SOCIAL EQUITY, ACCESSIBILITY AND THE TEMPORAL DIMENSION OF PUBLIC SERVICE DELIVERY

Tijs Neutens, Department of Geography, Ghent University, Krijgslaan 281 (S8), B-9000 Ghent, Belgium, E-mail: Tijs.Neutens@UGent.be

Matthias Delafontaine, Department of Geography, Ghent University, Krijgslaan 281 (S8), B-9000 Ghent, Belgium, E-mail: Matthias.Delafontaine@UGent.be

Tim Schwanen, Transport Studies Unit, School of Geography and the Environment, University of Oxford, South Parks Road, Oxford, OX1 3QY, United Kingdom, E-mail: tim.schwanen@ouce.ox.ac.uk

ABSTRACT

In the past two decades urban time policies have been proposed and implemented in many European cities as a complement to traditional spatial planning methods. Such policies seek to provide an answer to the growing number of people facing time problems as a result of an erosion of collective time rhythms and a desynchronization of different time structures of urban life. Particular emphasis is being placed on the reconciliation of opening hours of public service facilities with the travel and activity patterns of citizens in order to increase individual accessibility to urban services. In spite of the increasing relevance of time policies, only limited quantitative research has been conducted about the relationships between opening hours and accessibility. This paper seeks to extend this line of inquiry by exploring if and to what extent the accessibility of public facilities can be ameliorated by redesigning the timetables of service delivery. A method is proposed to optimize the temporal regime of public service delivery in terms of accessibility. The method is illustrated in a case study of accessibility of government offices within the city of Ghent (Belgium). Our findings suggest that by rescheduling the opening hours of public service facilities individual accessibility to service delivery can be improved significantly while preserving social equity. Our study may support urban service deliverers, policymakers and urban planners in defining more ‘accessible’ and equitable timetables of service provision.

Keywords: accessibility, equity, opening hours, time geography

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 getting 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 Weighenrieder, 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 maximize 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 behavior. 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 behavior (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 behavior and transport mode availability (see e.g., Weber and Kwan, 2002; Schwanen and De Jong, 2008; Neutens et al., 2010a).

The present paper examines how such individualized aspects of accessibility can be considered in the determination of socially optimal opening hours of public services. 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 maximizing 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 conflicting 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 optimize 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, 1993; 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 system. Further, transport and communication technologies 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 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 desynchronization of social times, and more diverse and complex activity schedules due to the increase of temporal constraints imposed by daily obligations (e.g. paid labor, childcare, etc.) and limited mobility resources. Given the large and growing number of women entering the European labor market and the concomitant decay of the old 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 potentially inequitable distributional effects of temporal practices (see e.g. Moccia, 2000; Hajer and Zonneveld, 2000; Nuvolati, 2003; Haley, 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 (Neutens et al., 2010c). 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* (*STP*) 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* (*PPA*).

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). 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 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 centers can help to improve the work-life balance of dual-earner families. Finally, Neutens et al. (2010a) 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 modeling 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. (2008, 2010b).

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 work and fetching children.

Let $s(p)$ denote the start time of an activity p, $e(p)$ the end time of p, and $t_c(p,q)$ the travel time between the location of p and another location q. Following Kwan and Hong (1998) and Ashiru et al. (2004), the space-time prism (*STP*) of individual *i* between two fixed activities can be specified as follows:

$$STP\left(i,j\right)=\left\{\left(f,t\right)\in F_i\times T\,\middle|\,\forall t:e\left(K_i\left(j\right)\right)+t_c\left(K_i\left(j\right),f\right)\le t\le s\left(K_i\left(j+1\right)\right)-t_c\left(f,K_i\left(j+1\right)\right)\wedge t\in H\left(f\right)\right\}\qquad [1]$$

with

K_i	chronologically ordered set of fixed activities of individual *i*;
$K_i(j)$	fixed activity *j* of K_i;
F_i	set of service facilities at *i*'s disposal;
$H(f)$	set of time intervals during which facility *f* is opened;
T	set of clock times.

The *STP* is a set of potential times between two fixed activities when an individual is able to participate in an activity at a certain facility. Eq. [1] ensures that a service facility is not eligible for activity participation if an individual cannot reach the service during its formal opening hours.

Let $\left[t_s,t_e\right]$ denote a positive time interval ($t_e \ge t_s$). Based on eq. [1], we define the potential path space (*PPS*) for an individual *i* over a time interval $\left[t_s,t_e\right]$:

$$PPS\left(i,\left[t_s,t_e\right]\right)=\left\{\left(f,\left[t_n,t_m\right]\right)\,\middle|\,\forall t\in\left[t_n,t_m\right]:\left(f,t\right)\in\bigcup_j STP\left(i,j\right)\wedge t\in\left[t_s,t_e\right]\right\}\qquad [2]$$

The *PPS* is the set of potential time intervals $\left[t_n,t_m\right]$ during which an individual is able to access a facility during the considered time interval $\left[t_s,t_e\right]$.

Assume $\left(f,\left[t_n,t_m\right]\right)\in PPS\left(i,\left[t_s,t_e\right]\right)$. It then follows that $\left[t_n,t_m\right]$ lies between two fixed activities of *i* and within the opening hours of *f*. For each $\left(f,\left[t_n,t_m\right]\right)$ we can then specify the locational benefit (*LB*) for *i* with respect to *f* over $\left[t_n,t_m\right]$ as:

$$LB\left(i,\left[t_n,t_m\right],f\right)=B_A\left(a_f\right)\cdot B_D\left(\left[t_n,t_m\right]\right)\cdot B_C\left(t_f\right)\qquad [3]$$

with

a_f	attractiveness of service facility *f*;
$B_A(a_f)$	benefit resulting from attractiveness a_f;
$B_D([t_n, t_m])$	benefit resulting from the activity duration $[t_n, t_m]$;
t_f	travel time cost to facility *f*;
$B_C(t_f)$	disutility resulting from travel cost t_f.

A *LB* 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 to/from this facility. To determine the different components in eq. [3], 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. [3] 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 (Ianoco et al., 2009). Incorporating the above assumptions in eq. [2] yields:

$$LB(i,[t_n,t_m],f) = a_f \cdot (t_m - t_n) \cdot \exp(-\alpha \cdot t_f) \quad [4]$$

The travel costs t_f in eq. [4] can be calculated as the detour travel costs for *i* to travel to *f* in between two fixed activities instead of travelling directly from the first to the second activity:

$$t_{dc}(i,[t_s,t_e],f) = t_c(K_i(j),f) + t_c(f,K_i(j+1)) - t_c(K_i(j),K_i(j+1)) \quad [5]$$

with $e(K_i(j)) \leq t_s \wedge s(K_i(j+1)) \geq t_e$.

Relying on the definition of an individual's *PPS* in eq. [2] and locational benefit with respect to a single facility as in eq. [4], we can specify the accessibility of a network of service facilities to an individual during a given time interval. When considering public facilities that offer highly comparable services – as is the case for the government offices – 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 maximizes the locational benefits over the available facilities during the considered time interval $[t_s,t_e]$. More formally, the accessibility of a network of service facilities to individual *i* over a time interval [t_s, t_e] is specified as:

$$A\left(i,\left[t_s,t_e\right]\right)=\max_{f\in F_i}\left(\sum_{\left(f,\left[t_n,t_m\right]\right)\in PPS\left(i,\left[t_s,t_e\right]\right)} LB\left(i,\left[t_n,t_m\right],f\right)\right) \quad [6]$$

Finally, the total accessibility derived by a set I of individuals during time interval $\left[t_s,t_e\right]$ is given by:

$$A\left(I,\left[t_s,t_e\right]\right)=\sum_{i\in I}\max_{f\in F_i}\left(A\left(i,\left[t_s,t_e\right]\right)\right) \quad [7]$$

3.2 Optimizing opening hours in terms of accessibility

Having introduced a measure of an individual's accessibility of a network of service facilities within a time interval, we now propose a method for identifying the opening hours that would generate the highest total accessibility for a set of individuals. It should be noted that we will only seek to optimize 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 assumed fixed during the computation procedure).

We propose a granulated approach that considers a certain temporal resolution (∂t), i.e. a minimum time interval for offering a service. Hence, a study period $\left[t_1,t_2\right]$ is divided into a sequence of non-overlapping intervals $\left[t_s,t_e\right]$ equal to $\left[t,t+\partial t\right]$. Let a tuple $\left(f,\left[t,t+\partial t\right]\right)$ denote the minimal opening interval (*MOI*) of facility f from t to $t+\partial t$. A combination of *MOI*s will be termed a *regime* R, i.e. a set of opening hours associated with a set of facilities. For convenience, we will consider a specific ∂t of one hour in the remainder of this paper and will term the associated *MOI* a *facility-hour*.

The method we propose is iterative: a regime is built up starting from one hour to the total number of hours that needs to be allocated to the complete set of service facilities (see Algorithm 1). To illustrate the procedure, let us consider the first iteration in which we try to find the optimal *one-hour regime* consisting of a single facility-hour, i.e. one facility out of the network is opened for only one hour. To this end, we calculate the total accessibility of the set I of individuals i as in eq. [7] for each facility-hour $\left(f,\left[t,t+\partial t\right]\right)$, with the network of facilities consisting solely of f ($\forall i: F_i=\left\{f\right\}$) and with f being open during $\left[t,t+\partial t\right]$. To clarify how accessibility is calculated per individual for a given facility-hour, a simple example is given in Box 1. The obtained total accessibility for each possible facility-hour (i.e. the sum of individual accessibility as calculated in Box 1 over all individuals i) expresses how well the set I of individuals i can reach the government offices during the considered opening hour. Finally, the facility-hour for which the highest total accessibility is obtained is stored as the optimal one-hour regime for the next iteration.

Box 1

Example

Consider a person *i* with a time budget of 120 minutes between two successive fixed activities, with the first activity $K_i(j)$ ending at 8.10 AM and the next activity $K_i(j+1)$ starting at 10.10 AM. Suppose the following travel times: 25 minutes from $K_i(j)$ to $K_i(j+1)$, 15 minutes from $K_i(j)$ to *f*, and 20 minutes from *f* to $K_i(j+1)$. Then, person *i* is able to visit *f* for 85 (= 120 – 15 – 20) minutes, of which 35 minutes are within [8 AM, 9 AM]. We then calculate the locational benefit of *i* for facility-hour (*f*, [8 AM, 9 AM]) using [4] and [5] as $a_f \cdot (35) \cdot \exp(-\alpha \cdot (15+20-25))$. This value is aggregated with the locational benefits for all other time budgets of *i* within this facility-hour (in this case none). This calculation is repeated for all facility-hours, i.e. for each facility for each hour. Per hour we then obtain the accessibility value for *i* as the maximal aggregated facility-hour benefit.

In the next iteration, we determine the optimal *two-hour regime*. We again run through all facility-hours – except the already chosen one – and calculate the total accessibility A_{add} that would be added to the one-hour regime after appending the second facility-hour. If the previously selected facility-hour (of a particular facility) is concurrent with this second facility-hour (of another facility), then both facility-hours will compete with each other as an individual can only derive his maximum locational benefit at one of both facilities. It is important to note that the maximative function in eq. [7] ensures that each facility accumulates only the accessibility values of the individuals for which it offers the maximal locational benefit in the two-hour regime. Finally, the optimal regime is given by the two-hour regime with the highest added accessibility of the second facility-hour since this will yield the highest total accessibility of any two-hour regime.

The same procedure applies to all subsequent iterations from an *n-hour regime* to an *(n+1)-hour regime*. A formal overview of the complete computational procedure is given in Algorithm 1.

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

Input:

$I = \bigcup i$	set of individuals (each individual *i* is associated with a chronological set of fixed activities K_i and a set of facilities at his/her disposal F_i)
$\left[t_1, t_2\right]$	study period
∂t	temporal resolution (e.g. one hour)
n	number of *MOI*s (e.g. 100 facility-hours)

Output:

$R_{opt} = \bigcup_{x=1}^{n} \left(f, \left[t, t+\partial t\right] \right)_x$	optimal *n*-hour regime as an ordered set of *MOI*s
A_{opt}	total accessibility for the optimal *n*-hour regime

Algorithm:

```
$R_{opt} = \varnothing$
$A_{opt} = 0$
for $x = 1$ to $n$
    $A_{max} = 0$
    $MOI_{max} = \varnothing$
    for $t = t_1$ to $t_2$ step $\partial t$
        for each $f \in \bigcup F_i \left| \left( f, \left[t, t+\partial t\right] \right) \notin R_{opt} \right.$
            $A_{add} = 0$
            for each $i \in I$
                $A_{add} = A_{add} + A\left(i, \left[t, t+\partial t\right]\right)$
            next $i$
            if $A_{add} > A_{max}$ then
                $A_{max} = A_{add}$
                $MOI_{max} = \left( f, \left[t, t+\partial t\right] \right)$
            end if
        next $f$
    next $t$
    $R_{opt} = R_{opt} \bigcup MOI_{max}$
    $A_{opt} = A_{opt} + A_{max}$
next $x$
return $R_{opt}, A_{opt}$
```

At this stage we are able to derive the optimal *n*-hour regime in terms of total accessibility for a specified number of *MOI*s. 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 *MOI*s scattered across the study period, which would be rather impracticable to implement by local authorities. In an attempt to derive the *n*-hour regime that accounts for continuity of service delivery, we propose a second algorithm (Algorithm 2) using a penalty and a reward parameter, denoted *p* and *r* respectively. The idea is that the total accessibility for an

MOI has to be revalued (multiplied by *r*) when an *MOI* connects with one of the previously selected *MOI*s of the same facility on the same day, whereas *MOI*s have to be devaluated (multiplied by *p*) if an MOI does not connect to one of the previously selected *MOI*s on the same day.

Although it would be straightforward to choose symmetric (i.e. inverse) values for *p* and *r*, we have intentionally introduced them as two different parameters as they have different effects on the allocation of *MOI*s across facilities. On the one hand, rewarding continuous opening hours ($r > 1$, $p = 1$) will favor a regime consisting of a limited set of facility-days with continuous opening hours. A penalty ($r = 1$, $p < 1$) for discontinuous opening hours, on the other hand, will favor a regime with many different facility-days yet with continuous opening hours. Both parameters can be adjusted by policymakers at will in order to derive meaningful regimes. It should be noted however that temporal continuity comes at the expense of accessibility: a regime tends to be less optimal in terms of accessibility if more continuity is aimed for (i.e. the more *r* and *p* deviate from 1). A formal representation of the computational procedure to determine the (sub)optimal connected *n*-hour regime given in Algorithm 2.

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

Input:

I , $[t_1, t_2]$, ∂t , n	(see Algorithm 1)
p	penalty
r	reward

Output:

$R_{opt} = \bigcup_{x=1}^{n} \left(f, [t, t+\partial t] \right)_x$	(sub)optimal connected *n*-hour regime as an ordered set of *MOI*s
A_{opt}	total accessibility for the optimal *n*-hour regime

Algorithm:

```
$R_{opt} = \varnothing$
$A_{opt} = 0$
for $x = 1$ to $n$
    $A^{pr}_{\max} = 0$
    $A_{max} = 0$
    $MOI_{max} = \varnothing$
    for $t = t_1$ to $t_2$ step $\partial t$
        for each $f \in \bigcup F_i \,\middle|\, \left( f, [t, t+\partial t] \right) \notin R_{opt}$
            $A^{pr}_{add} = 0$
            $A_{add} = 0$
            if $\exists \left( f, [t-\partial t, t] \right) \in R_{opt} \vee \exists \left( f, [t+\partial t, t+2\cdot\partial t] \right) \in R_{opt}$
                $q = r$
            else if $\exists s \in [t_1, t_2] \,\middle|\, \left( f, [s, s+\partial t] \right) \in R_{opt}$ then
                $q = p$
            else
                $q = 1$
            end if
            for each $i \in I$
                $A^{pr}_{add} = A^{pr}_{add} + q \cdot A\left(i, [t, t+\partial t]\right)$
                $A_{add} = A_{add} + A\left(i, [t, t+\partial t]\right)$
            next $i$
            if $A^{pr}_{add} > A^{pr}_{\max}$ then
                $A^{pr}_{\max} = A_{pr}$
                $A_{max} = A_{add}$
                $MOI_{max} = \left( f, [t, t+\partial t] \right)$
            end if
        next $f$
    next $t$
    $R_{opt} = R_{opt} \bigcup MOI_{max}$
    $A_{opt} = A_{opt} + A_{max}$
next $x$
return $R_{opt}, A_{opt}$
```

4. CASE STUDY

In order to illustrate the applicability of the method described in section 3, a case study will be elaborated. 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 1). The northern part of the study area is sparsely populated and known for its flourishing industrial and harbor 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 Modeling 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 this 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 since it is generally difficult to conduct them 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 1).

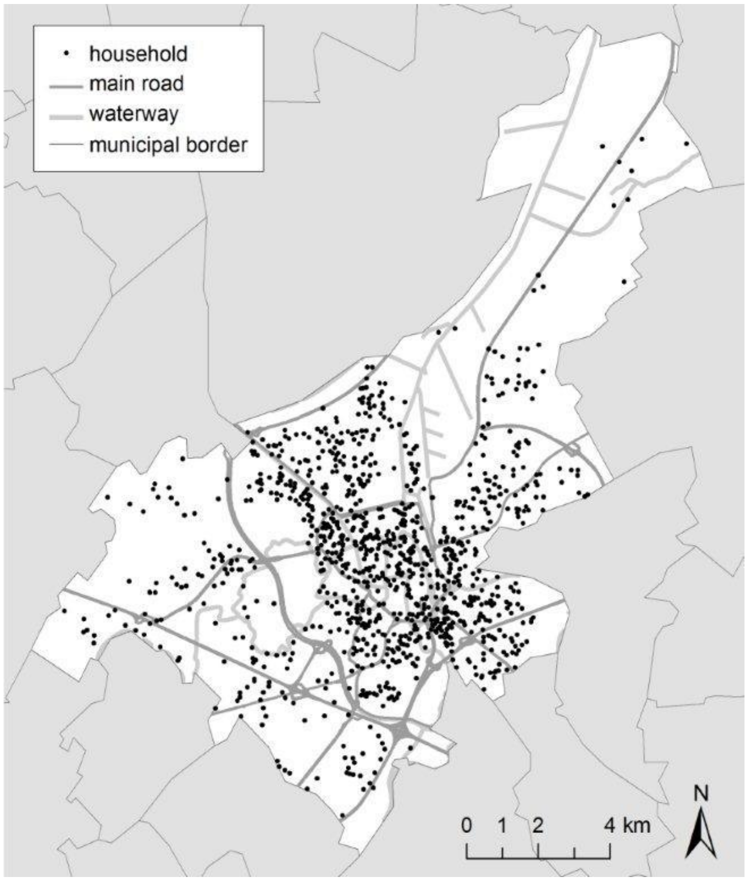

Figure 1 – Study area and sampled households.

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 2). 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.

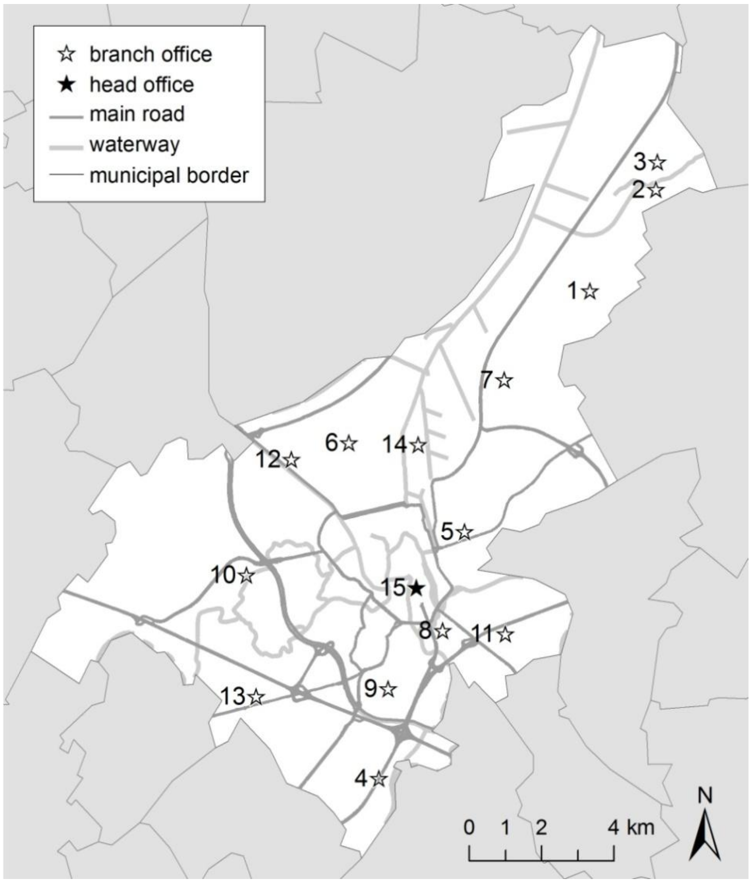

Figure 2 – Spatial distribution of government offices.

The current regime of opening hours is given in Table 1 (opening hours are grey-colored). 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. Given that people generally have less time constraints resulting from fixed activities on Sundays and in the evening (Neutens et al., 2010a), it is rather self-evident that citizens' accessibility will be improved significantly by shifting the current opening hours towards these time periods. Therefore, in our analysis we will specifically concentrate on the accessibility gains that can be made by applying the optimization algorithm within the current range of opening hours (i.e. 8 AM to 6 PM and Monday to Saturday). Within this range, the 15 government offices can maximally cover 900 possible opening hours – each office can be open for 10 hours between 8 AM to 6 PM for six days a week (Monday to Saturday). In the current regime, 405 of these 900 possible opening hours are covered by the 15 government offices.

Table 1 – Current regime of opening hours for the fifteen government offices.

Monday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM				■	■	■	■	■	■	■	■	■	■	■	■
9 AM-10 AM				■	■	■	■	■	■	■	■	■	■	■	■
10 AM-11 AM				■	■	■	■	■	■	■	■	■	■	■	■
11 AM-12 PM				■	■	■	■	■	■	■	■	■	■	■	■
12 AM-1 PM				■	■	■	■	■	■	■	■	■	■		■
1 PM-2 PM															
2 PM-3 PM				■	■	■	■	■	■	■	■	■	■		
3 AM-4 AM				■	■	■	■	■	■	■	■	■	■		
4 AM-5 AM			■												
5 AM-6 AM			■												
Tuesday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM				■	■	■	■	■	■	■	■	■	■		■
9 AM-10 AM				■	■	■	■	■	■	■	■	■	■		■
10 AM-11 AM				■	■	■	■	■	■	■	■	■	■		■
11 AM-12 PM				■	■	■	■	■	■	■	■	■	■		■
12 AM-1 PM				■	■	■	■	■	■	■	■	■	■		■
1 PM-2 PM															
2 PM-3 PM				■	■	■	■	■	■	■	■	■	■		
3 AM-4 AM				■	■	■	■	■	■	■	■	■	■		
4 AM-5 AM															
5 AM-6 AM															
Wednesday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM		■		■	■	■	■	■	■	■	■	■	■		■
9 AM-10 AM		■		■	■	■	■	■	■	■	■	■	■		■
10 AM-11 AM	■			■	■	■	■	■	■	■	■	■	■		■
11 AM-12 PM	■			■	■	■	■	■	■	■	■	■	■		■
12 AM-1 PM				■	■	■	■	■	■	■	■	■	■		■
1 PM-2 PM															
2 PM-3 PM				■	■	■	■	■	■	■	■	■	■	■	■
3 AM-4 AM				■	■	■	■	■	■	■	■	■	■	■	■
4 AM-5 AM				■	■	■	■	■	■	■	■	■	■	■	■
5 AM-6 AM			■	■	■	■	■	■	■	■	■	■	■	■	■
Thursday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM			■	■	■	■	■	■	■	■	■	■	■		■
9 AM-10 AM			■	■	■	■	■	■	■	■	■	■	■		■
10 AM-11 AM			■	■	■	■	■	■	■	■	■	■	■		■
11 AM-12 PM			■	■	■	■	■	■	■	■	■	■	■		■
12 AM-1 PM				■	■	■	■	■	■	■	■	■	■		■
1 PM-2 PM															
2 PM-3 PM															
3 AM-4 AM															
4 AM-5 AM															
5 AM-6 AM															
Friday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM				■	■	■	■	■	■	■	■	■	■	■	■
9 AM-10 AM				■	■	■	■	■	■	■	■	■	■	■	■
10 AM-11 AM				■	■	■	■	■	■	■	■	■	■	■	■
11 AM-12 PM				■	■	■	■	■	■	■	■	■	■	■	■
12 AM-1 PM				■	■	■	■	■	■	■	■	■	■		■
1 PM-2 PM															
2 PM-3 PM				■	■	■	■	■	■	■	■	■	■		
3 AM-4 AM				■	■	■	■	■	■	■	■	■	■		
4 AM-5 AM															
5 AM-6 AM															
Saturday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM															
9 AM-10 AM															■
10 AM-11 AM															■
11 AM-12 PM															■
12 AM-1 PM															
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3 AM-4 AM															
4 AM-5 AM															
5 AM-6 AM															

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). Two predominant transport modes in Ghent will be considered in this case study: car and bicycle. 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 under the authority of 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.

Table 2 – Congestion factor according to day type, 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

Specific information about specialized bicycle facilities (e.g. exclusive non-motorized 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 (El-Geneidy et al., 2007). Although the travel time estimations may be refined in future research, we believe that these are accurate enough for testing our method.

4.2. Data preparation

Prior to the optimization, 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. [4]) 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. [4]) has been estimated for car and bicycle separately, using the observed cumulative distribution of service trips according to travel time. Similar decay parameters have been found across both travel modes: $\alpha_{car} = 0.095$ and $\alpha_{bicycle} = 0.094$ (Figure 3).

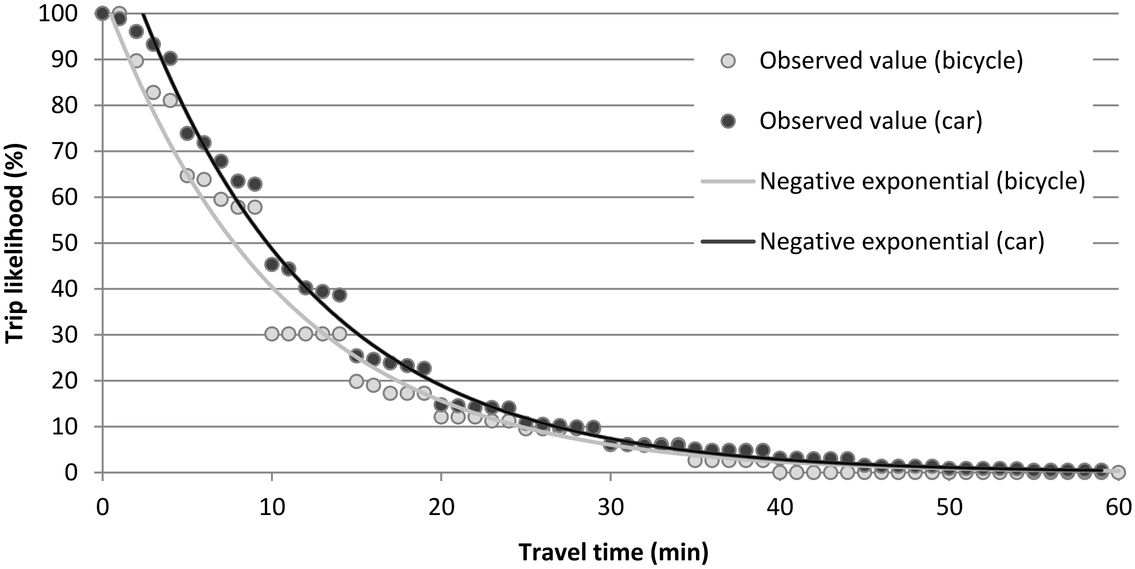

Figure 3 – Estimation of decay parameter.

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 described in section 3.2.

In order to gain insights into the relationship between opening hours and accessibility, we have calculated the optimal regimes and the associated total accessibility that they yield for an increasing number of opening hours within the current range of opening hours ranging from one to 900 according to eq. [7]. The value of 900 derives from the condition that 15 offices can be open for 10 hours between 8 AM to 6 PM for six days a week (15 offices x 10 hours x 6 days). We have also calculated the Gini coefficient for each of these 900 optimal regimes in order to evaluate to what extent the gains in accessibility are equitably distributed among the population (Figure 4). The Gini index is a measure of statistical dispersion of a variable – *in casu* accessibility – and ranges between 0 and 1. A low Gini coefficient indicates a more equal distribution of accessibility values among the population of individuals, with 0 corresponding to complete equality (i.e. all members of the population enjoy exactly the same level of accessibility). A high Gini coefficient indicates a more unequal distribution, with 1 corresponding to complete inequality (i.e. only one member of the population has a non-zero accessibility).

Figure 4 shows that the total accessibility increases with the number of opening hours at a decreasing rate. Accessibility increases quite rapidly for the first, say, 150 opening hours. Beyond this value the rate of the increase slows down until 820 opening hours. From that point on, expanding the opening hours does not increase the total accessibility anymore. This is 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 to go to surrounding offices.

Figure 4 also shows that, except for certain jumps in the beginning of the curve, the Gini coefficient decreases with an increasing number of opening hours. Thus, expanding the opening hours results in more equity of accessibility among the population (though at a decreasing marginal rate). The Gini index decreases rapidly until, say, 240 opening hours are included in the regime and then decreases gradually until all possible opening hours are included. A detailed inspection of the Gini coefficients reveals that the jumps in the beginning of the curve are due to the fact that the added opening hours improve accessibility to those who already enjoy a certain level of accessibility within the limited opening hours rather than provide access to those who are not yet able to reach a government office.

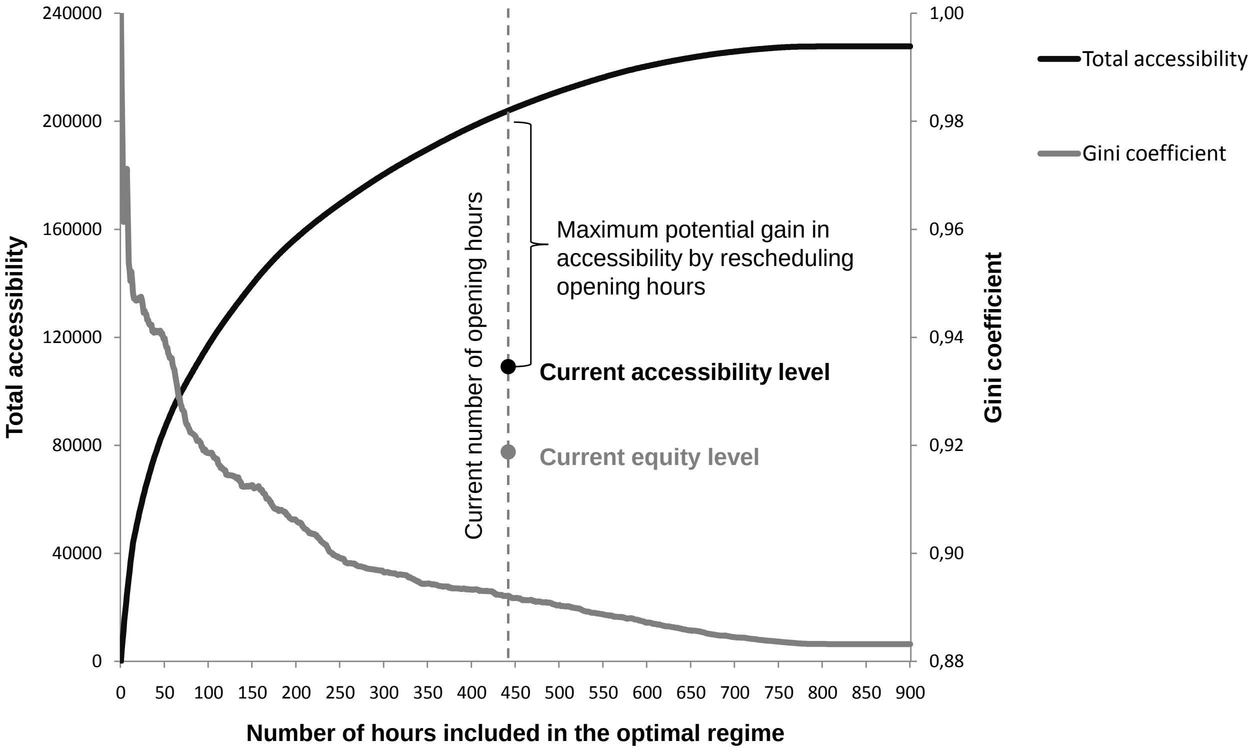

Figure 4 – Accessibility and Gini coefficients for all 900 optimal regimes with indication of the current regime.

Evaluating the current temporal regime

We have also calculated the total accessibility and the Gini coefficient of the current regime of 405 opening hours and have positioned this regime into the diagram depicted in Figure 4. The accessibility values on the left-hand vertical axis of this diagram have been calculated as a trade-off between attractiveness, possible activity duration and travel costs (eq. [7]) 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. 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 (and only a small loss in the level of equity) can be achieved with merely 98 opening hours if the optimal regime is adopted. The current regime is also not very equitable as revealed by the high Gini coefficient. Figure 4 indicates that much improvement in the level equity can be made in particular by reconfiguring the opening hours, whereas expanding the opening hours has relatively little effect.

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 p.m. and 6 p.m. 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. As well, it appears that the head office (no. 15) is continuously open on each day of the optimal regime. This could have been expected since this office was assigned a larger attractiveness.

Compared to the current regime, the total accessibility can be increased by 70% without expanding the number of opening hours. Meanwhile the Gini index drops by 3%. Only 214 opening hours (53%) are common to both the optimal and the current regime. These findings imply that accessibility can be improved significantly by rescheduling the opening hours while also even slightly improving the degree of social equity of accessibility among individuals.

However, the optimal 405-hour regime may appear rather impracticable as it contains 13 discontinuities (gaps within an office's day schedule) with nine isolated facility-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 to the same extent), starting from $r = p = 1$. We found that for $r > 1.3$ and $p < 1.3^{-1}$ 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 and the Gini coefficient have diminished by less than 1% compared to the optimal regime with 405 hours. In other words, by adjusting the reward and penalty parameters, we were able to develop a regime consisting of contiguous blocks of opening hours that both offers high levels of accessibility and is quite equitable. This regime may be used by local authorities as a basis for amending the opening hours of their network of service facilities.

Table 3 – Optimal 405-hour regime.

Monday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨			▨	▨	▨	▨	▨			▨
9 AM-10 AM					▨			▨	▨	▨		▨			▨
10 AM-11 AM					▨			▨	▨	▨		▨			▨
11 AM-12 PM					▨			▨		▨		▨			▨
12 AM-1 PM					▨			▨	▨	▨		▨			▨
1 PM-2 PM					▨			▨	▨	▨	▨	▨			▨
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3 AM-4 AM					▨			▨	▨	▨	▨	▨			▨
4 AM-5 AM					▨		▨	▨	▨	▨	▨	▨			▨
5 AM-6 AM					▨	▨	▨	▨	▨		▨	▨	▨		▨

Tuesday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM				▨	▨			▨				▨			▨
9 AM-10 AM					▨			▨				▨			▨
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4 AM-5 AM				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨
5 AM-6 AM				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨

Wednesday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨	▨		▨							▨
9 AM-10 AM					▨	▨		▨							▨
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3 AM-4 AM					▨	▨	▨	▨	▨	▨		▨	▨		▨
4 AM-5 AM					▨	▨	▨	▨	▨	▨		▨	▨		▨
5 AM-6 AM					▨	▨	▨	▨	▨	▨		▨	▨		▨

Thursday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨	▨		▨		▨					▨
9 AM-10 AM					▨	▨		▨							▨
10 AM-11 AM					▨	▨		▨							▨
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4 AM-5 AM			▨		▨	▨	▨	▨	▨	▨	▨	▨	▨		▨
5 AM-6 AM			▨		▨	▨	▨	▨	▨	▨	▨	▨	▨		▨

Friday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM			▨		▨	▨	▨	▨		▨					▨
9 AM-10 AM			▨		▨	▨	▨	▨		▨			▨		▨
10 AM-11 AM			▨		▨	▨	▨	▨		▨			▨		▨
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4 AM-5 AM					▨	▨	▨	▨	▨	▨	▨		▨	▨	▨
5 AM-6 AM			▨		▨	▨	▨	▨	▨	▨	▨		▨	▨	▨

Saturday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM			▨		▨	▨		▨			▨				▨
9 AM-10 AM			▨		▨	▨		▨			▨				▨
10 AM-11 AM			▨		▨	▨		▨			▨				▨
11 AM-12 PM			▨					▨			▨				▨
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1 PM-2 PM			▨		▨			▨			▨				▨
2 PM-3 PM			▨		▨	▨		▨							▨
3 AM-4 AM					▨			▨							▨
4 AM-5 AM					▨	▨		▨							▨
5 AM-6 AM					▨	▨		▨			▨				▨

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

Monday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨			▨	▨	▨		▨			▨
9 AM-10 AM					▨			▨	▨	▨		▨			▨
10 AM-11 AM					▨			▨	▨	▨		▨			▨
11 AM-12 PM					▨			▨	▨	▨		▨			▨
12 AM-1 PM					▨			▨	▨	▨		▨			▨
1 PM-2 PM					▨			▨	▨	▨	▨	▨			▨
2 PM-3 PM					▨			▨	▨	▨	▨	▨			▨
3 AM-4 AM					▨			▨	▨	▨	▨	▨			▨
4 AM-5 AM					▨		▨	▨	▨	▨	▨	▨			▨
5 AM-6 AM					▨	▨	▨	▨	▨		▨	▨			▨

Tuesday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨	▨		▨							▨
9 AM-10 AM					▨	▨		▨							▨
10 AM-11 AM					▨	▨		▨							▨
11 AM-12 PM					▨	▨		▨							▨
12 AM-1 PM				▨	▨	▨		▨							▨
1 PM-2 PM				▨	▨	▨		▨							▨
2 PM-3 PM				▨	▨	▨		▨		▨		▨			▨
3 AM-4 AM				▨	▨	▨		▨		▨		▨			▨
4 AM-5 AM				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨
5 AM-6 AM				▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨

Wednesday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨	▨		▨							▨
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10 AM-11 AM					▨	▨		▨							▨
11 AM-12 PM					▨	▨		▨		▨					▨
12 AM-1 PM					▨	▨	▨	▨	▨	▨		▨	▨		▨
1 PM-2 PM					▨	▨	▨	▨	▨	▨		▨	▨		▨
2 PM-3 PM					▨	▨	▨	▨	▨	▨		▨	▨		▨
3 AM-4 AM					▨	▨	▨	▨	▨	▨		▨	▨		▨
4 AM-5 AM					▨	▨	▨	▨	▨	▨		▨	▨		▨
5 AM-6 AM					▨	▨	▨	▨	▨	▨		▨	▨		▨

Thursday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨	▨		▨							▨
9 AM-10 AM					▨	▨		▨							▨
10 AM-11 AM					▨	▨		▨							▨
11 AM-12 PM					▨	▨		▨		▨					▨
12 AM-1 PM			▨		▨	▨		▨		▨	▨	▨			▨
1 PM-2 PM			▨		▨	▨		▨		▨	▨	▨			▨
2 PM-3 PM			▨		▨	▨		▨		▨	▨	▨			▨
3 AM-4 AM			▨		▨	▨		▨		▨	▨	▨			▨
4 AM-5 AM			▨		▨	▨	▨	▨	▨	▨	▨	▨	▨		▨
5 AM-6 AM			▨		▨	▨	▨	▨	▨	▨	▨	▨	▨		▨

Friday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM					▨	▨	▨	▨		▨			▨		▨
9 AM-10 AM					▨	▨	▨	▨		▨			▨		▨
10 AM-11 AM					▨	▨	▨	▨		▨	▨		▨		▨
11 AM-12 PM					▨	▨	▨	▨		▨	▨		▨		▨
12 AM-1 PM					▨	▨	▨	▨		▨	▨		▨		▨
1 PM-2 PM					▨	▨	▨	▨		▨	▨		▨		▨
2 PM-3 PM					▨	▨	▨	▨		▨	▨		▨		▨
3 AM-4 AM					▨	▨	▨	▨		▨	▨		▨		▨
4 AM-5 AM					▨	▨	▨	▨	▨	▨	▨		▨	▨	▨
5 AM-6 AM			▨		▨	▨	▨	▨	▨	▨	▨		▨	▨	▨

Saturday	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8 AM-9 AM			▨		▨	▨		▨			▨				▨
9 AM-10 AM			▨		▨	▨		▨			▨				▨
10 AM-11 AM			▨		▨	▨		▨			▨				▨
11 AM-12 PM			▨		▨			▨			▨				▨
12 AM-1 PM			▨		▨			▨			▨				▨
1 PM-2 PM			▨		▨			▨			▨				▨
2 PM-3 PM			▨		▨			▨			▨				▨
3 AM-4 AM			▨		▨			▨			▨				▨
4 AM-5 AM					▨			▨			▨				▨
5 AM-6 AM					▨			▨			▨				▨

5. CONCLUSION

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 optimizing the opening hours of public service delivery in terms of the accessibility experienced by a city's population with heterogeneous daily activity 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 only the opening hours of service facilities, while even slightly improving the equity among individuals.

The current study is extremely relevant in light of the growing attention to time problems and the increasing relevance of urban time policies. It offers policymakers a useful instrument to identify the margins within which access to services can be improved by temporal changes to service delivery. The approach could for instance be applied to maximize the accessibility to services experienced by particular (vulnerable) subgroups of the population. This would allow local authorities to gain insights into how they can maximize the accessibility of their public services by reconfiguring the opening hours to particular target constituencies within society. 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) have found that men tend to make up a greater share of the visitor population in libraries opened on four or five evenings a week (Monday–Friday) as these opening hours allows them to better combine library visits with full-time employment. With this in mind, an interesting avenue for future research would be to examine to what extent rescheduling the opening hours of public libraries may help to increase the accessibility to lower-educated visitors.

Although our optimization method has a sound and generic theoretical basis, a number of refinements could be made. First, more attention could be given to delay times encountered along the route due to vehicle parking, queuing, arriving ahead of the opening hours, etc. Further, a minimum activity duration could be introduced to eliminate locational benefits from infinitesimal activity durations, which seems useful for many types of activities (e.g. no utility can be derived from a one-minute library visit). Second, our approach has ignored the influence on travel costs of the potential added/decreased traffic volume that is induced locally due to the rescheduling of opening hours. While these effects could be neglected for facilities with a limited number of visits, such as government offices, they may become significant for large commercial (e.g. shopping malls, cinemas) or healthcare (e.g. hospitals) facilities. Third, while the accessibility measure used in this paper already captures a high degree of spatiotemporal behaviour, additional behavioural aspects warrant more attention in the definition of the locational benefits as expressed in eq. [4]. These aspects relate in particular to the valuation of the attractiveness and the possible activity duration. Whereas both components have currently been assumed directly proportionate to individual accessibility, behaviourally more appealing functions have been proposed to express this relationship. Examples include sigmoid functions for the relation between activity duration and utility that account for both a warming-up phase and satiation effects (Joh et al., 2001; Ettema et al., 2004). 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. Hence, the sample size should not only be representative for the considered population but should also be large enough to suppress the bias resulting from the observation of occasional activity patterns. Ideally, longitudinal data covering multiple days or even weeks should be used to verify the consistency of activity patterns over a longer time horizon. In this respect micro-simulation methods for deriving synthetic populations could be helpful since they allow for the generation of large sets of representative activity patterns for populations over long time horizons. Of course, the assumptions underlying these methods also heavily rely on revealed activity behaviour that possibly exhibit similar distortions. 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 maximize potential visitors' opportunity to pursue activities at facilities across cities and regions.

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