1 INTRODUÇÃO

O planejamento dos sistemas de transporte como um caminho para o desenvolvimento da mobilidade urbana sustentável é um tema discutido em todo o mundo. Muitas regiões metropolitanas enfrentam problemas similares provocados pela aglomeração não planejada de pessoas nos grandes centros urbanos. Segundo estimativas da ONU em 2030 aproximadamente 60% da população mundial estará vivendo em áreas urbanas. [1] page 9 Arthur D LItte.

No Brasil o crescimento da população economicamente ativa incentivou uma migração para os grandes centros urbanos, promovido pela ampliação do número de polos de emprego, serviços, cultura e lazer. Tudo isso ocorreu de forma desordenada quanto ao uso e ocupação do solo, o que gerou uma demanda por deslocamentos sem a elaboração de estudos de planejamento de transportes. Esses fatos levaram o Brasil a uma crise em sua mobilidade urbana, visto que a maior parte dos grandes centros urbanos do país encontram dificuldades em desenvolver meios para reduzir os congestionamentos e amenizar seus impactos. [2] pg 45 SEGURANÇA NAS INTERSEÇÕES URBANAS: VLT x VEÍCULOS

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O aumento dos congestionamentos nas cidades resulta em frustração de motoristas, tempos muito maiores de viagem, diminuição da produtividade da população, aumento no número de acidentes e nas taxas de seguros para automóveis, mais consume de combustível, maiores taxas de fretes e entregas e deterioração da qualidade do ar. [3] A Self Instructing COurse in ...

Em face destes problemas, é natural que a população voluntariamente busque a utilização de modais alternativos e exija maiores investimentos em políticas públicas que facilitem os deslocamentos dos cidadãos, como por exemplo, a extensão de ciclovias que possibilitem a condução de bicicletas de maneira mais segura.

Dentro deste contexto, este trabalho discute a construção de um modelo desagregado de escolha de modais no âmbito do Município do Rio de Janeiro, bem como propõe a visualização deste modelo através da implementação de um aplicativo para dispositivos móveis com sistema operacional Android.

* 1. Definição do Problema

O objetivo deste trabalho é discutir um modelo de escolha de modais para a cidade do Rio de Janeiro com o intuito de auxiliar a população nas tomadas de decisões levando em conta fatores microscópicos – características individuais dos viajantes ou atributos da viagem – tais como as alternativas de transporte oferecidos pela cidade, o tempo de deslocamento, o custo do deslocamento, a região de origem, a idade e a renda do viajante.

Além disso, pretende-se implementar um aplicativo que possibilite a visualização de uma versão simplificada do modelo proposto a fim de produzir uma ferramenta de utilidade pública capaz de facilitar as escolhas de modais diárias dos cariocas.

* 1. Justificativa

Trânsito. Aumento da qualidade de vida. Passar mais tempo com entes queridos. Mobilidade Urbana Sustentável. Consciência Cidadã.

* 1. Contribuições

Ferramenta de utilidade pública.

* 1. Estrutura do Trabalho

1. Revisão Bibliográfica

Discorrer sobre trabalhos anteriores acerca de mobilidade urbana e suas motivações

O estudo da dinâmica e da mobilidade das cidades motivado pela necessidade

Muitos analisam a mobilidade urbana nas cidades

Transportation is the backbone of our civilization and cities invest a lot of money for maintenance and improvements of public transport infrastructures. Research in this field is essential to develop sustainable cities and several factors need to be taken into consideration. From an *economical* perspective, cities administrations look for solutions to reduce the cost of the service and to improve its efficiency. From a *social* perspective, a Public Transport System (hereafter, PTS) ensures that all citizen are able to travel. From an *environ- mental perspective* PTS allows to save more energy compared to private transport. [vispts]

* 1. Escolha de Modais.

Travel mode choice have been widely investigated based on the random utility maximization theory and choice behavior theory, such as discrete choice model [1-3]. The essential concept of travel mode choice models is to understand the relationship between traveler’s choice and the contributing factors, such as the social-economic level and service level of modes

The factors that contribute to travel behaviors mainly fall into two categories: the macroscopic and microscopic factors [8,9]. The macroscopic factors are normally determined by the characteristics of the society, which include economic level, urban land use, etc. The microscopic factors are related to the individual traveler’s characteristics and travel attributes. They include travelers’ age, income, travel time, travel cost, etc. In regard to the macroscopic factors, Dowing and Gollner [10] investigated the effects of economic level, culture and environment on female’s mode choice and found that female motor vehicle use is increasing at a disproportionate rate to men's. In terms of the microscopic factors, many previous studies found that traveler age is a significant contributing factor to the travel behavior [8, 11-13]. It was found children’s increasing car travel are probably the most easy-changeable because their travelling are likely to be highly dependent upon the household’s social-economic characteristic. In addition, age, income and life stage have significantly different and interactive influences on the travel mode choices [14]. Nicolau [15] found income, family size and education have great effects on travel decision c. Bowman and Ben-Akiva [16] took age, income, travel time and cost as the mode choice variables to predict passengers’ travel behavior. Syam et al. [17] studied the mode choice behavior of travelers with a multicultural society and found that face took an effect on mode choice, for example, New Zealand Europeans are the largest group in car use. Compared with the microscopic factors which are individual dependent, the macroscopic factors are much more stable in a specific region and a certain period of time. In regard of the relative stability of the macroscopic factors, this study mainly focuses on the effects of the microscopic factors on the travel mode choice.

According to the existing researches and surveys, the microscopic factors affecting travel choice behavior can be categorized as personal attributes and service of travel mode [8, 10, 18, 19]. Travelers’ social-economic attributes include race, age, income, car ownership and occupation. Overall, travelers with higher income would like to choose a more comfortable mode. The car ownership largely determine if a traveler need to choose a public mode. In addition, it is likely commuters prefers travel modes with punctuality, such as the metro. The service of travel mode include travel cost, travel time, comfort and accessibility. For transit users, the cost is ticket fare, while the cost includes the fuel cost and the parking fee for car travelers. The travel time of transit users include the walking time to the station, waiting time, the time on board, transfer time, and the walking time to the destination. For car travelers, travel time include the walking to the parking lot and the in-vehicle time. It is regarded that car travel is more comfortable than the transit. Normally private traffic has a higher accessibility than the transit except for some special regions for personal vehicle forbidding.

The attitudes on travel time, cost, and the service level of the trip normally vary for travelers from different groups. For example, females and elders may regard comfort as the primary concern, while punctuality is the most important factor for commuters. Kevin [20] and Abolfazl [21] investigated females’ mode choice behavior and found that females have lower commuting use rate compared to male. Their findings are consistent with other studies showing that females have higher rates of leisure travel [22]. The study by Cutler [23] showed that elders’ accessibility reduces with the increase of age, and the reducing rate of elder females is fast than elder males. That is a possible reason why elder males prefers to drive but elder females prefer the transit by community [24].

In addition to the group division based on personal characteristic, group divisions based on other contributing factors have also been investigated. Tsamboulas [25] divided travelers into two groups based on parking payment type (hourly parking payment and monthly parking payment) to study the travel behavior. The study found that: 1) there are similar characteristics within the group; 2) travelers in the group of hourly parking payment are easier to change travel behavior than the other group. Trip behaviors in Chicago, divided into two groups (work trip and non- work trips) were also studied [26]. They found there are similarities between commuters’ and non-commuters’ travel behavior. However, a number of attributes such as station/stop security, lighting/safety and proximity to services et al. are considered more important by non-commuters (compared to commuters).

* 1. Visualização de dados de mobilidade

Various systems have been developed and used to visualize mo- bility data, and to reveal time-varying patterns. However, these ei- ther are complex visual analytic tools for urban planners or trans- portation experts, or only depict one traffic situation at a time, and show travel times independent of temporal traffic variations. [isoscope]

Most of the techniques present in the literature seems to fo- cus more on visualizations that help to understand the system usage and to improve urban planning, rather than to improve the usability and accessibility of the system for the travelers. [vispts]

When designing a visualization of Public Transport data, it is important to determine what tasks it needs to support. The tasks that the visualization has to support depend also on the end user. I identified two kind of users, namely the traveler and the transportation researcher. [vispts]

4.1. Traveller

The root of all the tasks that a visualization targeted for a traveler should support is *wayfinding*. When it comes to wayfinding every person has different capabilities and a vi- sualization tool needs to take this into account.

Travelers every day use the PTS for their journeys through the city, therefore they need to find a path from an origin to a destination. However, we need to take into consideration other factors such as user needs; for example a tourist might want the most enjoyable path, but a worker would probably prefer the journey that takes the least amount of time.

I have interviewed Jakob Erikkson, a transportation re- searcher that now is working on a project that has to do with improving access to transit, both in terms of on-demand rout- ing of vehicles, and in terms of better navigation support for transit users. An ideal result for his research would be a dra- matic improvement in the ease of use and efficiency of transit services and a tool to support navigation, such as an ambient

*Massimo De Marchi / Visualizing Public Transport Systems*

display on a wall [PS06], which allows passers-by to plan a real-time route through the transit network at a glance. He also mentioned Gnuplot [gnu] and Google Earth [gooa] as common tools that he uses to make sense of the data.

The visualizations described in section 5, enables the follow- ing tasks:

* Find the best journey in terms of time efficiency from the departure location to the arrival location.
* Find the journeys with the minimum waiting time at the departure and/or transfer stations (some users might pre- fer to take a longer ride rather than waiting more time at the station).
* Find the most "enjoyable" path from the departure station to the arrival station (the term enjoyable has not a unique measure and depends on the context [QSA14]).
* Show all the possible journeys from the departure point within a certain amount of time.  4.2. Transportation researcher  Transportation researchers would like to explore several as- pects of a PTS, such as the degree of connectivity of the network, the travel efficiency of a city, etc. Exploiting these information researchers are able to understand which areas of the city are less developed, find out inefficient usage of the PTS, understand what facilities are lacking and make predic- tions on the behaviors of the system.  I have interviewed Gennady Andrienko, an expert of visual analytics of movement, and he reported that a predictive and descriptive model for mobility would be an ideal result for his research. This reflect the fact that transportation re- searchers need tools able to predict the behaviors of travelers and of the system.  A list of the common tasks that a visualization tool that aim to help transportation researchers needs to support has been obtained analyzing the tasks that the tools in section 5 sup- port.
* Given a departure location, show reachable destinations within a given time span (this is important to answer ques- tions regarding the accessibility of a city, for example "how long does it take to get to the closest hospital?").
* Show possible routes that connects the origin location to the destination.
* Show and compare travel time of different routes.
* Display useful information along the routes, that are mo- bility factors such as waiting time at the transfer station, riding time on a vehicle, transfer time to walk to the next  transfer stop, etc.

Show accessibility to the primary activity centers of the  city.  [vispts]

* + 1. Isócronas

Isochrone maps [iso] are traditional visual representations used in transportation to show regions of equal travel time from a given departure location. Isochrone maps usually are visually encoded using colored contours and can be eas- ily overlaid on geographical maps. This technique is used in the literature [OMS00] [WFNH15] to represent accessi- bility information at a coarse grain, in fact is very difficult to use this technique to estimate precise travel time. More- over isochrone maps cannot reveal other mobility factors and therefore are often used in combination with other tech- niques, such as in the work of Zeng et al [ZFA⇤14]. [vispts]

Isochrone maps [39], or isochrone diagrams, are traditional visual rep- resentations used in transportation and urban planning for showing ar- eas of equal travel time from a given starting location. Isochrone maps usually employ contour lines/colors in its representation, and can be easily overlaid on geographical maps for depicting information such as accessibility [26, 12]. However, isochrone maps alone are insuffi- cient for revealing the exact travel time and routes from the starting location, as well as other mobility-related factors. [vispts, zeng]

Isochrone maps are an established method to depict areas of equal travel time, and have been used in transportation planning since the early 20th century. In recent years, interactive isochrone maps al- lowed users to select areas of interest, or explore temporal mobility patterns for different modes of transport. However, conventional isochrone maps depict one traffic situation at a time.

Isochrone maps (greek: *iso* = equal, *chronos* = time) show isolines on a map, connecting points that have the same travel time from a

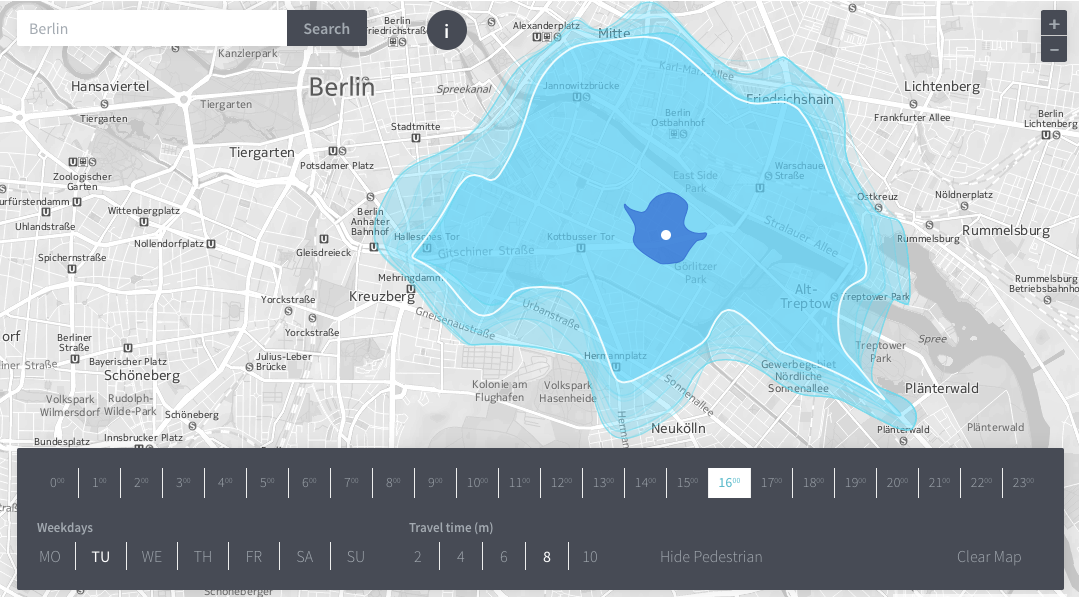


Figure 1: User interface with a) search bar, b) the main map with an Isoscope in Berlin, c) the 24 hours time selector, and d) additional buttons to select week day, travel time, and transport mode.

specified location, i.e. which can be reached within the specified time or less. For ground travel, they are typically following trans- portation routes such as roadways, or foot paths.

Isochrone maps for travel time have been displayed as subgraph in a road network [2], or as isolines [6]. The most common isochrone maps use multiple isolines to show travel time for differ- ent time spans (however without showing temporal variations).

In recent years, interactive travel maps have been created to explore urban transportation. Mapnificent [5] visualizes reachability by public transport in a given time. It uses time-table data to com- pute reachable area, and displays them as uncovered bubble shapes, while the rest of the map is grayed out. Public Transit Travel Time [7] uses heat maps to show transit travel times. In contrast to ide- alistic time table data, Isoscope incorporates actual road traffic data collected from sensors. And while both maps are available in major cities, due to our use of a traffic API with global range, Isoscope is applicable worldwide. The most important distinction, though, is that Isoscope is capable of revealing deviations in the reachable area due to changes in traffic conditions. [isoscope]

* 1. Analise de tempo/custo de deslocamento em cidades.
  2. Visualização de dados em dispositivos móveis

Talvez focar em mapas mobile!

1. REFERENCIAL TEÓRICO
   1. Modelos de Escolha de Modais

*Travel Mode choice model*

A simple Multinomial Logit (MNL) model was applied in this study for the travel mode choice analysis. The variables used in the utility functions include:

* Walking time: only for transit.

Waiting time: only for transit.

* In-vehicle time: only for transit.
* Fare: only for transit, it is the public transit’s ticket price.
* Comfort: only for transit, including three levels, very comfortable with seat, no seat but with some freedom of  movement, no seat also very crowded.
* Travel time: only for car users.
* Cost: only for car users, including fuel cost and parking fee.  An individual traveler is assumed to choose the travel mode with the maximum utility from different travel modes of 1 to J. A utility known by the traveler is expressed as *Unj ,* *j = 1,L,J* , as shown in Equation 1.  *Unj =Vnj +enj* (1)  where, *Vnj* is a function of the measured attributes which is also called Representative Utility; *enj* is the unobserved attributes.  The variables in the utility function are composed of travelers’ trip attributes. The travel information of the transit users includes waking time, waiting time, in-vehicle time, fare, and comfort; while the travel information of the car users include travel time and cost. Normally, the utility function is linearly correlated with its variables. The utility function for traveler n, alternative mode j is expressed as Equation 2 [30, 31].

*Vnj* *Xnj* *=åbkXknj =b1X1nj+b2X2nj+L+bKXKnj =b'Xnj k*  (2)

where, *X =(X ,X ,L,X )*, is a vector of attributes for alternative j, and*b =(b ,b ,L,b )'* , is a vector of

estimation coefficients. Based on the travel information from the RP/SP surveys, the estimation coefficients of each attributes can be

obtained through the regression using Biogeme. This procedure was taken for each group. The estimated mode choice can also be obtained based on the comparisons of the utilities of the transit travel and car travel. The estimated mode choice of each traveler was compared with the mode choice he/she claimed in the RP/SP survey to understand the accuracy of the prediction model. In addition, the estimation results of the proposed model using individual grouping was compared with that without grouping to know if individual grouping improves the estimation accuracy.

* 1. Isócronas e Isodistâncias
  2. Fecho Convexo

a region is convex if any two points of the region are visible to one another within the region. In this chapter, given a set of distinct points *S*, we are interested in constructing its *convex hull*. We can visualize the convex hull intuitively: if each point of *S* is a nail pounded into the plane, the convex hull is the region enclosed by an elastic rubber band stretched around all the nails. Figure 2.1(a) shows a nonconvex region containing a point set *S*; part (b) shows a convex region enclosing *S*. The convex hull of *S* is given in Figure 2.1(c). There are numerous practical applications for finding the convex hull, including collision detection, Geographic Information Systems (GIS), and pattern recognition.

Based on the intuition provided by the rubber-band analogy, the convex hull is the smallest convex region containing the point set *S*. The notion of “smallest” can be formally captured as follows.

Definition. The *convex hull* of *S*, denoted by conv(*S*), is the intersection of all convex regions that contain *S*.

Theorem 2.2. *For a point set S* = {*p*1,..., *pn*}*, the convex hull of S is the set of all convex combinations of S.*

*Proof.* Let *M* be the set of convex combinations of *S*. Formally,

*M*= λ1*p*1+···+λ*npn* λ*i*≥0, λ*i*=1 .

In order to prove conv(*S*) = *M*, we show conv(*S*) ⊆ *M* and *M* ⊆ conv(*S*).

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2.1 CONVEXITY **35**

PartI:conv(*S*)⊆*M*.Itiseasytoseethat*M*contains*S*.Ifλ*i* =1andall others are 0, we get *pi* in *M*. Thus, if we can prove that *M* is a convex region, then conv(*S*) ⊆ *M* since conv(*S*) is the intersection of all convex regions containing *S*. Let *x* and *y* be any two points in *M*; we need to verify the segment *xy* is in *M*. Since *x* is in *M*, it can be written as

*x*=λ1*p*1 +···+λ*npn* , (2.1) where λ*i* ≥ 0 and λ*i* = 1. Similarly, *y* can be written as

*y* = λ ′1 *p* 1 + · · · + λ ′*n p n* , where λ*i*′ ≥ 0 and λ*i*′ = 1. Moreover, any point of the segment *xy*

can be expressed as α*x*+β*y*=α λ*ipi* +β λ*i*′*pi* = (αλ*i* +βλ*i*′)*pi*,

forα≥0,β≥0,andα+β=1.Because(αλ*i* +βλ*i*′)≥0,and (αλ*i* +βλ*i*′)=α λ*i* +β λ*i*′ =α·1+β·1=1,

it follows that the segment *xy* is in *M*. Thus *M* is a convex region.

Part II: *M* ⊆ conv(*S*). We show that any point in *M*, which may be expressed as in equation (2.1), is in conv(*S*) by induction on *n*. It is clear this is true when *n* = 1; then *M* = conv(*S*) = *p*1. Assume it is true for every point set *S*′ containing fewer than *n* points, and now consider the set *S* with *n* points, *p*1, . . . , *pn*. By the induction hypothesis, any point

*x*=λ′1*p*1 +···+λ′*n*−1*pn*−1 isinconv(*S*′)⊂conv(*S*)ifandonlyifλ′ ≥0and λ′ =1.Nowwe

*iii*choose λ*i*′ = λ*i*/(1−λ*n*) because λ1 +···+λ*n*−1 = 1−λ*n*. Note that

we still satisfy the conditions above. And because conv(*S*′) ⊂ conv(*S*), we know that *x* is in conv(*S*). Because *pn* and *x* are both in conv(*S*), and since conv(*S*) is convex, then any point in the segment *xpn* is in conv(*S*). Thus

λλ  (1−λ*n*) 1 *p*1 +···+ *n*−1 *pn*−1 +λ*npn* =λ1*p*1 +···+λ*npn*

1−λ*n* 1−λ*n* is in conv(*S*), where λ*i* = 1.



This theorem gives considerable insight into what constitutes the convex hull, but it is not yet algorithmic. We turn to our first algorithm in the next section.

* 1. Forma Alpha e Fecho Côncavoo
  2. Fórmula de Haversine