Accessibility and the temporal organisation of public service facilities

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Samenvatting

Titel
Bereikbaarheid en temporele organisatie van openbare voorzieningen

Het garanderen van een klantgerichte dienstverlening en een goede bereikbaarheid van openbare voorzieningen voor alle geledingen van de samenleving is een fundamentele beleidsdoelstelling. Hoewel er verscheidene studies bestaan die de effecten van een ongelijke ruimtelijke verspreiding van voorzieningen en transportinfrastructuur in kaart brengen, bestaat er tot op heden slechts weinig (kwantitatief) onderzoek over de manier waarop de toegang tot openbare voorzieningen kan verbeterd worden door het herschikken of wijzigen van openingsuren. Dit komt onder meer omdat bereikbaarheid traditioneel geanalyseerd wordt als een statisch ruimtelijk fenomeen, zonder daarbij rekening te houden met potentiële conflicten tussen openingsuren enerzijds en de tijdsvensters van vaste activiteiten zoals werken of school lopen anderzijds. Dergelijke vaste activiteiten determineren nochtans in belangrijke mate het dagdagelijkse leven van elk individu en bijgevolg zijn/haar bereikbaarheid tot openbare voorzieningen.

In deze paper worden de implicaties van veranderingen in openingsuren bestudeerd op basis bereikbaarheidsindicatoren die, naast de ruimtelijke inrichting en de transportinfrastructuur, ook heel gedetailleerd de activiteiten en het verplaatsingsgedrag van individuen in rekening brengen. Op basis van twee verschillende gelijkheidsprincipes, worden twee benaderingen voor het herschikken van openingsuren van openbare voorzieningen voorgesteld: een utilitaire benadering waarbij het algemene niveau van bereikbaarheid gemaximaliseerd wordt over de volledige populatie (i); en een egalitaire benadering waarbij er niet alleen gestreefd wordt naar een optimale gemiddelde bereikbaarheid maar tevens getracht wordt om elk individu een zo gelijk mogelijke bereikbaarheid te verschaffen (ii). Beide methodes worden gevalideerd in een empirische gevalstudie omtrent de bereikbaarheid van bibliotheken in de stad Gent (België). Er wordt onder andere aangetoond dat de bereikbaarheid van de Gentse bibliotheken sterk verbeterd kan worden door het herschikken van openingsuren zonder deze uit te breiden. Anderzijds duidt de studie op de mogelijkheid om het huidige bereikbaarheidsniveau te handhaven met een aanzienlijk kleiner aantal openingsuren. Onze studie is bijzonder relevant voor lokale besturen en overheden die inzicht wensen te verwerven in de bereikbaarheidseffecten die mensen ondervinden als gevolg van wijzigingen in openingsuren.

1. Introduction

Achieving a higher and more equitable level of access to essential public services has been an issue of major concern in the urban service delivery literature for at least three decades (Bigman & ReVelle, 1979; Hero, 1986; Mclafferty, 1982; Schwanen et al., 2008; Talen & Anselin, 1998; Tsou et al., 2005). Within this well-developed and active line of research, attention has primarily been directed toward the variations in service levels between geographic subunits or social groupings as a consequence of an uneven spatial distribution of public services and transportation facilities within a city (Scott & Horner, 2008). Not only are local authorities and policymakers concerned with maximising the accessibility of public services, they are also sensitive to the degree to which the spatial configuration of service allocation favours particular constituencies over others.

While numerous studies have sought to analyse the distributional effects of the spatial configuration of public services, far less attention has been paid to the ways in which accessibility and equity of accessibility can be improved by amending the temporal organisation of service provision. This may in part be a corollary of the fact that accessibility to services has traditionally been analysed as a static spatial phenomenon and measured through indicators based on spatial proximity (for reviews about accessibility measures, see e.g. Guy, 1983; Handy & Niemeier, 1997; Kwan et al., 2003; Neutens et al., 2010a; Pirie, 1979). These indicators are a-temporal in the sense that they do not account for the scheduling conflicts that may arise between the opening hours of public service facilities and an individual's mandatory activities (e.g. paid labour). This is unfortunate since the implications of opening hour adjustments for accessibility are likely to be socially differentiated as people differ much in terms of the location, number, duration and timing of their mandatory activities (Cullen & Godson, 1975; Schwanen et al., 2008). As a consequence, changes to opening hours may remediate or exacerbate disparities in accessibility as much as do amendments to the spatial distribution of public service facilities.

Relying on earlier contributions in the realm of time geography (Hägerstrand, 1970; Lenntorp, 1978), a few authors have recently sought to substantiate empirically the importance of accounting for opening hours of service delivery in evaluative studies of accessibility. Weber and Kwan (2002), for example, have demonstrated that incorporating time into accessibility measures in the form of congestion and opening hours results in spatially uneven reductions in individual accessibility within cities. Schwanen and de Jong (2008), for their part, have foregrounded the coordination problems between paid labour and caring responsibilities that may arise from limited opening hours of childcare facilities. Finally, Neutens et al. (2010b) have shown that changes to the temporal regime of public service facilities may induce (unintended) social differences in individual accessibility. However, none of these studies offers clear insights into the ways in which opening hours can be employed as a policy instrument to improve the accessibility of public services in an equitable way.

This paper seeks to deepen our understanding about the relationships between individual accessibility, equity and opening hours of public service facilities. More specifically, the aim is to gain insights into how and to what extent individual accessibility to public services can be improved in an equitable way by amending the opening hours of service delivery. Two approaches based on different equity principles are presented to reschedule the opening hours of public service facilities: a utilitarian and an egalitarian approach. While the former seeks to maximize average level of individual accessibility regardless of its distribution among the population, the latter aims to provide each citizen a fair level of accessibility (Khisty, 1996). The relevance of both approaches for amending the opening hours of public services will be illustrated in a case study on the public libraries in the city of Ghent (Belgium). As with many other public services, public libraries are concerned with offering a high and equitable level of access to a large and socially diverse public. As well, prior research (Cole & Gatrell, 1986; Glorieux, 2007; Grindlay & Morris, 2004; Loynes & Proctor, 2000) has repeatedly shown that reduced accessibility through inadequate opening hours is one of the most important causes of a decline in annual book issues per capita. Furthermore, local authorities are currently reexamining the regimes of opening hours of public services within the city of Ghent to better attune these to the activity patterns of the active citizens. These aspects make our case study relevant and timely to illustrate our method.

2. Method

2.1. Accessibility measure

At the core of our method is an accessibility measure that relies on Burns' (1979) utility-theoretic framework for calculating locational benefit measures of individual accessibility. This framework has attracted increased attention in recent years because it is theoretically appealing and can nowadays straightforwardly be operationalised using geographical information systems (GIS) (Ashiru et al., 2003; Ettema & Timmermans, 2007; Hsu & Hsieh, 2004; Miller, 1999; Neutens et al., 2008; Neutens, et al., 2010a). A central premise in Burns' framework is that an individual's space-time path is constrained by his/her fixed activities, i.e. activities at fixed locations over a specific period of time. Fixed activities are mandatory commitments that are difficult to reschedule or relocate in the short run – if at all. Typical examples of fixed activities are common routine tasks such as professional and educational activities.

For an individual i, let $X(i) = \{x_1, x_2, \ldots, x_n\}$ denote the chronologically ordered set of fixed activities, where each activity x_j has a location $\mathrm{loc}(x_j)$ and a time span $[s_j, e_j]$ from s_j to e_j. Between each pair of subsequent fixed activities x_j and x_{j+1}, there is an amount of space and time available for discretionary activities, denoted as ST_j. Each ST_j is constrained by the compulsory trip from $\mathrm{loc}(x_j)$ at e_j to $\mathrm{loc}(x_{j+1})$ at s_{j+1}. In line with time geography, we will refer to this space-time volume ST_j as a *space-time prism* (Miller, 2005) (Figure 1). Let $H(f) = \{h_1, h_2, \ldots, h_m\}$ denote the chronologically ordered set of opening hour intervals $h_k = [s_k, e_k]$ of a service facility f. Then, the *potential activity window* (PAW) for individual i to participate in a discretionary activity at a facility f between two fixed activities x_j and x_{j+1} and during the opening interval h_k is given by (Figure 1):

$$\mathrm{PAW}(i, f, j, k) = \left[e_j + \mathrm{t}(x_j, f), s_{j+1} - \mathrm{t}(f, x_{j+1})\right] \cap [s_k, e_k] \qquad [1]$$

with $\mathrm{t}(x_j, f)$ the travel time from $\mathrm{loc}(x_j)$ to $\mathrm{loc}(f)$, $\mathrm{t}(f, x_{j+1})$ the travel time from $\mathrm{loc}(f)$ to $\mathrm{loc}(x_{j+1})$.

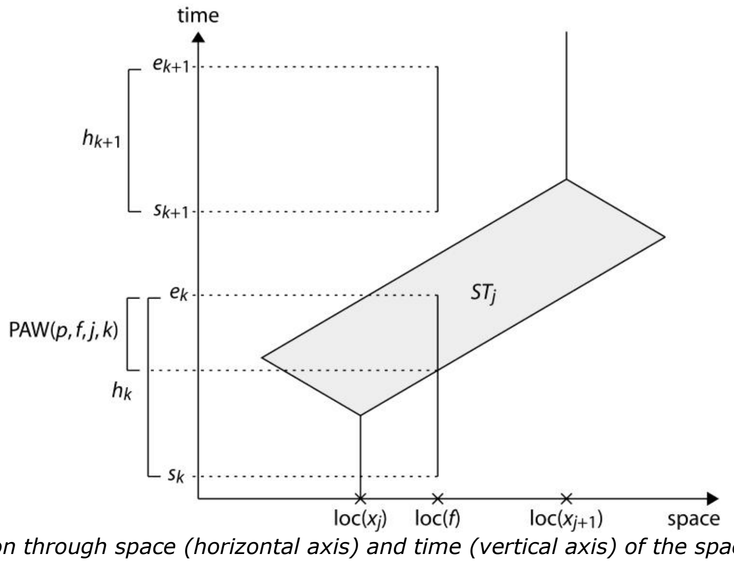


Figure 1. Cross section through space (horizontal axis) and time (vertical axis) of the space-time prism (grey) between fixed activities x_j and x_{j+1} of an individual i, with the indication of the PAW with respect to the opening hour interval h_k of service facility f.

According to earlier specifications by Burns (1979), each individual can be allocated a utility value for participating in an activity at a service facility based on three factors: the facility's attractiveness (i), the potential activity duration (ii), and the travel costs necessary to reach the activity location (iii). Based on [1], we specify the utility value, henceforth termed *locational benefit*, associated with a $\mathrm{PAW}(i,f,j,k) = [s,e]$ as follows:

$$\mathrm{LB}_{\mathrm{PAW}}(i,f,[s,e]) = a_f \cdot (e-s) \cdot \exp\left(-\alpha \cdot \mathrm{t}\left(x_j, f, x_j+1\right)\right) \qquad [2]$$

with a_f the attractiveness of facility f, α the calibration parameter of exponential travel cost decay, and $\mathrm{t}\left(x_j, f, x_j+1\right)$ the travel cost required to travel from $\mathrm{loc}\left(x_j\right)$ via $\mathrm{loc}(f)$ to $\mathrm{loc}\left(x_j+1\right)$.

The locational benefit for an individual i over an *arbitrary time window* (ATW) $[t_1, t_2]$ can then be expressed as:

$$\mathrm{LB}_{\mathrm{ATW}}(i,f,[t_1,t_2]) \ = \ \sum_j \sum_k \mathrm{LB}_{\mathrm{PAW}}\left(i,f,[t_1,t_2] \cap \mathrm{PAW}(p,f,j,k)\right) \qquad [3]$$

To determine the locational benefit accruing to an individual i when multiple facilities are available at the same time, we will consider the aggregated locational benefit (s)he attains when selecting per available time window the facility that yields the highest benefit. This is in line with the potential of each individual to act as a rationale decision maker who is only concerned with the most beneficial alternative. The locational benefit of an individual i over a time window $[t_1, t_2]$ with respect to a set of facilities F is specified as:

$$\mathrm{LB}_{\mathrm{ATW}}(i,F,[t_1,t_2]) = \sum_j \max_f \sum_k \mathrm{LB}_{\mathrm{PAW}}\left(i,f,[t_1,t_2] \cap \mathrm{PAW}(i,f,j,k)\right) \qquad [4]$$

This maximising form seems most appropriate for service facilities that are rather uniform in terms of the services they offer, as is the case for many public opportunities (e.g. libraries). Additive forms (Miller, 1999) on the other hand would be more suitable for opportunities that discern more unique characteristics (e.g. hotels, restaurants and bars). This is because an individual is more likely to find an opportunity that meets his/her preferences when the choice set is larger in the latter case.

2.2. A utilitarian rescheduling of opening hours

Having formally introduced locational benefits to express the accessibility for an individual with respect to a set of service facilities, we will now elaborate a utilitarian method to reschedule the opening hours of a set of service facilities over a given study period in order to maximise the aggregated locational benefit for a population. The utilitarian approach assumes that justice is done when the overall level of accessibility is maximized, regardless of how these benefits are distributed among the population (Khisty, 1996; Scott & Horner, 2008; Young, 1994).

In our approach, the study period at hand (e.g. one week) is subdivided into a discrete sequence of non-overlapping time intervals (e.g. hours). These *minimum time intervals* (MTIs) are the basic temporal units of analysis. We will refer to a MTI during which a service facility is open as a *minimum opening interval* (MOI) and denote it as a pair (facility, MTI). The complete schedule of opening hours of a set of service facilities can be represented as a set of MOIs, henceforth termed a *regime*. Starting from an empty regime *R* (zero MOIs), then, of all possible MOIs not in *R*, the MOI returning the highest additional benefit for the entire population with respect to the benefit of *R*, can be iteratively assessed using [4] and added to *R*. This best-first selection procedure is presented in Algorithm 1.

The algorithm takes as input a population I of individuals i with their fixed activities, a set F of service facilities f, a set C of all possible MOIs of facilities in F over the entire study period, and the number n of requested MOIs in the resulting regime. Obviously, n is limited to the number of MOIs in C. The output is the n-MOI regime (i.e. regime consisting of n MOIs) that yields the maximal aggregated locational benefit, which is returned as well. The algorithm consists of n iterations of two major steps. The first step (lines 3-18) is the nested iteration over all individuals and for each individual over all possible MOIs that are not yet in the regime so far. Each of these MOIs is alternately added to the set of opening hours of the corresponding facility in order to calculate the added benefit of its addition using [4] at lines 11 and 13. Thus, the algorithm keeps track of the added benefit over all individuals of each possible MOI to be added to the regime. The second step (lines 19-28) determines the MOI with the maximal added benefit and adds this MOI to the regime.

Algorithm 1

In	I	set of individuals i
	F	set of service facilities f, with $H(f)$ denoting the set of opening hours allocated to facility f
	C	set of all possible MOIs of facilities in F covering the study period
	n	number of MOIs
Out	R	n-MOI regime (ordered set of n MOIs) with maximal total benefit
	LB_{tot}	total benefit associated with R

Procedure

```
01  SET R to ∅, H(F) to ∅, LB_tot to 0
02  FOR 1 to n
03      SET M to ∅, MOI_max to ∅, LB_max to 0
04      FOR EACH i in I
05          FOR EACH (f, MTI) in C
06              IF NOT (f, MTI) in R THEN
07                  ADD (f, MTI) to H(f)
08                  IF EXISTS LB → (f, MTI, LB) in M THEN
09                      SUBTRACT (f, MTI, LB) from M
11                      ADD (f, MTI, LB + LB_ATW(i, F, MTI)) to M
12                  ELSE
13                      ADD (f, MTI, LB_ATW(i, F, MTI)) to M
14                  END IF
15                  SUBTRACT (f, MTI) from H(f)
16              END IF
17          END FOR
18      END FOR
19      FOR EACH (f, MTI, LB) in M
20          IF LB > LB_max THEN
21              SET MOI_max to (f, MTI)
22              SET LB_max to LB
23          END IF
24      END FOR
25      ADD MOI_max to H(f)
26      ADD MOI_max to R
27      ADD LB_max to LB_tot
28  END FOR
29  RETURN R_max, LB_tot
```

2.3. *An egalitarian rescheduling of opening hours*

The utilitarian n-MOI regime outlined in the previous subsection 2.2 will not necessarily be the most socially equitable regime. This is because the regimes resulting from Algorithm 1 are likely to favour those individuals with fewer space-time constraints (i.e. larger space-time prisms) for whom higher locational benefits are obtained. Given that space-time constraints are unequally distributed across individuals depending on their life cycle, household structure, socio-economic position, employment situation, mobility resources etc. (Neutens et al., 2010a), the utilitarian rescheduling method may introduce certain social disparities in access to services.

To attenuate social disparities, we introduce a rescheduling approach on the basis of the egalitarian principle which aims for an equal treatment of individuals in all respects (Khisty, 1996). To this end, we propose a normalisation of individual locational benefits. An individual's *normalised locational benefit* is defined as the ratio of his/her locational benefit to the total benefit (s)he would achieve in case all his/her space-time prisms are optimally exploited over the study period (i.e. when all service facilities are open for the entire study period). Each normalised benefit is scaled to the 0 to 1 range, whereas the relative proportions of separate locational benefits with respect to the same individual remain unaltered.

The rationale behind the normalisation is that, in the spirit of egalitarism, individuals receive an equal importance in terms of accessibility. However, social equity in accessibility may not be approached as a sole purpose disregarding the absolute level of accessibility. There is an area of tension between the absolute level of accessibility and the equality of its social distribution, worthwhile to explore. We therefore reconsider the approach of 2.2 with normalised benefits so that individuals have equal weight in the iterative selection procedure of opening hours, whereas the procedure still seeks to maximise this benefit. Implementing Algorithm 1 with normalised benefits requires prior computation of the maximum locational benefit per individual (i.e. the denominator of the normalisation ratio), as is pseudocoded in Algorithm 2. In Algorithm 2 (line 7) individuals with zero maximal benefit are excluded to avoid division by zero in the normalisation. In addition, this reduces further computational load and is in line with the purpose of the algorithm, as it would be irrelevant to derive an appropriate regime by considering individuals that cannot benefit from any regime at all. Algorithm 1 can now be applied with normalised benefits by dividing the added benefits in lines 11 and 13 by the individual's maximum benefit returned by Algorithm 2.

Algorithm 2

```
In      I, F, C     see Algorithm 1, H(F) denotes the set of opening hours allocated to facilities in F
Out     LB[ ]       list of benefit values, with LB[i] the maximum benefit of individual i in I
Procedure
01  SET H(F) to C
02  FOR EACH i in I
03     SET LB[i] to 0
04     FOR EACH MTI → EXISTS (f, MTI) in C
05        SET LB[i] TO LB[i] + LB_ATW(i, F, MTI)
06     END FOR
07     IF LB[i] = 0 THEN SUBTRACT i from I END IF
08  END FOR
09  RETURN LB[ ]
```

3. Accessibility of libraries in Ghent: a case study

To illustrate the applicability of the approaches described in section 2, a case study is elaborated. The aim of this case study is to examine to what extent individual accessibility to public libraries in the city of Ghent (Belgium) can be improved and made more equitable by rescheduling a full week regime of opening hours. Input data, computation and results are discussed in detail in the remainder of this section.

3.1. Data

The study area is Ghent (municipal boundary), the third largest city in Belgium and capital of the East-Flanders province (Figure 2). Ghent has about 240,000 inhabitants over an area of almost 160 km². The necessary data sources concerning Ghent's public libraries, their potential visitors, and the surrounding travel environment are described below.

Libraries

Information on the municipal network of public libraries is offered by the official website of Ghent city (http://www.gent.be). The network consists of one centrally located main library and 15 branch libraries dispersed over the city (Figure 2, Table 1). The libraries have a well-structured regime of weekly opening hours with similar schedules for all branch libraries (Table 2). 50 (24%) of the total of 209 opening hours are allocated to the main library, whereas most branch libraries individually account for merely 11 hours. There are no Sunday openings and these will not be considered further to preserve comparative consistency with the current situation. The basic services delivered in each library include the lending of articles (books, comic strips, dvd's, etc.), the consultation of reference works, magazines and informative leaflets, and free surfing on the internet. The main library is by far the most important in terms of service delivery, and it is the sole library with multiple subdivisions. For this case study, we have taken the natural logarithm of a library's collection size as a proxy for its attractiveness in [2] (Table 1). The natural logarithm ensures that attractiveness increases with collection size at a decreasing rate.

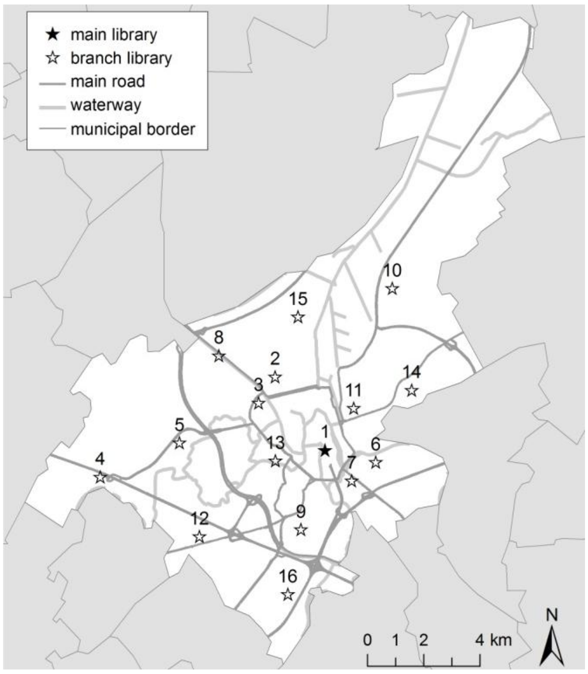


Figure 2. Public libraries in Ghent (2009).

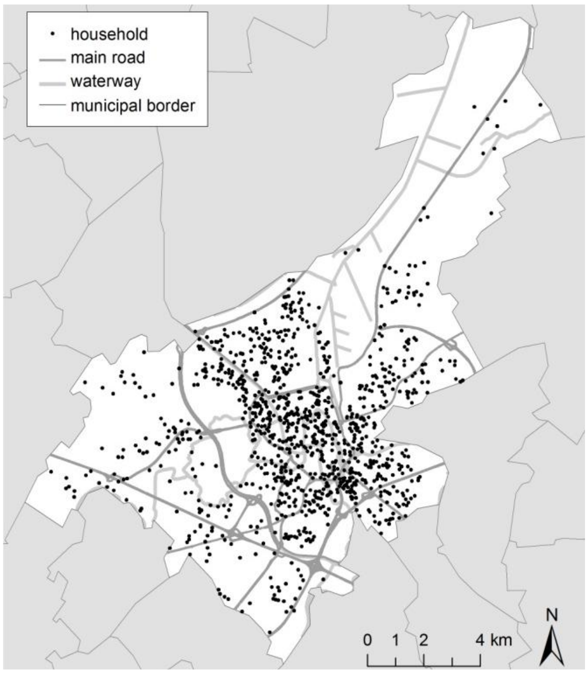


Figure 3. Sampled households in Ghent.

Table 1. Library collection size (2009) and attractiveness estimate.

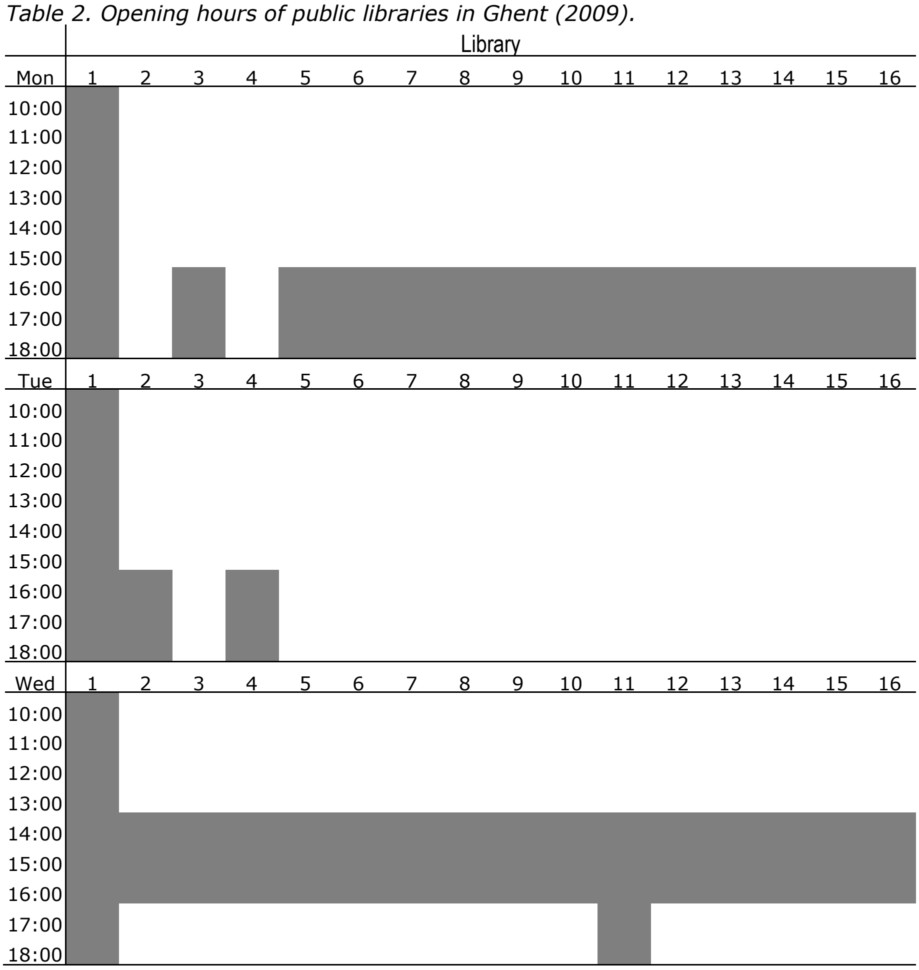
Nr	Name	Collection	Attractiveness
1	Zuid	368 907	12.82
2	Bloemekenswijk	7 387	8.91
3	Brugse Poort	7 669	8.94
4	Drongen-Baarle	7 314	8.90
5	Drongen-Centrum	16 543	9.71
6	Gentbrugge	13 791	9.53
7	Ledeberg	16 765	9.73
8	Mariakerke	15 330	9.64
9	Nieuw Gent	5 837	8.67
10	Oostakker	10 372	9,25
11	Sint-Amandsberg	19 228	9.86
12	St-Denijs-Westrem	9 723	9.18

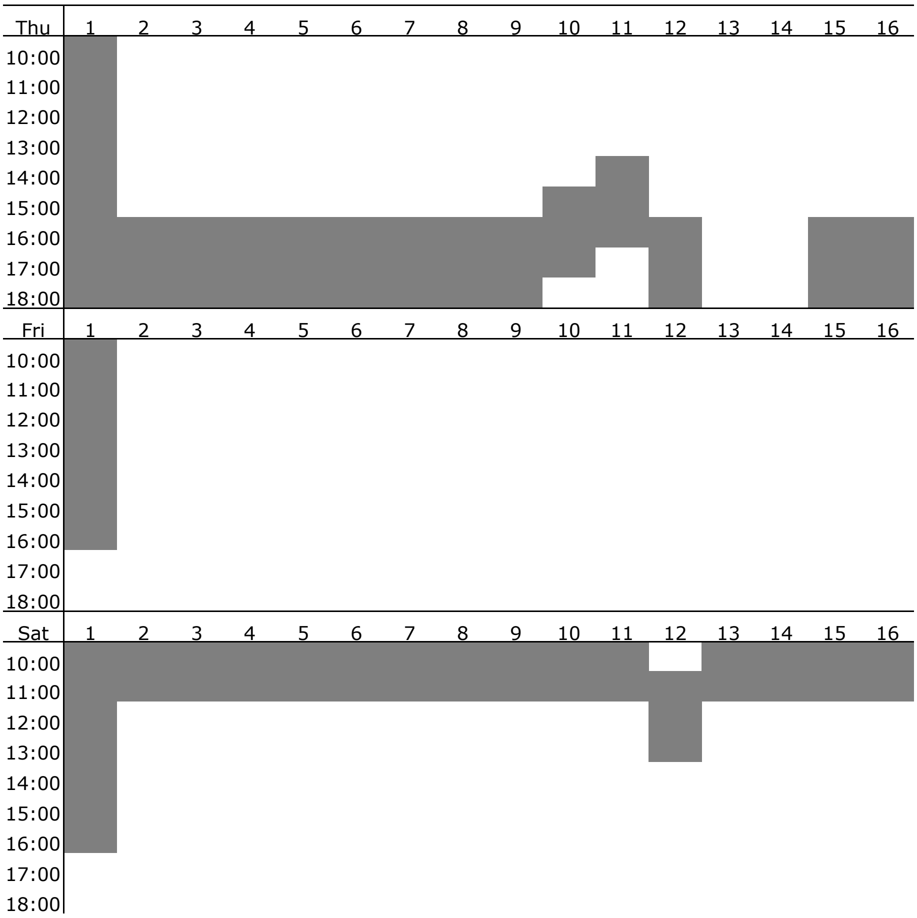
13	Watersportbaan	4 900	8.50
14	Westveld	8 889	9.09
15	Wondelgem	8 057	8.99
16	Zwijnaarde	10 122	9.22

Visitors

The second data source is an activity/travel data set consisting of two-day consecutive diaries of out-of-home activities of Ghent citizens aged five or more. This category of sampled individuals is considered representative for the target constituency of Ghent's municipal libraries. The data set has been collected in 2000 within the scope of the SAMBA project (Spatial Analysis and Modeling Based on Activities). As households have been randomly sampled for this project, the spatial distribution of home locations reflects the actual population density with a sparsely populated industrial and harbour area in the north of Ghent (Figure 3). As the fixity level of activities has not been documented, we have manually extracted fixed activities from the data set and geocoded their reported locations to the street level. To this end, the activities belonging to the purpose categories "work", "school", "pick up/drop off someone" and the like have been considered fixed, given the difficulty to conduct these at other places and times. Individuals sampled at the same day of the week have been grouped under the assumption that their fixed activities are representative for that weekday. In total 5,797 person-days were selected, ranging from Monday to Saturday. Since not all individuals have been sampled over the same period, each weekday has a similar but different number of sampled individuals. To correct for this bias, all individual benefits calculated in this case study have been weighted corresponding to the number of person-days within the weekday concerned.

Table 2. Opening hours of public libraries in Ghent (2009).





Travel costs

The third source of information concerns the travel environment. All travel costs required for the computation of benefits ([1-2]) have been estimated as travel times of temporal shortest paths calculated with ESRI’s ArcGIS Network Analyst (9.3.1) based on TeleAtlas® MultiNet™ (2007.10) road network data.

We have considered the two predominant travel modes in Ghent: car and bicycle. To account for these mobility resources, it has been assumed that adult car owners with a driving license travel by car, whereas others travel by bicycle. Car travel times have been corrected for congestion by means of a congestion factor based on road class, weekday, and time of day (Table 3). This congestion factor has been derived from average travel times recently reported by Maerivoet and Yperman (2008) under the authority of the Federal Government Service for Mobility and Transport. To obtain the corrected travel time estimates, temporal shortest paths have been segmented according to road class to multiply each segment’s travel time by the corresponding congestion factor. The corrected estimated time of an entire car trip then equals the sum of the corrected segment travel times.

Due to shortage of information on specialised bicycle facilities (e.g. exclusive non-motorised paths) in Ghent, a compromise approach has been adopted for the computation of bicycle travel times. The approach consisted of excluding highways and other exclusive motorways from the transport network and allowing travel directions for non-motorised travellers. Travel times were estimated as the product of the shortest path distance and an average cycling speed of 15 km/h. Although these travel time estimations may be refined in future research, we believe they are adequate for the exposition.

To calculate individual benefits, the travel cost component in [2] is computed as the detour travel time, i.e. the extra travel time that is experienced by the individual when making the detour to the concerned facility in between two fixed activities instead of making the direct travel between both activity locations. The decay parameter α of the negative exponential deterrence function in [2] has been estimated by means of the observed cumulative distribution of travel times of trips of individuals visiting a service. Similar estimates are obtained for car and bicycle travels, respectively α_{car} = 0.081 and α_{bicycle} = 0.092.

Table 3. Congestion factors according to weekday, day time and road class.

		Morning 6 AM – 9 AM	Midday 9 AM – 4 PM	Evening 4 – 7 PM	Night 7 PM – 6 AM
Weekday	Highways and ring roads	1.062	1.057	1.065	1.029
	Regional and main connection roads	1.202	1.117	1.249	1.117
	Other paved roads	1.118	1.094	1.196	1.094
Weekend	Highways and ring roads	1.013	1.000	1.026	1.007
	Regional and main connection roads	1.000	1.025	1.037	1.025
	Other paved roads	1.060	1.000	1.036	1.000

3.2. Computation

Based on an implementation of the algorithms in section 2, opening hour regimes for the public libraries in Ghent have been computed according to both the utilitarian and egalitarian approach. For consistency, an MTI of one hour and a study period from Monday to Saturday with potential MOIs ranging from 8:00 A.M. to 8:00 P.M. per day per facility have been postulated as fixed input parameters for the algorithms. For each regime, we have calculated the average locational benefit over all potential visitors and the Gini coefficient over all individual normalised locational benefits. The Gini coefficient is a widely used measure for statistical dispersion ranging from 0 (complete equality) to 1 (complete inequality). For this case study, it has been calculated as:

$$\frac{\sum_n^i \sum_n^j \left| b_i - b_j \right| \cdot w_i \cdot w_j}{2 \cdot \sum_n^i w_i \cdot b_i}$$

with n the number of individuals i, b_i the normalised locational benefit of i, and w_i the weight of i (according to weekday, see 3.1).

3.3. Results

Figure 4 shows the average locational benefit and Gini coefficient for the utilitarian and egalitarian regimes. To enable a detailed comparison with the current regime consisting of 209 opening hours, the 209-hour regimes of both approaches are presented in Table 4. The opening hours are gray-scaled into five classes of equal length depending on the order in which they have been selected in the algorithm.

Despite the different philosophy behind both approaches, a high similarity between the utilitarian and the egalitarian regimes can be observed. For both types, the average benefit shows a steep increase up till the 72-hour regime. This is due to the fact that there are only 72 hours in the study period (Monday to Saturday from 8:00 A.M. to 20:00 P.M.). Hence, the study period is first covered entirely by only one library per hour, before having two or more libraries opened simultaneously (Table 4). Consequently, the most effective way to improve library access in Ghent by rescheduling the opening hours will be to extend the current range of opening hours and to reschedule concurrent hours to cover the extended range. In comparison with the current regime, a regime with the same average benefit can already be obtained with merely 46 opening hours or 22% of the current occupation (Figure 4). In this case study, the first 72 opening hours in both regimes are all allocated to the main library (Table 4), which may be attributed to its higher attractiveness, its central location with respect to the location of households, and its well accessible position within the road network of Ghent. In brief, extending the opening hours of the main library seems an effective and equitable strategy to improve library access for citizens in Ghent. An important bend is observed in both curves at the point of full coverage (72 hours). From that point on all additional opening hours have to compete with the main library, producing only limited additional benefits.

The point of full coverage is also significant in terms of equity: for both approaches, the Gini coefficient decreases with about 70% in between the 1- and 72-hour regime (4), whereas it merely decreases with 10% in the ensuing regimes. As expected, the egalitarian regimes yield lower Gini coefficients and are thus more equitable with respect to potential visitors, although this is only significant for the first 72 regimes. In comparison with the current regime, both the utilitarian and egalitarian 209-hour regimes are about 12% more equitable. From the high similarity in both regimes, we may conclude that, in this case study, collective and individual interests go hand in hand (e.g. allocating many opening hours to the main library is highly beneficial for the entire population, but is also relatively beneficial for many individuals separately).

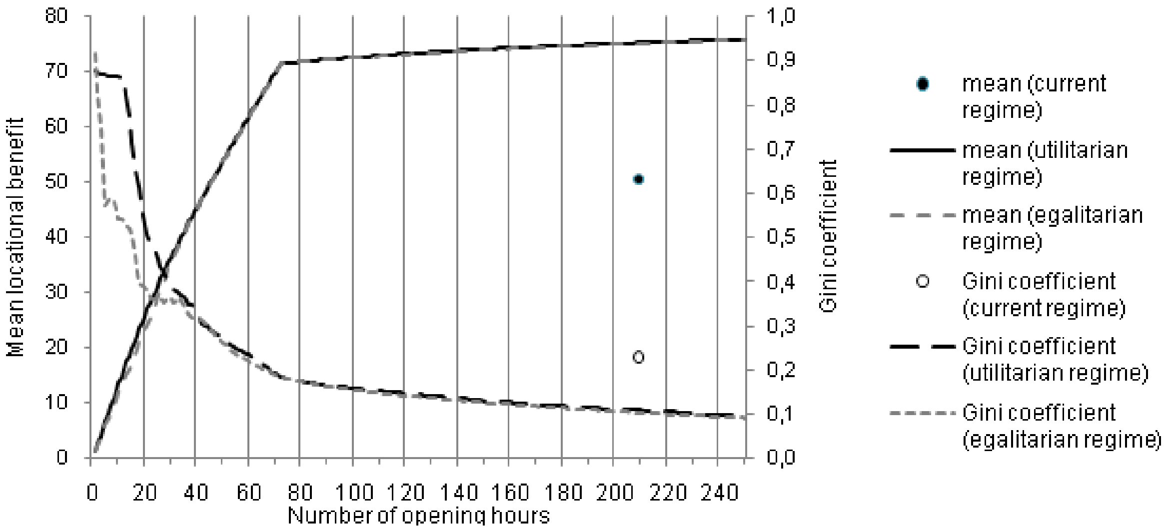


Figure 4. Mean locational benefit and Gini coefficient for the current, the utilitarian, and the egalitarian regimes.

Let us take a more detailed look at both 209-hour regimes (Table 4). They have 159 hours (76%) in common, for which the ranks of iterative selection are strongly correlated (0.84 Spearman's rank correlation). Nevertheless, there are some important differences between both regimes. In the utilitarian regime, the hours of the main library on Saturday are selected first, i.e. they yield the highest locational benefits. This is because people tend to have less fixed commitments on Saturday compared to weekdays giving them more temporal flexibility to visit a library. Apart from the main library, hours are allocated to only six branch libraries. The most important branches are 2, 3 and 11, which can be explained by their central position vis-à-vis the home locations of the sampled individuals and the transportation network, and the attractiveness for 11 (Figure 2 and 3; Table 1). The egalitarian regime on the other hand, allocates opening hours to 11 different branch libraries. Especially the hours between 4 p.m. and 8 p.m. are scattered among multiple libraries, except on Saturday. This may be related to the potential of library visits of commuters travelling all over the city after work or school, before returning home. That this effect is less pronounced in the utilitarian regime is because commuters, due to their relatively more restricted time budgets, achieve less absolute benefits giving them less influence on the determination of the utilitarian regime. With 46 hours, branch 3 is given equal importance as in the utilitarian case, though branches 2 and 11 are relatively less important in the egalitarian regime.

Conversely, more hours are allocated to the peripheral branches 5, 8, 10, 12, 14, and 15. This is due to the fact that the egalitarian regime better responds to local demands as it seeks to improve the accessibility of each potential visitor individually rather than to maximise the overall accessibility. Libraries 4, 9, 13, and 16 have not been allotted any opening hours at all in both regimes. Compared to other libraries, they do not offer sufficient benefits, partly due to their low attractiveness (4, 9, 13) and/or peripheral positions (4, 16).

Table 4. Utilitarian and egalitarian 209-hour regimes with indication of the rank of each allocated hour in the iterative selection process. Allocated hours are gray-scaled according to an equal interval classification of the selection order using five classes.

Utilitarian regime

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	37		125								203					
9:00	52		138													
10:00	60		141													
11:00	58		134													
12:00	42		113								208					
13:00	43		126													
14:00	48		127								206					
15:00	44		122								173					
16:00	30		90								143					
17:00	25		83					201		186	120					
18:00	18		82					187		178	117					
19:00	13		81					183		166	104					
Tue	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	39		158								172					
9:00	67		177								202					
10:00	70		180								205					
11:00	69		176								209					
12:00	59		159								182					
13:00	54		181								163					
14:00	53		207								160					
15:00	50		184								149					
16:00	31		140								130					
17:00	26		100								129					
18:00	21		88								119					
19:00	15		89								115					
Wed	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	35		139								188					
9:00	51		157													
10:00	57		154													
11:00	55		153													
12:00	38		118								191					
13:00	33		109								171					
14:00	34	106									168					
15:00	32	94									164					
16:00	28	87									161					
17:00	23	84									156					
18:00	17	80									144					
19:00	14	77			179						136					
Thu	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	41		91													
9:00	68		112													
10:00	71		105													
11:00	72		110													
12:00	62		92													
13:00	64		95													
14:00	66		107													
15:00	56		93													

Egalitarian regime

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	35		138								209					
9:00	62		177													
10:00	70		179													
11:00	68		173													
12:00	43		137													
13:00	47		151													
14:00	56		159													
15:00	51		152								200					
16:00	37		107								126					
17:00	12							85		160	94					
18:00	6				205		176	77		153	93					
19:00	2				194		154	76		80	110				206	
Tue	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	20		207								178					
9:00	57															
10:00	72															
11:00	69															
12:00	53		197													
13:00	55										191					
14:00	59										186					
15:00	45										161					
16:00	30	140									120					
17:00	11		86		201						111					
18:00	8	163			175			87			98					
19:00	1	83			100		164	195		183	92	199				
Wed	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	21		136								189					
9:00	42		187													
10:00	58		192													
11:00	63		188													
12:00	41		148													
13:00	39		131													
14:00	40		143								203					
15:00	38		135								193					
16:00	31	106									170					
17:00	15	91			190						156					
18:00	10	79			134						112					
19:00	4	78			105					182	97					
Thu	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
8:00	19		104											198		
9:00	52		146													
10:00	65		144													
11:00	71		145													
12:00	48		117													
13:00	60		133													
14:00	64		141													
15:00	50		129													

16:00	36		85								169					
17:00	27		76											152	174	
18:00	22		74								150				170	
19:00	19		73								145				167	
Fri	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
8:00	40	123									192					
9:00	61	148														
10:00	65	142														
11:00	63		151													
12:00	47		128													
13:00	46	131														
14:00	49	133														
15:00	45		116													
16:00	29	86			175						155					
17:00	24		79		162						137				165	
18:00	20	78			147						135					
19:00	16	75			146						132					
Sat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
8:00	3	98									185					
9:00	10	111									198					
10:00	11	124									197					
11:00	12	121									193					
12:00	9	114									189					
13:00	6	97									194					
14:00	8	101									204					
15:00	7	108									199					
16:00	5	99									200					
17:00	4	102									190					
18:00	2	103									196					
19:00	1	96									195					

16:00	36		95							147						
17:00	13		82											102	185	
18:00	7		75		167					96				168	181	
19:00	3		73		119					89	155				166	
Fri	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
8:00	27	123												132		
9:00	61		171													
10:00	67		169													
11:00	66		180													
12:00	46		149													
13:00	49		158													
14:00	54		162													
15:00	44		130													
16:00	34		90		204									139	184	
17:00	14		84		150	208				101				174	165	
18:00	9		81		142					157	99				172	
19:00	5	74			103	202				128				88	196	
Sat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
8:00	17	108														
9:00	25	114														
10:00	32		127													
11:00	33		125													
12:00	28		121													
13:00	24		113													
14:00	29	122														
15:00	26	124														
16:00	23	116														
17:00	22	118														
18:00	18	115														
19:00	16	109														

4. Conclusion

In contrast to the lion's share of accessibility literature that has dealt with the spatial organisation of public service delivery, this paper has focused on the ways in which accessibility can be improved by amending the opening hours of service facilities in an equitable way. To this end, two different rescheduling approaches, based on homonymous equity principles, have been put forward: a utilitarian and egalitarian approach. Both have been implemented and applied in an empirical case study. While both approaches improve the accessibility and equity level generated by the current regime of library opening hours significantly and to a comparable degree, the egalitarian regime results in more equity for regimes of fewer (< 72) opening hours. The egalitarian approach also tends to favour service facilities in peripheral areas more than the utilitarian regime.

The contribution of this paper to the academic literature is unique in that it has not only demonstrated explicitly to what extent individual space-time accessibility is influenced by opening hours, but it also proposes a space-time accessibility approach to derive suitable regimes of opening hours from scratch by employing two equity perspectives. As well, the space-time accessibility approach has relevance for policy as it allows policymakers to make *ex-ante* and *ex-post* evaluations of reconfigurations of the opening hours of services. This is important in view of the growing awareness of the impact of urban time policies on people's quality of life. In Ghent as well as in many other European cities, local authorities are currently re-examining the historically emerged opening hours of their municipal services in order to better attune these to the temporal needs and desires of the citizens, especially those who have multiple competing claims on their time (Mareggi, 2002). This paper provides important initial insights into how individual accessibility is affected by the temporal structure of urban systems.

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