level and accuracy in catchment area analyses. It is these improvements which makes it possible to examine changes in station entrances and/or street network.

Keywords: Catchment area, Service area, Detour factor, Street network, Walking accessibility

2 Introduction

High quality public transport systems like rail and light rail have fewer stops than transport systems of lower quality e.g. bus. Because of the fewer stops it is important that the stops are located as good as possible. This means that the stops should be located in areas with a high potential of travellers in order to offer the best possible service for public. Furthermore, this will secure that as many passengers as possible will use the public transport system. Areas with a high potential of travellers are areas with dense housing and many workplaces but also shopping areas, sport facilities and areas with entertainment (e.g. cinemas and amusement parks) can have a high potential of travellers.

Most of the travellers in public transport systems come from areas just around the stops [6] – not many passengers are willing to travel a long distance by foot, bike or car to get to the public transport system [4]. Therefore, the amount of travellers in the public transport system is more or less proportional to the amount of people living and working just around the stops in the so-called catchment area.

The potential of travellers in the catchment area can be examined using simple overlay analyses based on circular buffers around the stops (cf. section 3 Circular buffer approach). However, this method does not take the actual access time to the stop into account. By using Network Analyst it is possible to calculate more exact access times and thereby improve the accuracy compared to the simple buffers (cf. section 4 Network Analyst Service Area Approach). The two methods of calculating catchment areas are compared in section 5 Comparison on the two methods.

As the stops are the passenger's gateway to the public transport system it is important that it is easy to get to and from the stop. For some transport systems such as railways, the stop can have a certain geographical extent (e.g. most of the stations of the Copenhagen suburban railway are about 200 meters long). By adding entrances in both ends of the platform, the accessibility and thereby the catchment area can be improved (cf. section 6 Increasing the catchment area).

It is not only the number of entrances to a given stop which determines the size of the catchment area; also the street network surrounding the stop is an important aspect. By using Network Analyst instead of simple circular buffers around the stops it is possible to analyze the street networks influence on the size of the catchment area. Furthermore, it is possible to analyze how changes in the street network can make it easier to get to the stops (cf. section 6 Increasing the catchment area).

3 Circular buffer approach

The simplest way to analyze the potential amount of travellers for a station is to consider the Euclidean distance from the stop. Given a stop's location and detailed information on the stops neighbourhood, like a land-use map or a map with buildings, is possible to examine the area within a certain distance of the stop. In ArcGIS this can be achieved in two simple geoprocessing steps:

1. Making a circular buffer around the station
2. Intersecting the buffer with the maps describing the neighbourhood

Afterwards different land-use areas or buildings within the buffer can be examined and if data on e.g. population and workplace density is available it is possible to calculate a measure for the potential number of travellers.

At Centre for Traffic and Transport at the Technical University of Denmark this simple approach has been used the last couple of years to examine and optimize stop locations along new railway and light rail lines (e.g. [1] and [3]). Often the level of detail in the method has been increased by dividing the catchment area into different rings deepening on distance to the station. By applying weights for each ring it is possible to take into account that the expected share of potential travellers will drop when the distance to the station is increased.

Figure 1 shows the calculated catchment area for Noerrebro Station in the central Copenhagen. The catchment area is divided into an inner and outer ring, and the distances have (in this case) been set to 500 and 1,000 meters – the primary and secondary catchment areas.
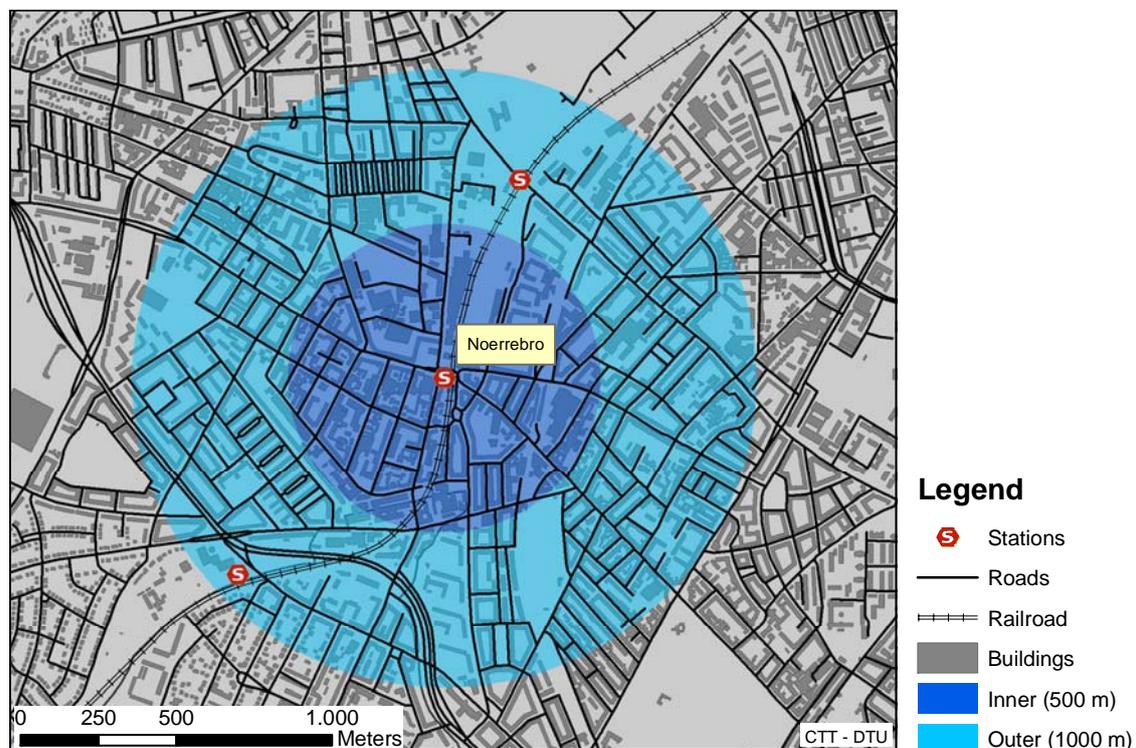

Figure 1 – Catchment area determined by circular buffer approach for Noerrebro Station in Copenhagen

The number of rings and the distances for each ring varies on the type of project and the accepted detail level for the results. Overall the catchment area should cover the distance, it seems reasonable to walk or bike to get access to the public transport system. This distance depends on the type of transport system. A high quality transport system like regional trains will normally have larger catchment areas than lower quality systems like light rail. The expected shares of potential travellers in each ring can then be determined based on market share investigations.

3.1 Weakness of the circular buffer approach

Even though the circular buffer approach is a fairly good way of examining the catchment areas for stops it has a weakness. The method does not take the stops geographical surroundings into account. Often the actually walking distance from a certain location to a stop is somewhat longer than the direct Euclidean distance. The reasons for this can be found in both natural barriers like rivers and canals, but also manmade obstacles like buildings and rail tracks. This disadvantage in the approach is often handled by applying a detour factor that reduces the buffer distance and is this way compensates for the fact that people have to walk longer in the real street network. However, in cases where the length of the detours varies a lot within the stop surroundings, this solution is not very precise. Furthermore areas which are separated completely from the stop by e.g. rivers can still be considered as part of the stops catchment area.

Figure 2 shows the catchment area for Christianshavn Metro Station in Copenhagen examined by the circular buffer method. Some parts of the catchment area are partly isolated form the station by the harbour, the canals and the lakes in the district. The actual walking distance from these parts to the metro station is longer than the assumed distance that people are willing to travel and. Hence, these parts should not be regarded as part of the catchment area.
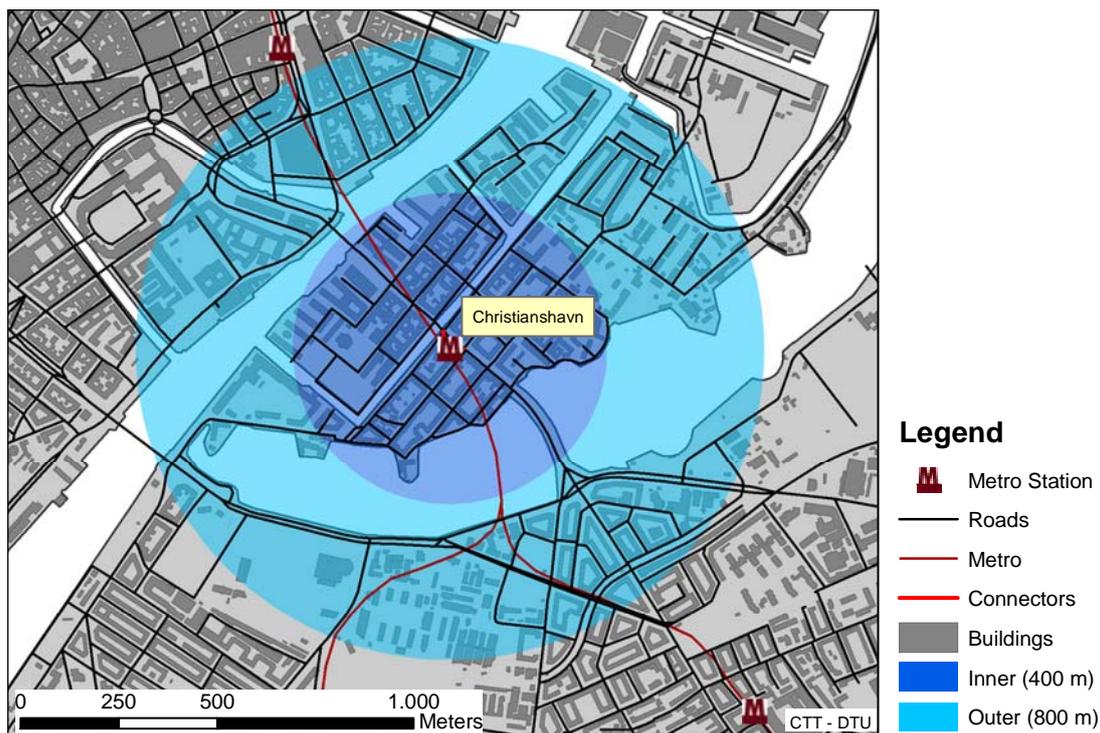

Figure 2 – Catchment area determined by circular buffer approach for Christianshavn Metro Station in Copenhagen.

4 Network Analyst Service Area Approach

Using network Network Analyst for ArcGIS it is possible to apply a more accurate method to determine the catchment areas for stops than with the circular buffer approach (cf. section 3 Circular buffer approach). In most cases, the road and path network in a city will give a good picture of the actual walking distance between two

locations. The Network Analyst's service area function makes it possible to create buffers based on the actual street network. The service area function calculates buffers by determining a point in each branch of the network based on impedance on each link and interpolating these branch points.

The Network Analyst functions require a network dataset. This dataset must be based on a detailed road map describing the streets and paths around the stop. Furthermore, it is necessary to connect the stops to the actual road network (if the stops are not located directly in the network nodes). This is done by creating connector links between the stop and the surrounding road network. Figure 3 shows how the suburban train station Oesterport in Copenhagen is connected to the surrounding road network in the calculations. To make the results as accurate as possible the connectors should resemble the actual station entrances. This is achieved by digitizing the connectors to the points in the road network where actual entrances are. Finally it is necessary to specify the impedance in the network dataset. In this paper the length on each road link is used but in other cases this could be the walking time instead. For the connectors the impedance is set to 0. In this way the buffers are calculated as the chosen distance from each entrance.
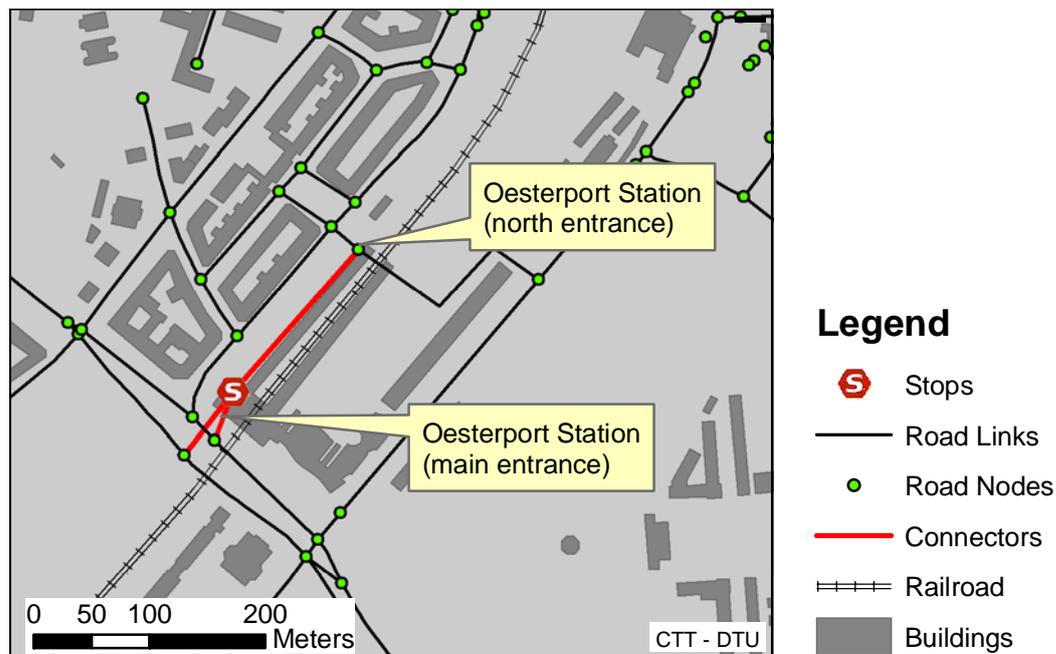

Figure 3 – The digitalizing of entrances for Oesterport Station in Copenhagen

When the network dataset is build the catchment area can be calculated by the service area tools in Network Analyst. In figure 4 is illustrated how a geoprocessing model can be set up to perform the calculations.
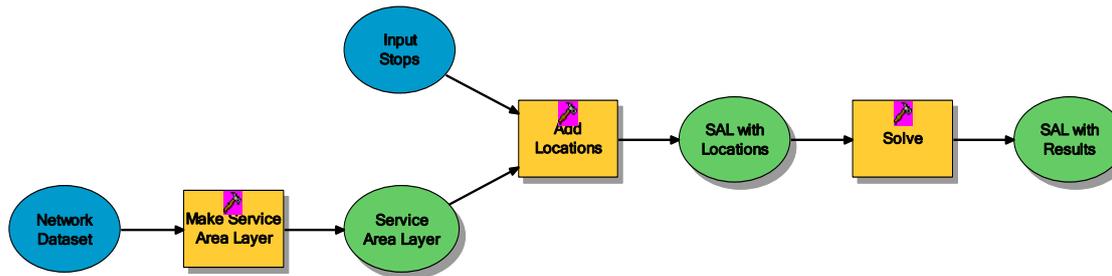
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Figure 4 – Geoprocessing model to calculate catchment areas with Network Analyst

Figure 5 shows the catchment area for Christianshavn Metro Station calculated with the Network Analyst method. Like for the circular buffers shown in figure 2 it is chosen to divide the catchment area into an inner and outer buffer. The shape of the calculated buffers now corresponds to the road network around them. Furthermore it can be seen that some of the areas which in the circular buffer approach was considered within the catchment area are excluded in the Network Analyst method. This is due to the limited possibilities for crossing the lakes and canals and corresponds with facts that people in these excluded areas don't have good access to the station.
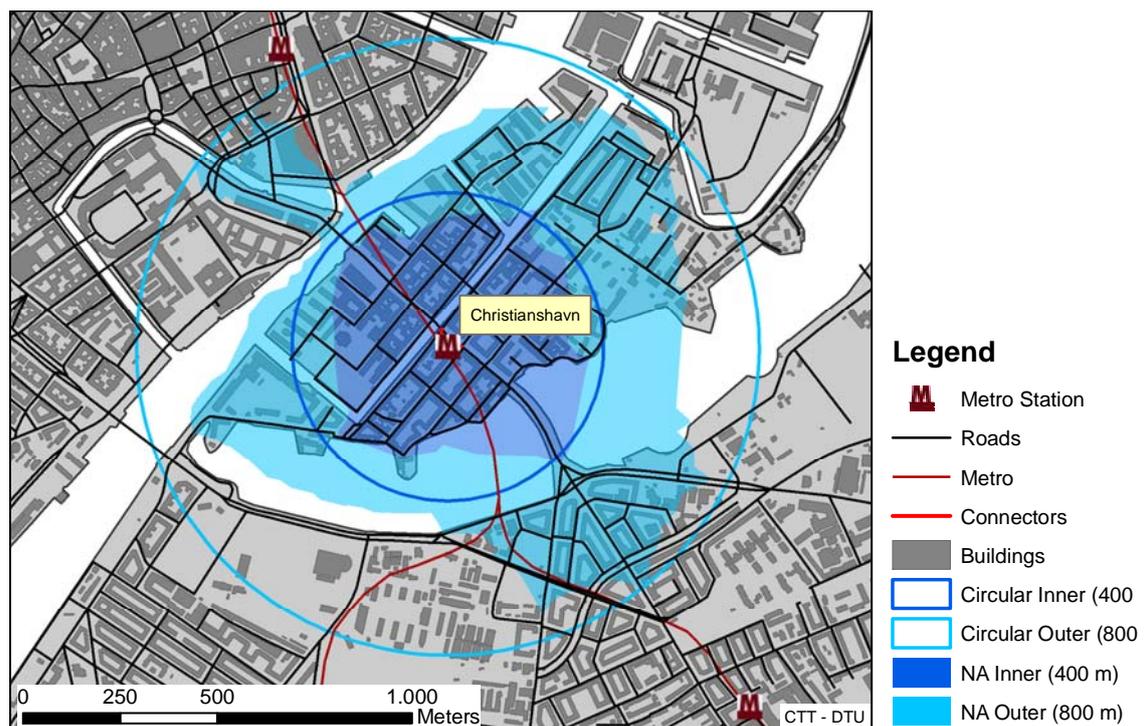

Figure 5 – Catchment area determined by Network Analyst approach for Christianshavn Metro Station in Copenhagen

5 Comparison on the two methods

As described above the results of the two methods differs a lot. The circular buffer approach (cf. section 3 Circular buffer approach) considers all locations within the chosen distance from the stop to be within the catchment area. The Network Analyst approach (cf. section 4 Network Analyst Service Area Approach) will exclude some of these locations due to the geographical surroundings and the detours people have to walk in the real street network. This means that the circular buffer approach

consistently overestimates the size of catchment area and thereby often also the potential number of travellers. When using the circular buffer approach this is sometimes handled by applying a detour factor on the buffer distance. How to determine the detour factor has often been disused. Basically it depends on the layout of the streets and geographical barriers in the stations surroundings. Since this can vary a lot from station to station and from city to city it is very doubtfully that a one detour factor can be applied to improve the accuracy of the circular buffer method in general.

To examine the variation of the detour factor, table 1 show catchment areas calculated for some selected stations in the Copenhagen area with both the circular buffer approach and the Network Analyst approach. The proportion between the size of the catchment area calculated by the circular buffer approach and the Network Analyst approach is also shown in table 1.

Station	Area (600m Circular Buffer)	Area (600m Network Analyst Buffer)	Proportion
Bispebjerg (S-tog)	1,130,970 m^2	419,879 m^2	0.37
Charlottenlund (S-tog)	1,130,970 m^2	728,505 m^2	0.64
Christianshavn (Metro)	1,130,970 m^2	663,117 m^2	0.59
Dybboelsbro(S-tog)	1,130,970 m^2	596,301 m^2	0.53
Hellerup (S-tog)	1,130,970 m^2	855,473 m^2	0.76
Jaegersborg (S-tog)	1,130,970 m^2	652,961 m^2	0.58
Nordhavn (S-tog)*	1,226,513 m^2	671,198 m^2	0.53
Noerrebro (S-tog)	1,130,970 m^2	842,050 m^2	0.74
Oesterport (S-tog)*	1,327,989 m^2	709,205 m^2	0.54
Sjaeloer (S-tog)	1,130,970 m^2	715,351 m^2	0.63
Svanemoellen (S-tog)	1,130,970 m^2	703,817 m^2	0.62
Sydhavn (S-tog)	1,130,970 m^2	654,828 m^2	0.58

(*) Station has more than one entrance

Table 1 – Proportions between the sizes of the catchment area calculated with the circular buffer approach and network analyst approach for a number of stations in the Copenhagen area.

Table 1 show that the proportion between the circular buffer approach and the Network Analyst approach vary a lot from 0.37 to 0.75. This variation indicates that it is not possible to apply one general detour factor to improve the circular buffer method (also [5] shows this tendency). Instead a method like the one Network Analyst offers where the actual geographical surroundings are included in the calculations is preferable.

6 Increasing the catchment area

As the catchment area is the area from where (most of) the passengers come from, it is important for the train operator to have as large a catchment area as possible. The Copenhagen suburban rail operator (DSB S-tog) has found out that the primary catchment area is a 600 meter circular buffer from the entrance to the station ([6] works with a catchment area of 400 to 800 meters).

Normally the stations at the Copenhagen suburban rail network do only have one entrance to the station (in one end of the platform). By establishing an extra entrance

in the other end of the platform – about 200 meters away – an additional 20% is added to the primary catchment area if using a 600 meter circular buffer approach, cf. figure 6.
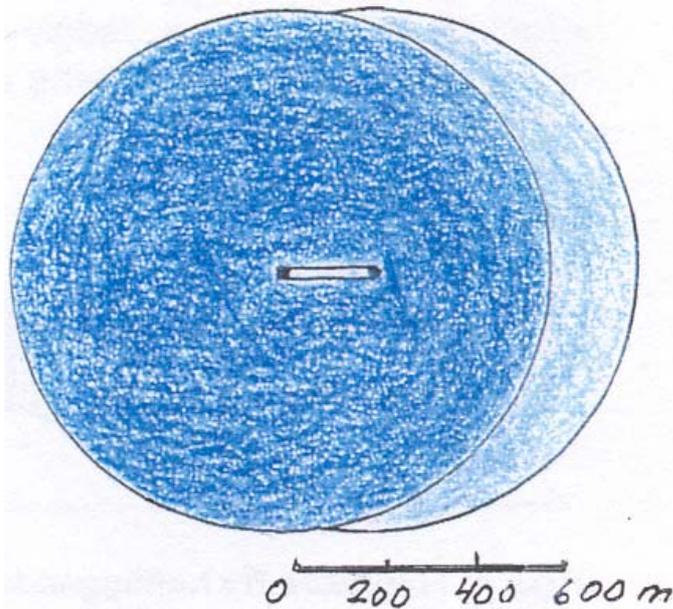

Figure 6 – Catchment area of one versus two entrances to the station [2]

Additional entrances to stations can extend the catchment area for both circular buffers and buffers calculated by Network Analyst. Figure 7 shows the extension of the catchment area for Herlev Station when adding an extra entrance. The catchment area is calculated for both circular buffers and buffers calculated by Network Analyst.
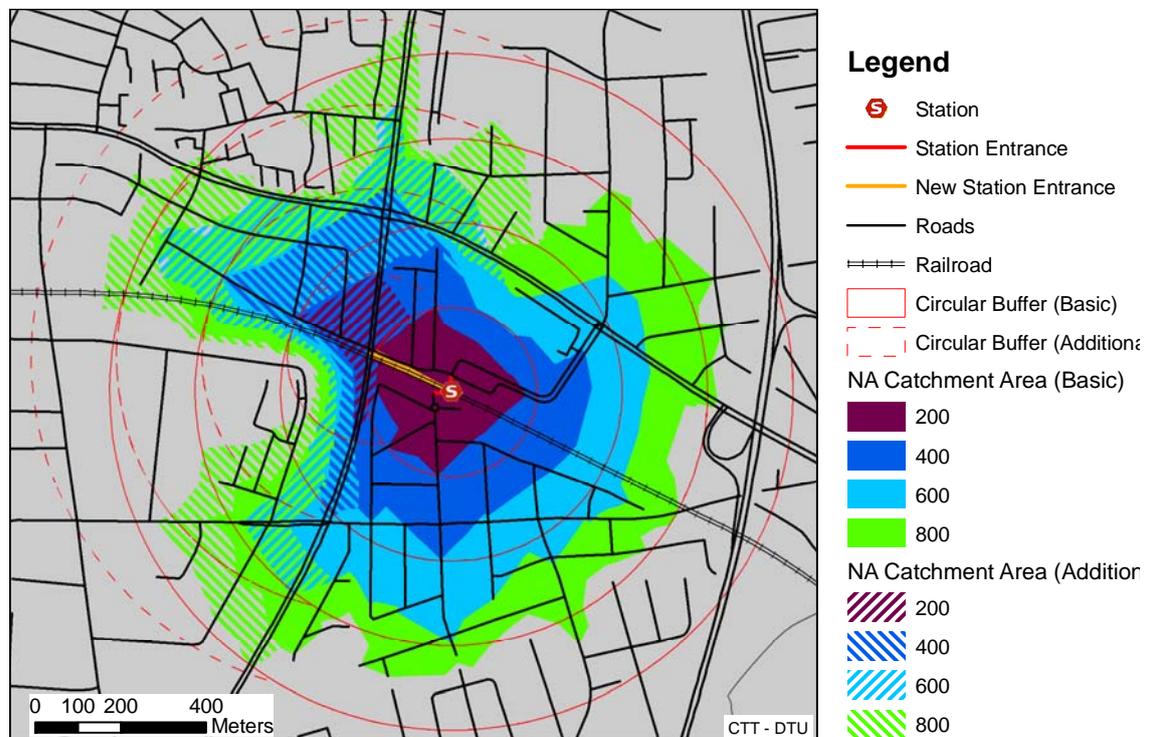

Figure 7 – Change in catchment area when an additional entrance is established at Herlev Station.

Figure 7 shows that the catchment area at Herlev Station is extended when an additional entrance is established. In fact the catchment area at Herlev Station is extended by 25% when calculating the catchment area as a 600 meters walking distance by Network Analyst. The 25% extension of the 600 meter catchment area is larger than the 20% extension as the theoretical situation described (cf. figure 6). The larger extension (in this case) is due to layout of the street network but in other situations the extension might be lower than 20% due to another layout of the street network. The difference of the Network Analyst buffers is illustrated in figure 8.
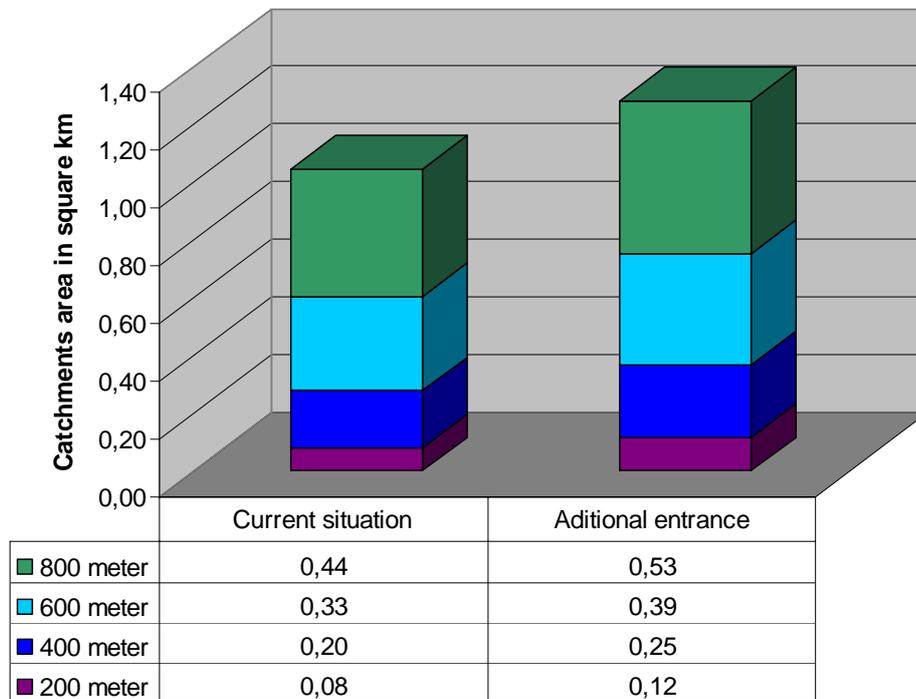

	Current situation	Aditional entrance
■ 800 meter	0,44	0,53
■ 600 meter	0,33	0,39
■ 400 meter	0,20	0,25
■ 200 meter	0,08	0,12

Figure 8 – Change in size of the catchment area when an additional entrance is established at Herlev Station. Calculated with Network Analyst.

The catchment area can not only be extended by establishing extra entrances to the stations – it is also possible to extend the catchment area by improving the street network. Improving the street network can result in shorter and thereby faster access to the station if e.g. a bridge or a tunnel is established to cross a barrier like a railway line or a river/stream. Figure 9 shows the difference in the catchment area calculated by Network Analyst for a situation with and without a tunnel under the railway line at Nordhavn Station.
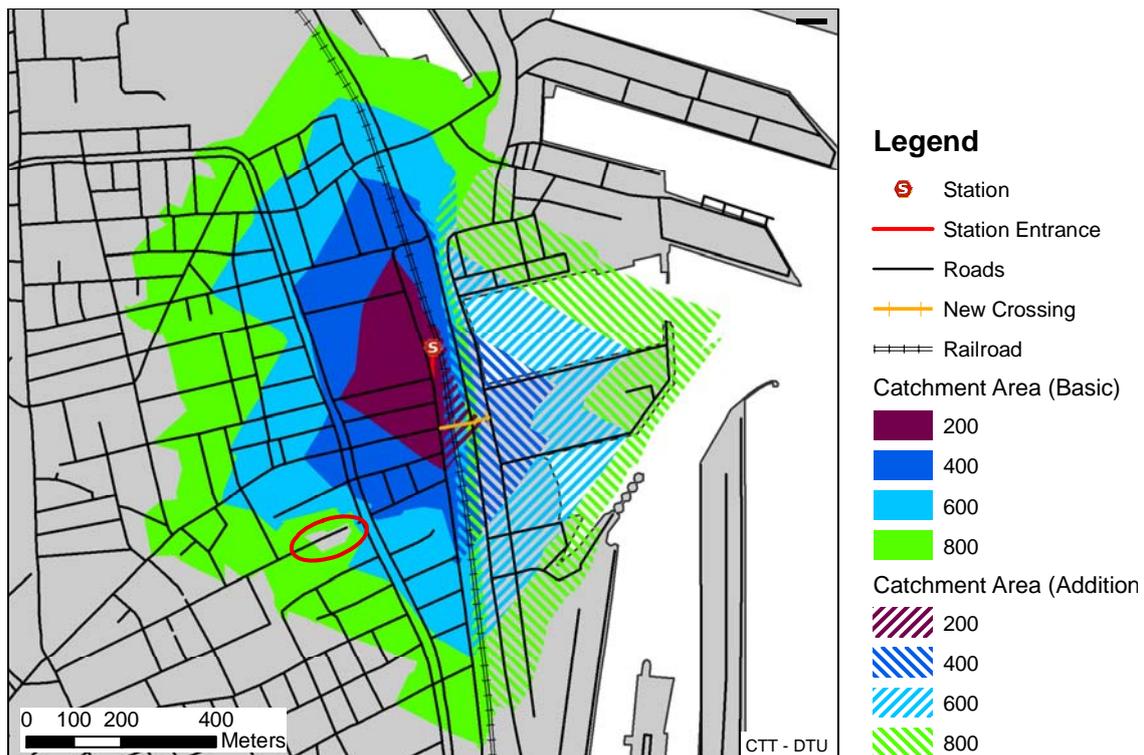
Figure 9 – Change in catchment area when a bridge to cross the tracks is established at Nordhavn Station.

Figure 9 shows that the catchment area at Nordhavn Station is extended with a tunnel under the railway line at Nordhavn Station. Besides the catchment area extension it is also shown that there might be gaps inside the catchment area which are not included in the catchment area hence the layout of the street network results in a long way to the station, cf. the red circle on figure 9.

7 Conclusions

For some years GIS-analyses have been used in the planning process when new stops on e.g. railway lines had to be placed. Using GIS-analyses to place the new stops made it possible to place the stops near as many households and workplaces as possible. However, the catchment area of households and workplaces has been calculated as the direct Euclidean distance. Since the actual walking distance often are longer than direct Euclidean one this will over estimate amount of potiential travellers. This has traditionally been corrected (if at all) by a detour factor reducing the radius of the catchment area.

The paper has shown that the detour factor can vary significantly from station to station. Therefore, the traditional circular buffer approach is inaccurate. Fortunately the Network Analyst extension for ArcGIS can calculate the catchment area by walking distance instead of the Euclidean distance in a simple way. Using the Network Analyst to calculate the catchment areas you get a more accurate calculation of the catchment area.

Just like the circular buffer approach the Network Analyst approach can also calculate the extension of the catchment area by adding an additional entrance to the station. However, the extension in percent using the circular buffer approach and the Network

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Analyst approach is not necessarily the same. This is due to the layout of the street network is included in the calculations. If it is difficult to get to and from the new station entrance, the catchment area will only be slightly extended using the Network Analyst approach. On the other hand, if the accessibility to the station is much better at the new station entrance than the old entrance, the proportion of the extension of the catchment area might be larger using the Network Analyst approach than using the circular buffer approach.

As the Network Analyst approach uses the street network to calculate the catchment area, it is possible to analyse the improved/worsened accessibility to the station when changes in the street network is made. The paper has shown that it is possible to extend the catchment area (using Network Analyst) by making it easier to cross barriers.

The overall conclusion of this paper is that the accuracy of calculating catchment areas can be improved by using Network Analyst instead of circular buffers. Furthermore, the Network Analyst approach makes it possible to examine the changes of the size of the catchment area when changing the street network – an analysis which was not possible using the circular buffer approach.

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