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Research highlights

- Individual accessibility to services is influenced by opening hours of facilities.
- We propose a method to determine opening hours that maximise accessibility.
- Example case on rescheduling government office opening hours in Ghent (Belgium).
- Substantial improvements in accessibility can be made by rescheduling opening hours.

1. Introduction

In recent years there has been increasing awareness about the impact of urban time policies on people's quality of life. Especially in Europe, several projects have been launched, seeking to improve the temporal organization of public service provision (Mückenberger and Boulin, 2002; Boulin, 2006). These temporal policies concentrate on the ways in which the opening hours of urban service delivery can be better attuned to the activities and travel patterns of citizens. Due to the erosion of collectively maintained time rhythms and the fragmentation of activities in space and time, people's time use patterns are becoming increasingly individualized and intensified (Breedveld, 1998; Couclelis, 2004; Glorieux et al., 2008). Public service administrations try to respond to these trends by rescheduling the opening hours of public service facilities in order to increase the accessibility of services to particular constituencies and to improve the quality of urban life. As such, temporal planning is increasingly becoming a critical aspect of city government (Boulin, 2005).

Micro-economists have extensively studied the strategic aspects of opening hour decisions, but have primarily focused on the provision of private services with price competition. A number of authors have concentrated on the implications of changes to temporal regulations and the liberalization of service hours (e.g. Clemenz, 1994; Thum and Weichenrieder, 1997; Rouwendal and Rietveld, 1999; Jacobsen and Kooreman, 2005). Others have sought to derive the socially optimal service hours by specifying utility-theoretic models that maximise both consumer surplus and industry profits (Shy and Stenbacka, 2006, 2008). While insightful, these studies fail to address the heterogeneity of consumers' space-time activity patterns and travel behaviour. This is to be considered a critical inadequacy in the context of public service provision because, in the absence of price competition, consumer surplus primarily relates to consumers' accessibility benefits at public service locations and thus indirectly to their space-time behaviour (Miller, 1999). Transport geographers have long since stressed the importance of individual-specific space-time constraints on activity participation when evaluating individual accessibility to urban services. In particular, a large number of researchers have shown that individual accessibility is shaped by *inter alia* an individual's mandatory activity schedule, trip chaining behaviour and transport mode availability (see e.g. Weber and Kwan, 2002; Kim and Kwan, 2003; Kwan and Weber, 2008; Schwanen and De Jong, 2008; Neutens et al., 2010c, b; Neutens et al., 2010d).

The present paper examines how such individualized aspects of accessibility can be considered in the determination of optimal opening hours of public services in terms of accessibility. Rather than to look for the most cost-efficient regime of opening hours, we want to examine the ways in which opening hours can be amended to improve individual accessibility. More specifically, a novel, sample-based geocomputational procedure is developed that determines the collectively optimal regime of opening hours of a network of service facilities by maximising the overall accessibility of citizens. The proposed procedure can aid urban service deliverers, policymakers and urban planners in defining optimally accessible timetables of service provision. It is applied in a case study of government offices in the city of Ghent, Belgium. These government offices take care of the administration concerning marriage, cohabitation, birth, death, residential moves, elections, and so on. The case study is particularly timely because local authorities are currently seeking to reschedule and curtail the historically emerged opening hours of the government offices and to tailor these to the daily activity patterns of the citizens.

The paper is organized as follows. The next section reviews prior research on the relationships between space-time demands, opening hours and accessibility, and identifies relevant research gaps. Section 3 presents a measure of the space-time accessibility of public services based on the concept of locational benefits, and discusses a method to optimise service opening hours in terms of accessibility. The methodology is illustrated in a case study. Data and data preparation are described in section 4.1 and 4.2. Results are reported in section 4.3. Finally, we conclude with the major findings and outline some avenues for future work.

2. Space-time demands, opening hours and accessibility

In the past two decades, lack of time has become an important social issue that is felt in virtually all strata of society (Glorieux et al., 2008). More and more people seem to have become caught up in a 'temporal treadmill' (Law and Wolch, 1999; Jarvis, 2005; Szollos, 2009), experiencing competing claims on their time-space resources by different responsibilities. Negative effects of continued time shortage on wellbeing can be profound and can include work-life imbalance, lower family satisfaction and such health issues as stress, over-fatigue and burn-out (Pelfrene et al., 2001; Ritsema van Eck et al., 2005). People's experience of time shortage seems to be exacerbated by malfunctioning urban infrastructures, exemplified by road congestion and delays in public transport systems. Further, transport and communication technologies, which are often believed to accelerate activity patterns and make them more efficient (e.g. by reducing travel time), seem to have complex and contradictory effects in practice. While technologies such as the Internet and the mobile phone imply that people can be reached more easily anywhere, anytime and that home-work boundaries become more blurred for many (Schwanen and Kwan, 2008), transport infrastructures intended to speed up daily travel are often used to travel longer distances rather than shorter times (Harris et al., 2004; Metz, 2008). As a result, individual activity patterns are frequently stretched out across multiple geographical scales, exceeding the administrative boundaries of cities and regions.

Activity patterns have also become more fragmented over time. Recent years in particular have witnessed a tendency towards a desynchronisation of social times, and more diverse and complex activity schedules due to the increase of temporal constraints imposed by daily obligations (e.g. paid labour, childcare, etc.) and limited mobility resources. Given the large and growing number of women entering the European labour market and the concomitant decay of the traditional male breadwinner model, scheduling incompatibilities are emerging most strongly within dual-earner families – families with young children in particular – who are juggling employment, housework, care-giving and leisure activities (e.g. Kwan, 1999; Jarvis, 2005; McDowell et al., 2006; Schwanen, 2007).

The above and related developments imply that the demand for urban services fluctuates and shows irregular patterns over time, and that individual accessibility can no longer be measured straightforwardly in terms of physical proximity to the residence or workplace (Weber and Kwan, 2003). Rather, accessibility has become a matter of connectivity, which implies that access to places and services not only depends on spatial proximity but also on the tense interface between individual daily time schedules and the temporal rhythms of the city.

The increasing importance of connectivity in relation to time problems is currently challenging the efficiency of traditional planning methods such as zonal land-use plans which are largely focused on improving accessibility on the basis of stationary populations within administrative boundaries (Zandvliet et al., 2008). Recently, however, a number of scholars have expressed their concern about the a-temporal nature of spatial planning policies and have called for more attention to the distributional effects of temporal practices (see e.g. Hajer and Zonneveld, 2000; Moccia, 2000; Nuvolati, 2003; Healey, 2004; Deffner, 2005; Zandvliet and Dijst, 2005). Their concern develops in tandem with a growing number of initiatives in European cities for harmonizing the time structures of urban environments with the needs and the desires of the inhabitants (for overviews see e.g. Mückenberger and Boulin (2002); Boulin (2006)).

While interest in temporal planning is starting to grow, only few studies have been carried out about the ways in which opening hours can be amended to enhance individual accessibility to services and to foster the quality of life in cities. Research that has made *ex-ante* and *ex-post* evaluations of temporal regimes of opening hours by means of accessibility measures is virtually non-existent. This may in part be attributed to the paucity of accessibility measures that can adequately capture the temporal dimension of individuals' mobility patterns. The majority of accessibility measures proposed to date does not explicitly consider the potential temporal mismatch between individuals' mandatory activity schedule and the opening hours of services.

An exception to the neglect of temporal connections in accessibility research lies in the strand of literature that has evolved around time geography. Time geography (Hägerstrand, 1970) is a conceptual framework for analyzing spatiotemporal activity patterns and individual accessibility on the basis of a set of space-time constraints. The nature of these constraints is threefold: *(i) capability constraints* are linked with physiological capabilities such as the need or wish to sleep and eat, *(ii) coupling constraints* refer to the need to join other people or material artefacts in space-time, and *(iii) authority constraints* are imposed by laws, norms and regulations such as the opening hours of public services and the timetables of public transport. A key concept within time geography is the *space-time prism* which delineates all possible space-time points that an individual can reach within a given time budget (i.e. the time available for travel and discretionary activity participation between two mandatory activities). The spatial footprint of the space-time prism is called the *potential path area*.

Relying on these time-geographical concepts, various so-called space-time accessibility measures (STAMs) have been proposed that incorporate the performance of the transport network (Miller, 1991; Kwan, 1998; Neutens et al., 2008b; Miller and Bridwell, 2009; Kuijpers et al., 2010). Spurred on by the developments in geographical information systems (GIS) and the availability of disaggregate travel data, the use of network-based STAMs has developed rapidly in the past decade. Within the STAM tradition, at least three studies are important for evaluation of accessibility along the temporal dimension. Weber and Kwan (2002) have calculated various STAMs for 200 individuals in Portland (OR, USA), such as the number of accessible opportunities and the total length of accessible road segments, and have shown that ignoring the effects of traffic congestion and opening hours of opportunities may produce spatially uneven reductions in individual accessibility. Their work has been continued in the ethnographic space-time accessibility analysis by Schwanen and De Jong (2008) who have demonstrated that extending the opening hours of childcare centres can help to improve the work-life balance of dual-earner families. Finally, Neutens et al. (2010c) have shown that individuals with certain personal and household attributes are affected differently by changes to the temporal regime of public service facilities.

While previous research has clearly foregrounded the ramifications of opening hours for individual accessibility, no attempt has been made thus far to explore the ways in which opening hours can be amended to achieve a higher accessibility of urban services. In what follows, we will extend accessibility research in this direction.

3. Method

3.1 Measuring accessibility

The point of departure of our method is an accessibility measure that takes into account the spatial and temporal dimensions of people's daily activity paths. The measure presented here is based on Burns' (1979) utility-theoretic framework that assesses accessibility in terms of the benefits accruing to individuals at particular activity locations – henceforth termed *locational benefits*. Burns' framework has been extended to transport networks and reconciled with consumer surplus approaches by Miller (1999). Ever since, the approach has received increased attention in the transport modelling field, which is exemplified by the various extensions to the framework that have been proposed in recent years, including Ashiru et al. (2003), Hsu and Hsieh (2004), Ettema and Timmermans (2007), and Neutens et al. (2008a; 2010a).

A central assumption of the Burns/Miller framework is that, when seeking to perform a discretionary activity, individuals are both spatially and temporally constrained by a set of fixed activities that bind them to particular places at specific times of the day (Cullen and Godson, 1975; Schwanen et al., 2008). Fixed activities are mandatory commitments that are difficult to reschedule in the short run and include such activities as paid labour and fetching children.

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 (Figure 1). 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 the *space-time prism* (Miller, 2005).

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:

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

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 $\mathrm{loc}(x_{j+1})$.

[insert Figure 1 here]

A $\mathrm{PAW}(i, f, j, k)$ is located between two fixed activities of i and within the opening hours of f. Each PAW can be assigned a utility value expressing the benefit an individual enjoys from participating in an activity at a service facility over the time span of the PAW. For a given $\mathrm{PAW}(i, f, j, k) = [s, e]$, this utility value, henceforth termed *locational benefit*, can be specified as:

$$\mathrm{LB}_{\mathrm{PAW}}(i, f, [s, e]) = B_A(a_f) \cdot B_D([s, e]) \cdot B_C(t_f) \qquad [2]$$

with a_f attractiveness of service facility f;
$B_A(a_f)$ benefit resulting from attractiveness a_f;
$B_D([s, e])$ benefit resulting from the activity duration$[s, e]$;
t_f travel cost to facility f;

$B_C(t_f)$ disutility resulting from travel cost t_f.

A locational benefit measures the benefit that an individual derives from participating in an activity at a certain facility as a function of the facility's attractiveness, the duration of the activity and the physical separation with this facility. To determine the different components in eq. [2], we follow earlier specifications by Burns (1979). For the attractiveness and activity duration components, we use a simple linear function to express that benefits increase proportionately to the attractiveness of and the activity duration at a service facility. The advantage over other functional forms (e.g. a positive power function) is that the linear function does not require complex parameter estimation procedures and dedicated data collection methods. For generality, a minimum required activity duration threshold will be left unspecified; this and other refinements (such as delay times) should be accommodated in future work. The multiplicative functional form of eq. [2] ensures that an individual will not derive any utility if a service facility is not attractive or if an individual cannot spend time at the service facility. For the disutility component associated with the travel costs, we adopt a negative exponential function with parameter α. This function implies that the willingness to travel to services decays most rapidly at low travel costs. Since the negative exponential form declines more gradually relative to power functions, it is better suited to express travel impedance for shorter trips such as those to the government offices considered in our case study (Iacono et al., 2009). Incorporating the above assumptions in eq. [2] yields:

$$\mathrm{LB}_{\mathrm{PAW}}(i, f, [s, e]) = a_f \cdot (e - s) \cdot \exp\left(-\alpha \cdot t_f\right) \qquad [3]$$

The travel cost t_f in eq. [3] can be calculated as the detour travel costs $\mathrm{t}(x_j, f, x_j + 1)$ for i to travel to f in between the first and the second fixed activity instead of travelling directly between both fixed activities:

$$\mathrm{t}(x_j, f, x_j + 1) = \mathrm{t}(x_j, f) + \mathrm{t}(f, x_j + 1) - \mathrm{t}(x_j, x_j + 1) \qquad [4]$$

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

$$\mathrm{LB}_{\mathrm{ATW}}(i, f, [t_1, t_2]) \ = \ \sum_j \sum_k \mathrm{LB}_{\mathrm{PAW}}\big(i, f, [t_1, t_2] \cap \mathrm{PAW}(p, f, j, k)\big) \qquad [5]$$

Based on eq. [5], we can specify the locational benefit of a network of service facilities to an individual over a given time interval. When considering public facilities that offer highly comparable services – as is the case for the government offices (see further in section 4) – an individual may not benefit from having a larger set of facilities to choose from. In other words, it is assumed that an individual is a rational decision maker who patronizes the service facility that yields the largest locational benefit. Therefore, when calculating an individual's accessibility to a network of facilities, we will assume that an individual maximises the locational benefits over the available facilities during the considered ATW. More formally, the accessibility of a network of service facilities to individual *i* over an ATW $[t_1, t_2]$ is specified as:

$$\mathrm{LB}_{\mathrm{ATW}}(i, F, [t_1, t_2]) = \sum_j \max_f \sum_k \mathrm{LB}_{\mathrm{PAW}}\big(i, f, [t_1, t_2] \cap \mathrm{PAW}(i, f, j, k)\big) \qquad [6]$$

For clarification, a simple example of how a locational benefit is calculated over a time interval is given in the box below.

<u>Example</u>

Consider a person *i*, for whom we would like to assess his/her locational benefit $\mathrm{LB}_{\mathrm{ATW}}(i, f, M)$ over the time interval M from 8.00 AM to 9.00 AM with respect to the facility *f*. Suppose that *f* is opened over a time interval h_k from 8.00 AM to 12.00 AM, and that *i* has two fixed activities x_j and x_{j+1} with x_j ending at 8.10 AM and x_{j+1} starting at 10.10 AM. Suppose that it takes 25 minutes to travel from x_j to x_{j+1}, 15 minutes to travel from x_j to *f*, and 20 minutes to travel from *f* to x_{j+1}. Then, from eq. [1] it follows that $\mathrm{PAW}(i, f, j, k) = [8.25\ \mathrm{AM}, 9.50\ \mathrm{AM}]$, of which 35 minutes are within M. We then calculate the locational benefit $\mathrm{LB}_{\mathrm{ATW}}(i, f, M)$ of *f* to *i* over M using eq. [3], [4] and [5] as

$a_f \cdot (35) \cdot \exp(-\alpha \cdot (15+20-25))$.

3.2 Optimising opening hours in terms of accessibility

Having introduced a measure for evaluating the accessibility of a network of service facilities to a population of individuals over a time interval, we now propose a method for identifying the opening hours that would generate the highest total accessibility for a given population. It should be noted that we will only seek to optimise along the temporal dimension of service delivery; spatial relocations of service facilities will not be considered in this paper (i.e. facility locations will be considered fixed during the optimisation procedure).

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 an 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), 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 eq. [6] 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 total locational benefit, which is returned as well. The algorithm consists of two major nested iterations. The inner iteration (lines 5-16) runs through all remaining MOIs in the study period that are not yet included in the optimal regime so far. Each of these MOIs is alternately added to the set of facility opening hours in the regime in order to assess the total locational benefit of its addition by cumulating all individual totals using eq. [6] at line 9. From this inner iteration, the algorithm holds back the MOI whose addition returns the highest total benefit and adds it to the regime in the outer iteration (lines 2-19). The latter is done until the regime contains the requested number of MOIs.

Algorithm 1 Computational procedure to determine the optimal *n*-MOI regime

In	I	set of individuals i
	F	set of service facilities f, with $H(F)$ denoting the set of MOIs allocated to facilities in 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 locational benefit
	LB_{tot}	total benefit associated with R

Procedure

01 SET R to $\emptyset$, $LB_{tot} = 0$
02 FOR 1 to n
03   SET $H(F)$ to R
04   SET MOI_{max} to $\emptyset$, $LB_{max} = 0$
05   FOR EACH (f, MTI) in SUBTRACT R from C
06         $LB_{add} = 0$
07   ADD (f, MTI) to $H(F)$
08   FOR EACH i in I
09             $LB_{add} = LB_{add} + \mathrm{LB}_{\mathrm{ATW}}(i, F, MTI)$
10   END FOR
11   IF $LB_{add} > LB_{max}$ THEN
12                 $LB_{max} = LB_{add}$
13   SET MOI_{max} to (f, MTI)
14   END IF
15   SUBTRACT (f, MTI) from $H(F)$
16   END FOR
17   ADD MOI_{max} to R
18     $LB_{tot} = LB_{tot} + LB_{max}$

END FOR
RETURN R_{max}, LB_{tot}

At this stage we are able to derive the optimal n-MOI regime in terms of total accessibility. However, since no conditions have been specified concerning the internal consistency of a regime, it may well be that a regime consists of combinations of non-contiguous MOIs scattered across the study period, which may be impracticable and undesirable to implement by local authorities. In an attempt to derive the n-MOI regime that accounts for continuity of service delivery, we propose a second algorithm using a penalty and a reward parameter, denoted p and r respectively. The idea is that the locational benefits for an added MOI have to be valued higher (multiplied by r) when an MOI connects with one of the previously selected MOIs of the same facility, whereas they have to be devaluated (multiplied by p) if the MOI is not temporally adjacent with a yet included MOI. This extended approach has been pseudo-coded in Algorithm 2.

Although it would be straightforward to choose symmetric (i.e. inverse) values for p and r, i.e. $p = r^{-1}$, we have intentionally introduced these as two different parameters, because they have different effects on the allocation of MOIs across facilities. On the one hand, rewarding contiguous opening hours (r > 1, p = 1) will favour a regime consisting of contiguous opening hours for a limited set of facilities. Penalising (r = 1, p < 1), on the other hand, will favour a regime with contiguous opening hours for multiple facilities.

Both parameters can be adjusted by policymakers at will in order to derive meaningful regimes. It should be noted, however, that temporal contiguity may come at the expense of accessibility: the more contiguity is aimed for (i.e. the more r and p deviate from 1), the less optimal a resulting regime may be in terms of the number of people who can access the evaluated facility or facilities.

Algorithm 2 Computational procedure to determine the (sub)optimal connected *n*-MOI regime

In	*I*, *F*, *C*, *n*	see Algorithm 1
	p	penalty factor
	r	reward factor
Out	*R*	connected *n*- MOI regime (ordered set of *n* MOIs) with (sub)optimal total locational benefit
	LB_{tot}	total benefit associated with *R*

Procedure

```
SET R to ∅, LB_tot = 0
FOR 1 to n
    SET H(F) to R
    SET MOI_max to ∅, LB_max = 0
    FOR EACH (f, MTI) in SUBTRACT R from C
        LB_add = 0, q = 1
        ADD (f, MTI) to H(F)
        IF ADJACENT(f, MTI, R)* THEN
            q = r
        ELSE
            q = p
        END IF
        FOR EACH i in I
            LB*_add = LB*_add + q . LB_ATW(i, F, MTI)
            LB_add = LB_add + LB_ATW(i, F, MTI)
        END FOR
        IF LB*_add > LB*_max THEN
                LB*_max = LB*_add
                LB_max = LB_add
                SET MOI_max to (f, MTI)
         END IF
         SUBTRACT (f, MTI) from H(F)
    END FOR
    ADD MOI_max to R
    LB_tot = LB_tot + LB_max
END FOR
RETURN R_max, LB_tot
```

* The Boolean function ADJACENT(*f*, *MTI*, *R*) returns true if the MOI (*f*, *MTI*) is temporally adjacent with an existing MOI of facility *f* in regime *R*; otherwise false is returned

4. Case study

In order to illustrate the applicability of the method described in section 3, we will now elaborate a case study. In this case study we will try to find the optimal regime of opening hours for the government offices in the city of Ghent (Belgium). The input data, data preparation and results will be discussed below.

4.1 Data

The study area is the city of Ghent, which is the third largest city in Belgium and capital of the province of East-Flanders. Ghent has a population of approximately 240,000 inhabitants and an area of almost 160 km² (Figure 2). The northern part of the study area is sparsely populated and known for its flourishing industrial and harbour activities.

For this case study, we rely on the following data sources:

Individuals

The first data source is an activity/travel data set consisting of a two-day consecutive diary of out-of-home activities of persons aged five or more living in the Ghent region. The data set was collected in 2000 within the framework of the SAMBA project (Spatial Analysis and Modelling Based on Activities) (see Tindemans et al., 2005). Reported activity locations were geocoded at the street level. Individuals sampled at the same day of the week are grouped and their fixed activities are considered representative for the type of activities that they usually undertake on that day of the week. Since no fixity levels are available for the reported activities, fixed activities were determined on the basis of the activity purpose. The categories “work”, “school”, “pick up/drop off” and categories closely related to these were considered fixed, given that it is generally difficult to conduct these at other places and times. In total 3,047 person-days were selected, ranging from Monday to Saturday. Sunday openings will not be considered in this case study as they relate to different societal constraints and are not considered by the local authorities. Given that households were randomly sampled within the SAMBA project, we will assume that the spatial distribution of the home locations of the selected individuals mirrors the general distribution of the actual population (Figure 2).

[insert Figure 2 here]

Service facilities

The second source of data comprises information about the government offices in Ghent. The addresses, opening hours and services offered are obtained for each government office from the official city website (http://www.gent.be). Two types of government offices are distinguished: head and branch offices (Figure 3). The centrally located head office forms the core of the municipal service delivery network. In addition to the conventional administrative services delivered at all branch offices, the head office offers few additional though rather exceptional formalities. Furthermore, this office is generally able to process administrative documents (e.g. identity cards) quicker than the branch offices.

[insert Figure 3 here]

The current regime of opening hours is given in Table 1 (opening hours are grey-coloured). The opening hours of government offices 4-15 exhibit a lot of overlap, while the opening hours of offices 1-3 in the northern part of the city are very limited.

[Insert Table 1 here]

Transport system

The third data source is TeleAtlas® MultiNet™ (version 2007.10) road network data for Belgium. Based on this data set, travel times were estimated using ESRI®'s Network Analyst (ArcGIS 9.3.1). Two predominant transport modes in Ghent will be considered in this case study: car and bicycle. Local public transportation is not addressed in this study because it would significantly increase the computational intensity and requires among others information about the location of stops and the time tables for each of the different public transportation alternatives (i.e. trains, trams and buses) in Ghent, which were not available to us.

To compute travel times by car, we have manipulated our data set in order to account for congestion. Therefore, we relied on a recent report prepared for the Federal Government Service for Mobility and Transport (Maerivoet and Yperman, 2008), where average travel times are reported for Ghent and its conurbation for three different road classes at four different times of the day for both weekdays and weekends. A factor for each of these categories has been determined (Table 2). As expected, the highest congestion (i.e. highest factor) is found during weekday mornings and weekday evening peaks, while the lowest congestion (i.e. lowest factor) occurs during weekend middays and nights. These congestion factors allow us to estimate time-varying travel times by car as the weighted product of the uncongested travel time (based on TeleAtlas® MultiNet™) with the corresponding factors in Table 2. If the uncongested travel time covers different congestion periods, factors are weighted accordingly.

[insert Table 2 here]

Specific information about specialized bicycle facilities (e.g. dedicated bicycle paths) was not readily available for the city of Gent. Hence, in order to compute travel times by bicycle, we had to adopt a compromise solution following Ianoco et al. (2009). This compromise solution consisted of excluding highways and other exclusive motorways from the transport network and allowing travel directions for non-motorized travelers – one-way streets for motorized vehicles passable in both directions for bicyclists are common in Ghent. Travel times by bicycle were estimated as the product of the shortest path distance and a mean travel speed of 15 km/h. Note that these estimates can be refined based on recent empirical studies about pedestrian and bicycle travel that have shown travel times and speeds to vary with micro-level characteristics of the built environment (Krizek and Roland, 2005; Krizek et al., 2009) and according to age and gender (Wendel-Vos et al., 2004; Gomez et al., 2005). However, we believe that the current estimations are accurate enough for testing our method and leave such refinements for future work.

4.2 Data preparation

Prior to the optimisation, the input data needs to be adapted. The following issues have been dealt with. First, all necessary detour travel costs have been calculated as described in section 4.1. To account for mobility resources, we have assumed that car-owners with a driving license are able to travel by car, whereas others are assumed to travel by bicycle. Second, the attractiveness value a_f (see eq. [3]) was determined for each government office. On the basis of the number of extra services provided at the head office and in consultation with the local authorities, we have specified the attractiveness difference between the head office and the branch offices at the proportion of 1 for the central office to 0.8 for the other offices. Third, the decay parameter α of the negative exponential deterrence function (see eq. [3]) was estimated for car and bicycle separately, using the observed cumulative distribution of service trips according to travel time (Figure 4). Similar decay parameters were found across both travel modes: α_{car} = 0.081 (R^2 = 0.97) and $\alpha_{bicycle}$ = 0.092 (R^2 = 0.98).

[insert Figure 4]

Finally, the algorithms 1 and 2 presented in section 3.2 have been implemented in a Visual Basic module.

4.3 Results

Optimal temporal regimes by number of opening hours

We start our analysis by examining if and to what extent the accessibility of Ghent's government offices can be improved by rescheduling the current opening hours using Algorithm 1. We will consider MTIs of one hour, which reflect the minimal time span for a government office to be open, as is also the case in the current regime (office 3, Table1). Given that people generally have less time constraints resulting from fixed activities on Sundays and in the evening (Neutens et al., 2010c), it is rather self-evident that citizens' accessibility will be improved significantly by shifting the current opening hours towards these time periods. Therefore, we will restrict our analysis to the accessibility gains that can be made by applying the optimisation algorithm within the current range of opening hours (i.e. 8 AM to 6 PM and Monday to Saturday). Within this range, the fifteen government offices can maximally cover 900 possible opening hours (MOIs) – each office can be open for ten hours between 8 AM to 6 PM for six days a week (Monday to Saturday). Currently, the government offices cover 405 of these 900 possible opening hours.

Using Algorithm 1, we have assessed the 900 optimal regimes ranging from one to all 900 opening hours in the study period. Figure 5 shows that the accessibility increases with the number of opening hours at a decreasing rate. The accessibility values on the vertical axis of this diagram have been calculated as a trade-off between attractiveness, possible activity duration and travel costs (eq. [6]) and express how well the complete set of individuals is able to access the network of government offices during a given regime of opening hours. Figure 5 offers a yardstick regarding the number of opening hours to be included in a temporal regime. One can see that accessibility increases quite rapidly for the first, say, 150 opening hours. Hence, a curtailment of these hours would considerably harm the overall accessibility of government offices. Beyond this value the marginal utility of adding extra opening hours declines until 820 opening hours. From that point on, expanding the opening hours does not increase the total accessibility anymore because none of the added opening hours is able to attract (i.e. offer higher benefits to) individuals from government offices with concurrent opening hours that were already included in the optimal regime. In other words, for the remaining 80 opening hours – covered only by the peripheral government offices no. 1 and 2 – people are better off if they go to surrounding offices.

[Insert Figure 5 here]

Evaluating the current temporal regime

We have also calculated the total accessibility of the current regime of 405 opening hours and have positioned this regime into the diagram depicted in Figure 5. Vertical movements in the diagram represent gains or losses in accessibility caused by rescheduling the current number of opening hours; horizontal movements represent curtailing or expanding the opening hours. Clearly, the current regime is suboptimal in terms of accessibility since the same level of accessibility can be achieved with merely 98 opening hours if the optimal regime is adopted. In other words, Figure 5 indicates that significant improvements in the total accessibility can be made by simply reconfiguring the existing opening hours without expanding them.

Improving accessibility by rescheduling opening hours

To improve the accessibility of the government offices, a suitable strategy would be to reschedule the current 405 opening hours within the current range of opening hours. The regime that yields the maximum total accessibility with 405 opening hours has been calculated using Algorithm 1 and is depicted in Table 3. At least two characteristics of this optimal regime can be identified. First, a relatively large share of government offices have been allocated opening hours between 4 PM and 6 PM on weekdays, reflecting that many individuals in the sample have time available for accessing a government office upon completing (mandatory) paid work activities. Second, opening hours tend to be allocated to government offices that are located centrally within the city – offices 5, 8 and 15 in particular. This can be explained by the high concentration of residences and employment (or other fixed activity) locations within this area from which people tend to access the government offices. The optimal regime of 405 opening hours also implies that the small demand for branch offices 1 and 2 can easily be taken over by the other offices. Also, it appears that in the optimal regime the head office (no. 15) is continuously open on each day of the study period. This could have been expected since this office was assigned a larger attractiveness and is located centrally.

[Insert Table 3 here]

While, compared to the current regime, the total accessibility can be increased by 70% without expanding the number of opening hours, the optimal 405-hour regime is rather impracticable as it contains 13 discontinuities (gaps within an office's day schedule) with nine isolated hours (offices opened for only one hour). To overcome this issue, we have computed the (sub)optimal 405-hour regime using Algorithm 2 with symmetric reward r and penalty p parameters (i.e. $p = r^{-1}$). In order to limit the impact of connectedness on the total accessibility, we have gradually increased the impact of both factors simultaneously (increased r and decreased p by increments of 0.1 to the same extent), starting from $r = p = 1$. We found that for $r \geq 1.3$ and $p \leq 1.3^{-1}$ regimes without any discontinuities are obtained. The results of the adjusted regime are depicted in Table 4. Since 96% of the opening hours of the optimal regime are preserved in the adjusted contiguous regime, the total accessibility has diminished by less than 1% compared to the optimal regime with 405 hours. In other words, by adjusting the reward and penalty parameters, we are able to develop a regime consisting of contiguous blocks of opening hours that offers high levels of accessibility among the population. This regime may be used by local authorities as a basis for amending the opening hours of their network of service facilities.

[Insert Table 4 here]

5. Conclusion and avenues for future work

The purpose of this paper has been to study the relationship between opening hours and accessibility in the context of public service delivery. More specifically, a method has been presented and implemented that allows optimising the opening hours of public service delivery in terms of the accessibility experienced by a city's population with heterogeneous activity and travel patterns. Accessibility has been specified by means of locational benefits which express the desirability for an individual to participate in an activity at a certain service facility on the basis of the facility's attractiveness, the potential activity duration and the travel costs involved. The proposed method has been illustrated for a case study of public service delivery in the city of Ghent, Belgium. Our initial findings have shown that substantial improvements in total accessibility can be made by rescheduling instead of expanding the existing opening hours of service facilities. We believe that the current study is relevant in light of the growing attention to time problems and the increasing relevance of urban time policies. Optimal temporal regimes in terms of accessibility offer policymakers a useful benchmark to identify the margins within which access to services can be improved by temporal changes to service delivery.

Although our optimisation method has a sound and generic theoretical basis, a number of refinements could and should be made in future work. The first and perhaps most important issue from a policy point of view concerns the absence of equity considerations in our algorithm. While we were able to identify the regime of opening hours that maximises the accessibility over the entire (sample of the) population, we did not account for the inequalities in the distribution of individual accessibility that may ensue from this regime. One way to promote a more equitable distribution of individual accessibility would be to weight the individual benefits in the optimisation procedure, such that larger weights are assigned to the benefits of individuals with less discretionary time available. In this way policymakers could give priority to the preferences of those persons who are most vulnerable to a modification of opening hours. For example, local authorities may want to 'humanize' the timetables of public service delivery by making these more compatible with the activity schedules of those constituencies who generally face considerable space-time demands in their daily lives, such as dual earner households or young women with children. Policymakers may also want to alter the temporal regime of public service delivery to attract more visitors from particular socioeconomic groups. Visitor surveys of library use, for example, have already provided initial support that the opening hours of public libraries affect the social composition of their visitor populations (Glorieux et al., 2007).

Second, the realism of the space-time accessibility measure used in this paper can be improved further. Some temporal aspects warrant more attention including the incorporation of delay times, waiting times, minimum activity duration and local changes in travel times due to a rescheduling of opening hours. The valuation of attractiveness and possible activity duration also deserves more attention. Whereas both components have currently been assumed directly proportionate to individual accessibility, behaviourally more appealing functions have been proposed to express this relationship (see e.g. Joh et al., 2001; Ettema et al., 2004). Increasing the behavioural realism of space-time accessibility can also be achieved by accounting for dependencies between household members with respect to car allocation, ride sharing and task re-allocation strategies (Zhang and Fujiwara, 2006; Soo et al., 2009). Since these aspects may impose additional coupling constraints on activity participation, they should be incorporated in future work. Finally, given that our approach is sample-based, it is important to point out that the resulting optimal regime highly depends on the size and the accuracy of the travel diary data at hand. This is because activities reported in a travel diary on a particular day may not be representative for the type of activities that an individual is likely to regularly engage in that day. Ideally, longitudinal data covering multiple days or even weeks should be used to verify the consistency of activity patterns over a longer time horizon.

Third, at a more general level, rescheduling of the operational hours of public services, commercial activities and employment may have downsides for family and social life and at some point begin to reduce social welfare. This is because those services, commercial activities and firms whose operational hours are to be rescheduled will demand that at least some of their employees will have to come to work at the rescheduled hours. These hours may well coincide with times that children, spouses, friends and others will experience fewer space-time constraints and are available for social and leisure activity participation. This situation of rescheduled employment hours is most likely to occur for people with low levels of sovereignty over their employment hours, many of whom will occupy the lower steps on the occupational ladder, hold less secure jobs, and will be lowly educated and female (Breedveld, 1998; Hildebrandt, 2006). Hence, the disadvantages that a large-scale rescheduling of opening hours would have for family and social life will be distributed unevenly across socio-economic groups in society (Mills and Taht, 2010). There are at least two ways to account at least to some extent for the negative effects of a rescheduling of operational hours on family and social life. One, which has also been adopted here, is to a priori determine a time window, during which opening hours can be rescheduled. Certain periods of time, such as late evenings and Sundays, could in this way be excluded from the rescheduling process. Second, it would be possible to incorporate people's time-of-day preferences regarding when they would like to participate in certain types of activities into the Burns/Miller accessibility measures (see also Neutens et al., 2010c). Blocks of time during the week and during which large groups of people would prefer to engage in social activities with family, friends and others rather than visit a public service or commercial activity would then have a lower weight in the calculation of the optimal regime of opening hours. The value of this second approach could be explored in future work.

Despite these refinements to be made, we believe that the proposed method can be a valuable instrument aiding policymakers, facility managers and others to explore different configurations of opening hours that maximise potential visitors' opportunity to pursue activities at facilities across cities and regions.

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Table captions

Table 1. Current regime of opening hours for the government offices in Ghent (1-15).

Table 2. Congestion factor according to day type, day time and road class.

Table 3. Optimal 405-hour regime.

Table 4. Contiguous sub-optimal 405-hour regime.

Figures

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.

Figure 2. Study area and sampled households.

Figure 3. Spatial distribution of government offices.

Figure 4. Estimation of distance decay parameters.

Figure 5. Total accessibility for all 900 optimal regimes with indication of the current regime.