Playground accessibility and spatial equity: Does capacity matter?

How does the capacity of playgrounds relate to the spatial equity of playground accessibility?

Bachelor thesis – Final version

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Summary

This thesis analyses the impact of household poverty levels on playground accessibility to assess spatial equity. In this, the capacity of playgrounds is taken into account for the first time by comparing access to playgrounds and units of playground equipment in the Dutch city of Arnhem. This makes it possible to answer the following research question: *How does the capacity of playgrounds relate to the spatial equity of playground accessibility?* Two methods are chosen to measure accessibility: coverage and congestion. The former counts the number of playgrounds within a buffer, the latter uses the two-step floating catchment area to factor in distance decay and usage levels. Both methods were also deployed with a small variation to test for sensitivity. Results consistently indicate a significant, but weak positive impact of household poverty levels on playground accessibility, independent of the chosen object of analysis, metric or method variation. The lack of difference between playgrounds an units of playground equipment suggests that playground capacity matters little with regards to accessibility at the municipal level, although more local differences can be found.

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1 Introduction

1.1 Background

There is substantial evidence of the impact of physical activity on the physical and mental health of children (Ahn and Fedewa, 2011). The quality of the physical environment impacts the amount of physical activity undertaken by children (Giles-Corti et al., 2005). As playgrounds are one of the most important determinants of children's physical activity (McCarthy et al., 2007), it is perhaps unsurprising that there is evidence of playground quality impacting the degree and intensity of physical activity among children (Colabianchi et al., 2009). This suggests that access to playgrounds has a positive effect on children's health.

There is a lack of agreement on whether playground size is one of the determinants of playground quality impacting physical activity levels. Delidou et al. (2015) found that 12-year-olds' physical activity during recess increased with the size of the school playground, while True et al. (2017) concluded that a larger school playground was associated with an increase in preschool childrens' motor competence. On the other hand, Reimers and Knapp (2017) did not find a relationship between playground size and levels of physical activity. However, it should be noted that both Delidou et al. (2015) and Reimers and Knapp (2017) found that variety of playground equipment was associated with an increase in users' physical activity levels. Some Dutch municipalities have updated their playground design guidelines accordingly (Bouwmeester, 2006).

However, accessibility to playgrounds is not equally important for every child and in each neighbourhood. This can be explained using the notion of spatial equity, most simply defined as the provision of service and the level of need being equal (Lucy, 1981, cited by Smoyer-Tomic et al., 2004, p. 290). As people with lower incomes tend to have smaller gardens and less resources for access to private recreational activities such as sports clubs, neighbourhoods with higher levels of poverty generally experience a greater level of need for playgrounds (Smoyer-Tomic et al., 2004). This principle may explain the focus on poverty of existing research in this area.

Previous quantitative studies on playground accessibility have tended to find that playground accessibility is higher in areas with a lower socio-economic status (Smoyer-Tomic et al., 2004; Pereira, 2004; McCarthy et al., 2017; Martori et al., 2019). However, when playground quality is taken into account, evidence for such a link becomes much thinner (Smoyer-Tomic et al., 2004; McCarthy et al., 2017). Regarding ethnicity, disparities in race (McCarthy et al., 2017) and relative immigrant population (Martori et al., 2019) have not been found to impact access to playgrounds. Hence, existing research does not consistently show evidence for socio-economic factors and playground accessibility being correlated.

One characteristic shared by all these studies is that the capacity of playgrounds is not taken into account. Logically, a playground with more pieces of equipment will tend to have higher capacity and may also be considered more attractive by children. This is underlined by evidence of higher physical activity in more varied playgrounds (Delidou et al., 2015; Reimers and Knapp, 2017). The impact of capacity is especially important when congestion is considered. Indeed, Martori et al. (2019) suggested future research should consider the characteristics of the facilities. Moreover, Smoyer-Tomic et al. (2004) concluded that, if playground quality is taken into account, the positive correlation between levels of poverty and playground accessibility found in many studies declined. This suggests that a similar pattern may be found if the amount of playground equipment is considered.

Higher volumes of users can make a facility less attractive and accelerate its deterioration (Martori et al., 2019). Moreover, taking into account playground capacity can produce new insights on weak spots in the provision of playgrounds. Therefore, focusing on capacity can be a valuable input for municipal policy, thereby potentially increasing physical activity among children.

To study this, the municipality of Arnhem, in the eastern Netherlands, was chosen as a location. This is in large part because of the focus on inequality. The municipality of Arnhem has the joint seventh-highest Gini coefficient of capital nationwide (CBS, 2019), indicating a high degree of inequality (see Table 1).

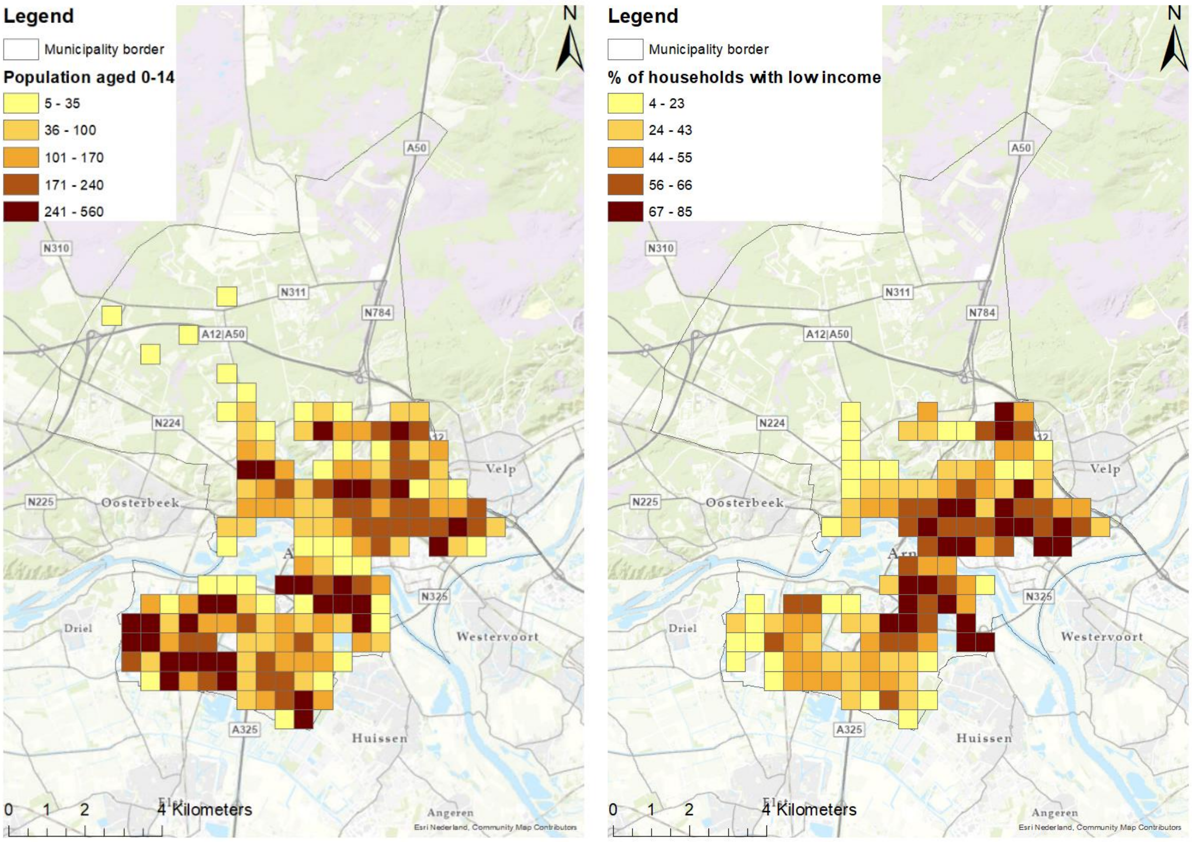
Table 1 – Gini coefficient of capital in 2017

Area	Gini coefficient
Arnhem	0.85
The Netherlands	0.79

Source: CBS (2019)

Figures 1 and 2 show how levels of household poverty and the childhood population vary across the municipality. The wide range of the former underlines the high levels of inequality in Arnhem seen in Table 1.

Figure 1 and 2 – Child population density and levels of low-income households in Arnhem



Source data: CBS (2021)

Moreover, Arnhem has the ninth-highest percentage of people living in poverty in the country (SCP, 2019). This increases differences in the level of need, making spatial equity a more pressing matter. Finally, a high-quality dataset by Cluster Openbare Ruimte van de Gemeente Arnhem (2018) on playgrounds and playground equipment was available for this municipality.

1.2 Research problem

The purpose of this paper, then, is to analyse whether focusing on playground equipment instead of playgrounds as single entities yields different results regarding accessibility. To allow for comparison to previous studies, the focus on spatial equity (i.e. levels of poverty) adopted in the past is to be replicated here. Hence, the following research question will be used:

How does the capacity of playgrounds relate to the spatial equity of playground accessibility?

1.2.1 Subquestions

To what extent are coverage and congestion of playgrounds related to levels of poverty in the municipality of Arnhem?

To what extent are coverage and congestion of units of playground equipment related to levels of poverty in the municipality of Arnhem?

1.3 Outline

This paper will first proceed by introducing a number of definitions in section 2. This results in the theoretical framework used here, which in turn gives way to the hypotheses. From here, the methodology of previous papers is explored in section 3, this forms a basis for the choice of methods in this thesis. These methods are then explained in detail. Moreover, the datasets used for the analysis are also outlined here. The results are then presented in a comparative nature in section 4, consistently showing the results of each metric for both playgrounds and units of playground equipment alongside each other. In section 5, the conclusion draws upon these comparisons to answer the research question and accompanies this with reflection on the process and findings.

2 Theoretical framework

As discussed in the introduction, the use of playgrounds has recreational value (Smoyer-Tomic et al., 2004) and impacts the level of physical activity undertaken by children (McCarthy et al. 2007). This has a positive effect on their physical and mental health (Ahn and Fedewa, 2011). For children who grow up in poorer households, the importance of playgrounds is greater, as their access to other options for both recreation and physical activity is relatively limited (Smoyer-Tomic et al., 2004). Therefore, poorer neighbourhoods experience a greater level of need for the provision of playgrounds (Smoyer-Tomic et al., 2004). This relates back to the basic definition of spatial equity of need and provision being equal (Lucy, 1981, cited by Smoyer-Tomic et al., 2004, p. 290).

However, the provision of playgrounds does not depend on their existence in given neighbourhoods, but on their accessibility. Accessibility is defined in accordance with previous studies, in that it is the ease with which amenities (here playgrounds or units of playground equipment) can be accessed (Handy and Niemeier, 1997). This is dependent on the distance and the volume of users (Martori et al., 2019).

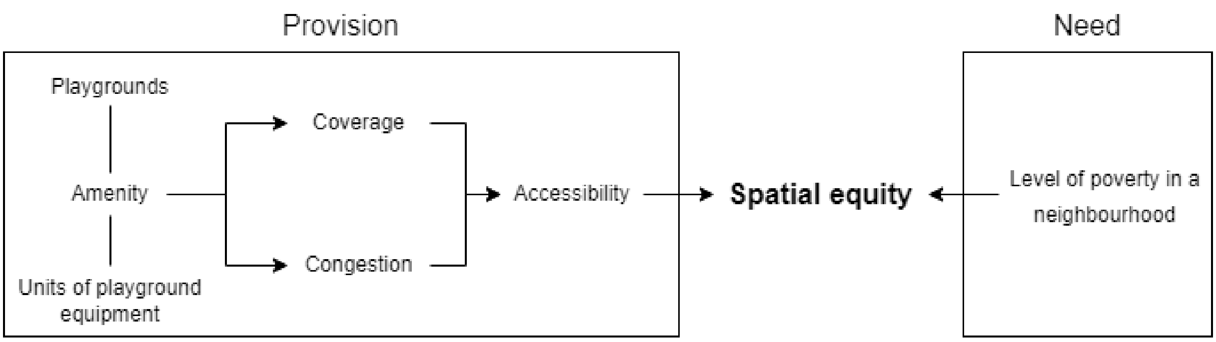
In this thesis, two metrics will be used to measure accessibility: coverage and congestion. The definition of coverage is similar to the one used by Smoyer-Tomic et al. (2004), but must be amended to fit both variables. Hence, it is defined here as the number of amenities (i.e. playgrounds or units of playground equipment) within a given distance of the centroid of a neighbourhood. The definition of congestion follows that of Martori et al. (2019) as the following: The weighted number of children (defined as aged 0-14 here) within a given distance of an amenity.

The level of poverty in a neighbourhood is based on the percentage of households with a low income. Students are not included in this metric, as this risks skewing the analysis given that student income has little effect on poverty experienced by children.

With this specification of need and provision for this particular topic, it is possible to return to the basic definition of spatial equity and specify it for the purposes of this thesis. If need and provision are to be equal, playground accessibility must be greater for poorer neighbourhoods. Hence, spatial equity is defined here as the existence of a positive relationship between levels of poverty and accessibility of amenities on a neighbourhood level. This implies that coverage must be greater in poorer neighbourhoods, whereas congestion must be lower.

From these definitions, reasonings and research questions, the conceptual model follows.

Figure 3 – Conceptual model



With this framework in mind, it is possible to form the hypotheses.

2.1 Hypotheses

The null hypothesis for the first subquestion is that there is no significant correlation between levels of poverty and playground coverage, nor between levels of poverty and playground congestion. Previous studies have found better accessibility to playgrounds for neighbourhoods with higher poverty levels, also when coverage (Smoyer-Tomic et al., 2004) or congestion (Martori et al., 2019) were used as metrics. If the findings of this study will be in accordance with this, the null hypothesis would therefore be rejected on both counts.

For units of playground equipment, the null hypothesis is defined in an identical manner to ensure comparability. Hence, it is hypothesised that there is no significant correlation between levels of poverty and coverage of units of playground equipment, nor between levels of poverty and congestion of units of playground equipment. As discussed previously, there is no prior research on this metric to compare and contrast with, although Smoyer-Tomic et al. (2004) and McCarthy et al. (2017) found no conclusive evidence of a link between poverty levels and access to playgrounds of higher quality. For both subquestions, accepting the null hypothesis implies no evidence of spatial equity.

Returning to the research question itself, it is necessary to compare the findings for the measures of coverage and congestion found between both objects of analysis. The null hypothesis is then that there is no significant difference between the findings on both congestion and coverage, depending on if playgrounds or units of playground equipment are analysed.

3 Methodology

This section is divided into three subsections. First, the choice of research method is discussed. This is followed by a more thorough explanation of the chosen methods. Finally, the data used in this thesis is introduced.

3.1 Method choice

In previous studies on playground accessibility, the most common method used to determine accessibility levels is the minimum-distance method. It works by calculating the distance from the centroid of the neighbourhood to the nearest playground and can be deployed both with both Euclidean and network distance. In this field, it was first adopted and advocated by Talen and Anselin (1998). The minimum-distance method has since been adopted in a variety of other papers on playground accessibility (Smoyer-Tomic et al., 2004; McCarthy et al., 2017; Martori et al., 2019).

However, there are two reasons why this method is not suitable for this thesis. Firstly, Talen and Anselin (1998) argue that the quality of playgrounds is mostly homogeneous and that this is a reason to apply the minimum-distance method to it. This notion is disputed by other authors, as Smoyer-Tomic et al. (2004) and McCarthy et al. (2017) both take playground quality into account in their work. Moreover, it ignores the capacity of playgrounds, upon which the research question in this thesis is based.

Secondly, and most importantly, the minimum-distance method is not suitable for the objects of analysis chosen here. Units of playground equipment are, of course, located in playgrounds. This means that the closest unit of playground equipment will be in the closest playground, and therefore the outcome will automatically be the same for both objects of analysis. This means that the minimum-distance method cannot be applied for a capacity-based approach like the one in this thesis.

Therefore, other methods are chosen here. While it is possible to use surveys, a previous survey-based article on playground accessibility by Pereira (2004) suffered from a low sample size, suggesting that this is not the most suitable approach either. Therefore, other methods of spatial analysis are used in this thesis.

One such method is the coverage method, previously deployed by Smoyer-Tomic et al. (2004). The principle of this method is to calculate the number of objects of analysis within a given distance of a point. In the case of Smoyer-Tomic et al. (2004), this is the number of playgrounds within 800 metres of the centroid of the census tract. The advantage of this approach compared to the minimum-distance method is that not only the closest object is taken into account. This is highly useful for this thesis, as it means that different results will occur if units of playground equipment are used instead of playgrounds.

Another such method is the enhanced two-step floating catchment area method, as used by Martori et al. (2019). This method is also known as the congestion method, as it measures differences in the amount of users of a certain amenity. The underlying principle is that the closer the distance between a person and the amenity, the more likely they are to use it. This principle is used to calculate the level of congestion of each amenity using distance weights. By then combining the amount of amenities within a given distance of a certain point with their level of congestion, it can be measured how much congestion people at this point experience. Because all amenities within a given distance are taken into account, this method will also provide different results for playgrounds and units of playground equipment, making it applicable for this thesis.

An obvious consequence of using a different method is that it may yield different, potentially inaccurate results (Talen and Anselin, 2008). However, the minimum-distance method and the coverage method showed a similar link between playground accessibility and social need in Edmonton, Canada (Smoyer-Tomic et al., 2004). Moreover, both the minimum-distance method and the congestion method indicated a positive relationship of poverty levels and playground accessibility in Barcelona (Martori et al., 2019). Therefore, both methods are found to be suitable for this thesis.

3.2 Method explanation

For the level of coverage, the buffering method used by Smoyer-Tomic et al. (2004) is followed. For each neighbourhood centroid, a buffer is created. The size of this buffer is arbitrary to some extent. Smoyer-Tomic et al. (2004) based the radius for their buffer (800 metres) on municipal planning guidelines. While the municipality of Arnhem does not have such a guideline, the association of Dutch municipalities VNG recommends using the one adopted by the municipality of Leiden (Bouwmeester, 2006). This guideline bases itself on the distance children travel from their home. This distance varies with age, hence there are three separate so-called 'play radii' used for the guideline, these can be seen in Table 2.

Table 2 – Play radii for different age groups

Age group	Play radius
0-5 years	150 metres
6-12 years	400 metres
13 years and above	1000 metres

Source: Bouwmeester (2006)

In this thesis, the middle radius is used, for two reasons. For one, it is the median radius for the age group of 0-14 years used here. For another, the lower radius would mean the buffers are smaller than the neighbourhood sizes of 500 by 500 metres, while the higher radius would cause neighbourhoods on the edge of the municipality to have large parts of their buffer outside the area of analysis, adding systemic bias. The number of playgrounds and the number of units of playground equipment within this buffer of 400 metres are then calculated. Higher values indicate higher levels of coverage.

For calculating the level of congestion with the enhanced two-step floating catchment area, a similar calculation adopted by Martori et al. (2019) is used. However, to better reflect the greater importance of the same playground for a neighbourhood that is closer to it, the distance decay will be factored in twice, following the formula used by Luo and Qi (2009, p. 1102). First, the weighted playground-to-population ratio R_i of a playground at location i is calculated. Note that this step is identical to the one of Martori et al. (2019).

$$R_i = \frac{S_i}{\sum_{k\in\{d_{ki}\in D_r\}} P_k W_r} = \frac{S_i}{\sum_{k\in\{d_{ki}\in D_1\}} P_k W_1 + \sum_{k\in\{d_{ki}\in D_2\}} P_k W_2 + \sum_{k\in\{d_{ki}\in D_3\}} P_k W_3}$$

In which P_k is the child population of neighbourhood k of which the centroid falls within the catchment of i ($d_{ki} \in D_r$), d_{ki} the distance between the centroids of neighbourhoods k and i, D_r the rth distance zone within the catchment, W_r the distance weight, and S_i the number of playgrounds at location i. By substituting the number of units of playground equipment for the number of playgrounds as the enumerator, this method can be used to take playground capacity into account. In this case, R_i is the weighted playground equipment-to-population ratio.

For the distance zones, the same distances as for the coverage calculation were used. As the data for child population concerns the ages 0-14, the weights are based on the percentage of children within this age group for which the playground is accessible, assuming an equal age distribution. The resulting weights can be found in Table 3.

Table 3 – Distance weights based on age groups

Age group	Play radius	Distance weight
0-5 years	150 metres	15/15 = 1
6-12 years	400 metres	9/15 = 0.6
13 years and above	1000 metres	2/15 ≈ 0.133

Source: based on Bouwmeester (2006)

For each neighbourhood j, each playground i within the distance threshold of the greatest distance zone (1000m) is taken into account, summing each R_i while accounting for the distance decay to calculate the congestion measure A_j:

$$A_j = \sum_{j \in \{d_{ij} \in D_r\}} R_i W_r = \sum_{j \in \{d_{ij} \in D_1\}} R_i W_1 + \sum_{j \in \{d_{ij} \in D_2\}} R_i W_2 + \sum_{j \in \{d_{ij} \in D_3\}} R_i W_3$$

Where d_{ij} is the distance between playground i and the centroid of neighbourhood j and a higher A_j indicates a lower level of congestion for neighbourhood j. The same calculation is performed for units of playground equipment, in which i refers to a unit of playground equipment rather than a playground.

The key difference with the formula used by Martori et al. (2019) is that the distance decay is not applied to the second step there. This means that, for Martori et al. (2019), a playground at 1 metre from a centroid has the same effect on the congestion measure as one at 999 metres. However, a child is more likely to play in the playground at a distance of 1 metre than the one at a distance of 999 metres. Hence the decision to follow the formula of Luo and Qi (2009).

To analyse the results derived from these methods, three statistical tests are deployed. First, Pearson's correlation is used to determine the size of any effect of levels of household poverty on playground provision. However, this test does not test the significance of the effect, hence a linear regression is adopted to do this. For the coverage method, a multiple linear regression is used, taking into account the child population as well as this is expected to be a main contributing factor for the spatial distribution of playgrounds. For the congestion method, doing this makes little sense as the population size is already taken into account in this measure, therefore only a simple linear regression is used here. SPSS is used for this statistical analysis. Finally, the correlations of playgrounds and units of playground equipment with poverty levels are compared using the Fisher's z-test in the cocor model (Diedenhofen & Musch, 2015) to compare the results.

3.3 Data

To answer the research question, two data sources are used. The first is the *Spelenkaart* ('Play map') of the municipality of Arnhem. It includes all playgrounds and playground equipment for which the municipality is responsible. The definition of playground used here is relatively wide, as it also contains publicly accessible sports facilities and associated equipment such as Cruyff courts or basketball hoops, in addition to designated youth meeting places (Cluster Openbare Ruimte van de Gemeente Arnhem, 2018). The advantage of such a definition is that it also includes facilities aimed at older children. In addition to the type of playground and playground equipment, the location is also included in the dataset.

For data on poverty and the number of children per area, the most granular source available is the 500x500m level of *CBS Vierkantstatistieken*, the grid data of the national statistical agency (CBS, 2021). This data source uses age groups with intervals of 10 to 20 years, as mentioned previously, the youngest age group is 0 up to and including 14 years (Van Leeuwen & Venema, 2021) and is therefore used as the measure for the number of children in a grid cell. With regards to poverty, household poverty data is used. CBS defines a low-income household as being in the 40% of households with the lowest spendable income in the Netherlands (Van Leeuwen & Venema, 2021). Crucially, student households are excluded from this data. Hence, the level of household poverty in a grid cell is the percentage of households within this grid cell that form a part of these 40% poorest households within the country (Van Leeuwen & Venema, 2021). This data is not available at the 100x100m level. As the *Spelenkaart* is based on 2018 data and the household poverty data is not available for more recent years than 2018, it was ensured that all data used concerned this same year.

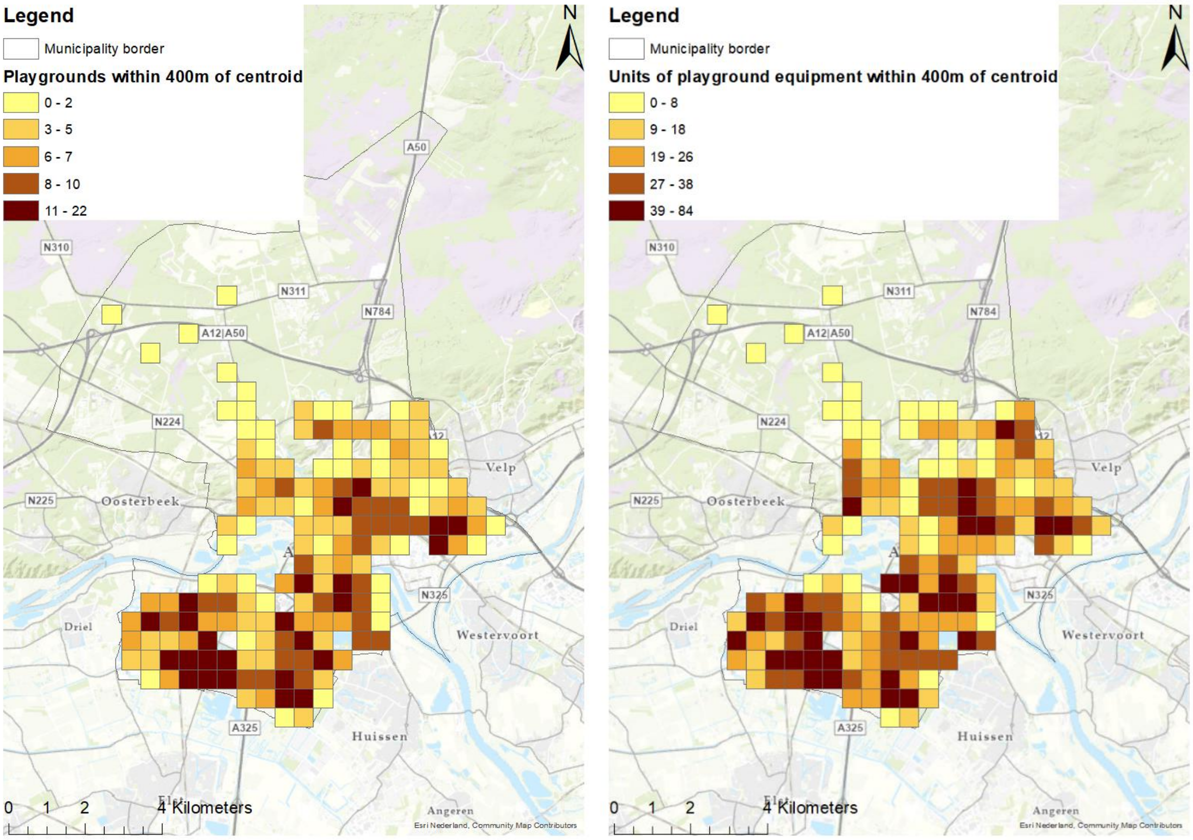
A major constraint for all publicly available data in the Netherlands is that privacy concerns mean certain data is not publicly available if the sample size is too low for a given area, in this case a grid cell. The population for any given age group in a grid cell is only given if it is at least 5, therefore grid cells with a population aged 0-14 that is below 5 has no data and must therefore be excluded from analysis. A number of the remaining grid cells that do have this data, do not have household poverty data available. This is because this data is only available for grid cells with at least 100 households, of which at least 5 have a low income according to the aforementioned definition (Van Leeuwen & Venema, 2021). These grid cells can be included in the congestion calculation, but had to be excluded from the statistical analysis. This means that grid cells with a low population density are somewhat underrepresented in the analysis. As these will disproportionately be for example at the edges of the city or partially in the river, this may cause a small bias in the research, however it should be noted that the number of children not taken into account is relatively small.

4 Results

This section consists of two halves: first coverage, then congestion. For both metrics, the spatial differences are displayed first, followed by the statistical analysis. Then, the variation in the method is introduced, from where it is tested whether this yields different results. Throughout this section, the results for playgrounds and units of playground equipment are presented simultaneously to allow for comparison.

4.1 Coverage

Figure 4 and 5 – Coverage of playgrounds and units of playground equipment



Source data: CBS (2021) and Cluster Openbare Ruimte van de Gemeente Arnhem (2018)

Figures 4 and 5 show the spatial distribution of coverage of playgrounds and units of playground equipment. Although these are mostly similar, the maps suggest that a number of neighbourhoods north of the Nederrijn have better coverage for units of playground equipment, suggesting that average playground capacity is higher in these areas. Densities are generally the highest in the southwestern part of the city, which was previously identified as an area with a particularly high child population. This illustrates the importance of controlling for population aged 0-14 when analysing whether poverty levels and playground provision are linked.

Tables 4, 5 and 6 show the results of the statistical analyses for the coverage metric. Table 4 indicates the results of the correlation test, Table 5 shows the outcome of the multiple linear regression for each independent variable and then the regression model outcome as a whole, Table 6 presents the outcome of the Fisher's z-test.

Table 4 – Correlation analysis of the coverage metric

	Playground coverage	**Playground equipment coverage**

	Population 0-14	*% low-income households*	*Population 0-14*	*% low-income households*
Sample size (N)	133	133	133	133
Pearson's correlation coefficient (ρ)	0.557	0.203	0.569	0.178
Significance (2-tailed)	< 0.001	0.019	< 0.001	0.040

Table 5 – Regression analysis of the coverage metric

	Playground coverage		**Playground equipment coverage**	
	Population 0-14	*% low-income households*	*Population 0-14*	*% low-income households*
Sample size (N)	133	133	133	133
Regression slope (B) with 95% confidence interval	0.019 (0,015 – 0,069)	0.042 (0,015 – 0,024)	0.080 (0,061 – 0,099)	0.151 (0,042 – 0,259)
Coefficient t-value	7.996	3.087	8.183	2.744
Significance	< 0.001	0.002	< 0.001	0.007
Model explained variance (R^2)	0.357		0.361	
Model F-value	36.151		36.724	
Model significance	< 0.001		< 0.001	

Table 6 – Correlation comparison of the coverage metric

	Playground vs. playground equipment coverage
Sample size (N)	133
Fisher's z	0.2092
Significance	0.8343

The results for both playgrounds and units of playground equipment are quite similar here, as reflected by the insignificant outcome of the Fisher's z-test. While both the correlation test and the regression show a significant (linear) relationship between household poverty and coverage levels for both units of analysis, it is also evident that this relationship is quite weak. The regression slope is steeper for playground equipment coverage, but this can of course be explained by the greater number of units of playground equipment compared to the number of playgrounds.

The regression slopes suggest that, controlling for child population, the number of playgrounds within a 400-metre radius of the neighbourhood centroid increases by 0.042 when the percentage of households with low income increases by 1. For units of playground equipment, this increase is 0.151. This is consistent with the correlation coefficient, which suggests a weak relationship between household poverty and both playground and units of playground equipment coverage. Conversely, the correlation between population aged 0-14 and both units of analysis is, perhaps unsurprisingly, strong.

4.1.2 Sensitivity analysis

It is, of course, possible that the size of the radius has an impact on findings. To verify whether this is the case for Arnhem, the same procedure was repeated with a radius of 1000 metres, the play radius of teenagers defined by the municipality of Leiden (Bouwmeester, 2006). The results of this are presented in Tables 7, 8 and 9 in the same manner as previously.

Table 7 – Correlation analysis of the coverage metric, with adjusted radius

	Playground coverage		**Playground equipment coverage**	
	Population 0-14	*% low-income households*	*Population 0-14*	*% low-income households*
Sample size (N)	133	133	133	133
Pearson's correlation coefficient (ρ)	0.419	0.234	0.449	0.245
Significance (2-tailed)	< 0.001	0.007	< 0.001	0.005

Table 8 – Regression analysis of the coverage metric, with adjusted radius

	Playground coverage		**Playground equipment coverage**	
	Population 0-14	*% low-income households*	*Population 0-14*	*% low-income households*
Sample size (N)	133	133	133	133
Regression slope (B) with 95% confidence interval	0.039 (0.018 – 0.060)	0.176 (0.059 – 0.293)	0.179 (0.095 – 0.262)	0.752 (0.283 – 1.221)
Coefficient t-value	3.734	2.975	4.231	3.170
Significance	< 0.001	0.003	< 0.001	0.007
Model explained variance (R^2)	0.146		0.174	
Model F-value	11.134		13.655	
Model significance	< 0.001		< 0.001	

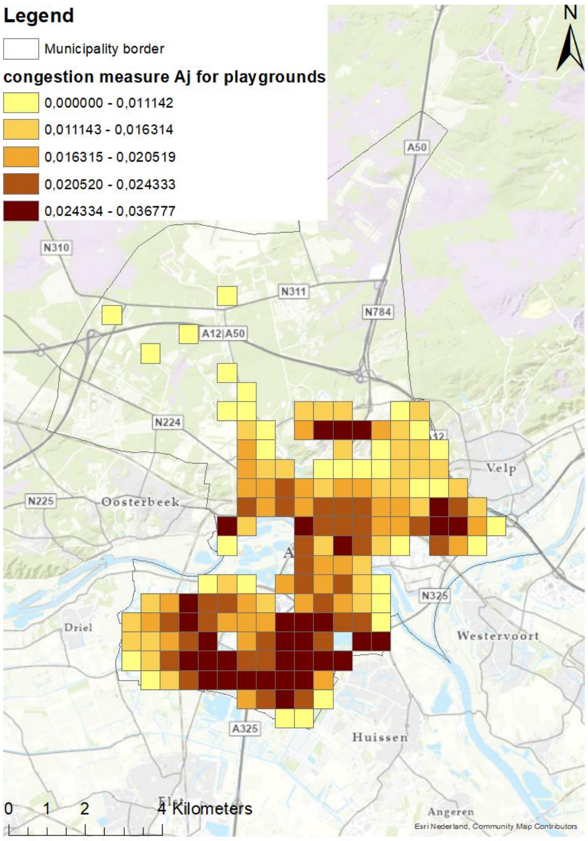
Table 9 – Correlation comparison of the coverage metric, with adjusted radius

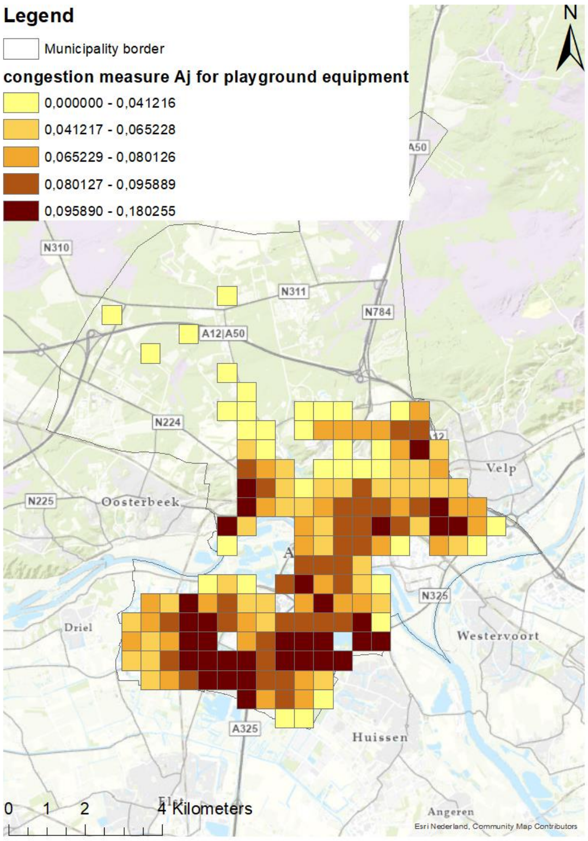
	Playground vs. playground equipment coverage
Sample size (N)	133
Fisher's z	-0.0941
Significance	0.9250

As this table shows, increasing the radius has little effect on the findings regarding the size of the impact of household poverty on playground coverage. For units of playground equipment, the found size of this impact may be a bit stronger, but this does not cause a significant difference with playgrounds. However, the explanatory power of the model decreases by more than half. Moreover, the correlation with population aged 0-14 falls to moderate levels for both playgrounds and units of playground equipment. As the results provided little reason to work with a greater radius, further analysis with the 1000-meter buffer was not performed.

4.2 Congestion

Figure 6 and 7 – Congestion of playgrounds and units of playground equipment





Source data: CBS (2021) and Cluster Openbare Ruimte van de Gemeente Arnhem (2018)

When looking at the levels of congestion for each neighbourhood, Figures 6 and 7 suggest a north-south divide, with less congestion in the southern parts of Arnhem. This divide can be seen independent of whether playgrounds or units of playground equipment are used for analysis. Moreover, a cluster of grid cells where much higher congestion is found for units of playground equipment than for playgrounds in the north of the city, this was not the case for coverage. On the other hand, the same two areas where scores strongly improve when units of playground equipment are used are present for both coverage and congestion.

Tables 10, 11 and 12 show the results of the statistical analysis for the congestion metric. The ordering is the same as for the coverage metric, however, only percentage of households with a low income is used as a dependent variable here.

Table 10 – Correlation analysis of the congestion metric

	Playground congestion	**Playground equipment congestion**
Sample size (N)	133	133
Pearson's correlation coefficient (ρ)	0.258	0.270
Significance (2-tailed)	0.003	0.002

Table 11 – Regression analysis of the congestion metric

	Playground congestion	**Playground equipment congestion**
Sample size (N)	133	133

Regression slope (B) with 95% confidence interval	0.0000897 (0.000031 – 0.000145)	0.000367 (0.000140 – 0.000593)
Coefficient t-value	3.206	3.206
Significance	0.003	0.007
Model explained variance (R^2)	0.067	0.073
Model F-value	9.368	10.278
Model significance	0.003	0.002

Table 12 – Correlation comparison of the congestion metric

	Playground vs. playground equipment congestion
Sample size (N)	133
Fisher's z	-0.1040
Significance	0.9172

The findings here are very similar to those for coverage, with no significant difference between the congestion measure based on playgrounds and the one based on units of playground equipment. Moreover, the found correlation is once again weak. The regression slopes are very low here, which can be explained by the low values inherent to the formula used for the regression measure. The main difference with the coverage model is that the explanatory power is lower here, perhaps because population was already taken into account in the metric and there is therefore only one explanatory variable here.

4.2.2 Sensitivity analysis

To account for differences with the work of Martori et al. (2019), the analysis was repeated using the formula of this article, i.e. the formula used previously without the distance decay in the second step. The results of this can be found in Tables 13, 14 and 15.

Table 13 – Correlation analysis of the congestion metric, without distance decay in step 2

	Playground congestion	**Playground equipment congestion**
Sample size (N)	133	133
Pearson's correlation coefficient ρ	0.290	0.311
Significance (2-tailed)	0.001	< 0.001

Table 14 – Regression analysis of the congestion metric, without distance decay in step 2

	Playground congestion	**Playground equipment congestion**
Sample size (N)	133	133
Regression slope (B) with 95% confidence interval	0.000398 (0.000171 – 0.000624)	0.00173 (0.000814 – 0.00264)
Coefficient t-value	3.472	3.741
Significance	0.001	< 0.001
Model explained variance (R^2)	0.084	0.097
Model F-value	12.057	13.992
Model significance	0.001	< 0.001

Table 15 – Correlation comparison of the congestion metric, without distance decay in step 2

	Playground vs. playground equipment congestion
Sample size (N)	133
Fisher's z	-0.1861
Significance	0.8523

Both the explanatory power of the regression model and the correlation coefficient increase slightly compared to the results using the original formula, with the latter narrowly reaching moderate levels for units of playground equipment. This raises the question whether the method above is more appropriate, or if it simply makes it easier to find an association by potentially problematic simplification. In any case, there is still no significant difference between the correlations of both objects of analysis.

5 Conclusion and discussion

5.1 Conclusion

This thesis focused on the spatial equity of accessibility to playgrounds while taking capacity into account. Spatial equity was seen as being present if neighbourhoods with higher levels of need, in this case those with lower income levels, experience a greater level of accessibility. These higher levels of need are due to the greater role of playgrounds in enabling physical activity and recreation, which are associated with physical and mental health benefits, for children in poorer households. Capacity was taken into account by differentiating between playgrounds and units of playground equipment, where the number of units of playground equipment was used as a proxy for capacity. Accessibility was measured with two metrics: coverage and congestion. Moreover, each of the four calculations was also redone with a small variation that was identical for each unit of analysis to test the sensitivity of the calculations.

The similarity for each of the calculations was striking. Independent of the metric, unit of analysis and variation, results indicated a significant, but weak, positive association between levels of low household income and playground accessibility. Hence the null hypotheses for both subquestions must be rejected, as these stipulated that there would be no link between either coverage or congestion and access to either playgrounds or units of playground equipment. Following the theoretical framework, the positive relationship suggests that spatial equity of playground accessibility is present, as children in poorer neighbourhoods with a greater social need tend to experience a higher level of access to playgrounds and units of playground equipment. However, the low strength of the association means that particularly strong conclusions can not be drawn from this research.

The lack of significant difference between access to playgrounds and access to units of playground equipment implies that the capacity of individual playgrounds has little effect on the spatial equity of playground accessibility at the level of the municipality. Hence, the null hypothesis of the main research question is accepted. However, at the level of the neighbourhood, some patterns can be found. For both coverage and congestion, two clusters of grid cells – one in the west, one in the northeast – that experienced notably greater levels of access when playground equipment was taken into account can be identified. Interestingly, the northeastern cluster has a higher degree of low-income households than average, while the opposite holds true for the western cluster. Moreover, a relatively rich cluster of grid cells that was found to experience much higher levels of congestion of playground equipment than of playgrounds is found in the north of the city. This cluster was not clear for the coverage metric. This suggests that, at the neighbourhood level, both taking capacity into account and using a variety of accessibility measures can provide new insights for municipalities on where playground provision is currently lacking.

The positive relationship between playground accessibility and levels of poverty in a neighbourhood is consistent with previous research, although it may be that this thesis found a weaker association than most other articles. However, if a greater number of units of playground equipment is taken to indicate a greater level of playground quality, then there is a discrepancy with previous research. The work of Smoyer-Tomic et al. (2004) and McCarthy et al. (2017) suggests that evidence of the spatial equity of playground accessibility is weaker when playground quality is taken into account. However, this is not something that can be concluded from the results here, as the results did not vary significantly between playgrounds and units of playground equipment.

5.2 Discussion

Even taking into account the relatively weak evidence presented here, there are still some weaknesses in this research that may undermine the conclusions. For one, both the coverage and the congestion metric used Euclidean distance rather than walking distance, as the grid cell centroids are not automatically connected to the road network. However, this means that areas with relatively direct walking routes may have been underrated compared to those with less direct routes. If the directness of walking routes and the levels of poverty in a neighbourhood are linked, this could cause errors in this research.

Another potential source of bias is the privacy concerns that constrain the household income data used here. As mentioned previously, privacy laws mean that only neighbourhoods with at least 100 households of which at least 5 are in the lowest 40% of spendable income nationwide could be included. However, this may have caused neighbourhoods with sufficient total population, but homoegeneously high income levels, as well as less densely-populated areas, to have been omitted from analysis. Therefore, the grid cells analysed here may not be fully representative of Arnhem as a whole.

Finally, this thesis did not take into account differences between younger and older children. Younger children have a smaller play radius and prefer different kinds of playgrounds and playground equipment than older children (Bouwmeester, 2006), hence there is a difference between their respective needs that was not taken into account here.

In terms of future research, it would be desirable to address the weaknesses discussed above to improve the quality of the research methods, if possible. For example, the research could be repeated, but with different radii for different age groups and taking into account the target age range of each playground and each unit of playground equipment. This would also increase the level of granularity. This would require playground, playground equipment and child population data that is split into different age groups; the latter was not available for Arnhem. Moreover, it could be tested whether playground capacity impacts differences in playground accessibility between other (e.g. ethnic) types of social groups. Finally, the methods used here could be repeated at a more local level, as their value may be at their greatest that way. This could also be done using surveys in order to gather individual data instead of using a neighbourhood-based approach, thereby including health data.

6 References

Ahn, S., & Fedewa, A. L. (2011). A Meta-analysis of the Relationship Between Children's Physical Activity and Mental Health. *Journal of Pediatric Psychology*, 36(4), 385–397.

Bouwmeester, H. (2006). Spelen met ruimte: handboek gemeentelijk speelruimtebeleid. Utrecht: Jantje Beton/VNG/NUSO.

CBS (2019). *Ongelijkheid in inkomen en vermogen*. Retrieved on October 8, 2021 from https://longreads.cbs.nl/welvaartinnederland-2019/ongelijkheid-in-inkomen-en-vermogen/. Den Haag: CBS.

CBS (2021). *Statistische gegevens per vierkant 2018*. Retrieved on October 20, 2021 from https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische-data/kaart-van-500-meter-bij-500-meter-met-statistieken. Den Haag: CBS.

Cluster Openbare Ruimte van de Gemeente Arnhem (2018). *Spelenkaart.* Retrieved on September 30, 2021 from https://rug.maps.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=e5b0b0ab8849448cbc419f11afb97ffa.

Colabianchi, N., Kinsella, A. E., Coulton, C. J., & Moore, S. M. (2009). Utilization and physical activity levels at renovated and unrenovated school playgrounds. *Preventive Medicine*, 48(2), 140–143.

Delidou, E., Matsouka, O., & Nikolaidis, C. (2015). Influence of school playground size and equipment on the physical activity of students during recess. *European Physical Education Review*, 22(2), 215–224.

Diedenhofen, B. & Musch, J. (2015). cocor: A Comprehensive Solution for the Statistical Comparison of Correlations. *PLoS ONE*, 10(4): e0121945.

Giles-Corti, B., Timperio, A., Bull, F., & Pikora, T. (2005). Understanding Physical Activity Environmental Correlates: Increased Specificity for Ecological Models. *Exercise and Sport Sciences Review*s, 33(4), 175–181.

Handy, S. L., & Niemeier, D. A. (1997). Measuring Accessibility: An Exploration of Issues and Alternatives. *Environment and Planning A*, 29(7), 1175–1194.

Leeuwen, N. van & Venema, J. (2021). *Statistische gegevens per vierkant en postcode 2020-2019-2018: 4. Beschrijving cijfers*. Retrieved on October 19, 2021 from https://www.cbs.nl/nl-nl/longread/diversen/2021/statistische-gegevens-per-vierkant-en-postcode-2020-2019-2018/4-beschrijving-cijfers. Den Haag: CBS.

Luo, W., & Qi, Y. (2009). An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians. *Health & Place*, 15(4), 1100–1107.

Martori, J. C., Apparicio, P., & Séguin, A.-M. (2019). Spatial Potential Accessibility of Playgrounds in Barcelona City. *Applied Spatial Analysis and Policy*, 13(2), 489–506.

McCarthy, S. M., Hughey, S. M., & Kaczynski, A. T. (2017). Examining Sociodemographic Differences in Playground Availability and Quality and Associations with Childhood Obesity. *Childhood Obesity*, 13(4), 324–331.

Pereira, B. (2004). Children's playground accessibility in the North of Portugal. *World Leisure Journal*, 46(1), 38–45..

Reimers, A. K., & Knapp, G. (2017). Playground usage and physical activity levels of children based on playground spatial features. *Journal of Public Health*, 25(6), 661–669.

Smoyer-Tomic, K. E., Hewko, J. N., & Hodgson, M. J. (2004). Spatial accessibility and equity of playgrounds in Edmonton, Canada. *The Canadian Geographer/Le Géographe Canadien*, 48(3), 287–302.

Sociaal en Cultureel Planbureau (2019). *Waar wonen de armen in Nederland?* Retrieved on October 8, 2021 from https://digitaal.scp.nl/armoedeinkaart2019/waar-wonen-de-armen-in-nederland//.

Talen, E., & Anselin, L. (1998). Assessing Spatial Equity: An Evaluation of Measures of Accessibility to Public Playgrounds. *Environment and Planning A*, 30(4), 595–613.

True, L., Pfeiffer, K. A., Dowda, M., Williams, H. G., Brown, W. H., O'Neill, J. R., & Pate, R. R. (2017). Motor competence and characteristics within the preschool environment. *Journal of Science and Medicine in Sport*, 20(8), 751–755.