INSTITUTO SUPERIOR TÉCNICO
Universidade Técnica de Lisboa

IMPROVING PEDESTRIAN MOBILITY IN CITIES OF UNFAVORABLE OROGRAPHY

Campo dos Mártires da Pátria in Lisbon - a Study Case

L. Magalhães, M.R. Macário, P.F. Teixeira

Department of Civil Engineering and Architecture (DECivil), Instituto Superior Técnico, Universidade Técnica de Lisboa

October 2010

ABSTRACT

The aim of this work is to examine the feasibility of introducing escalators in three areas that allow pedestrians to access *Campo dos Mártires da Pátria* in Lisbon. To achieve this end, the cost of each piece of escalators throughout its lifecycle was estimated as well as time saved on trips with the installation of these systems in each area. Based on the time value of an European study, the number of trips required to monetize the system was determined and using pedestrians' counts carried out in the study areas it was found that in only one of these areas is not expected to reach the number of necessary trips. The valuation of dwellings in the study area due to improved accessibility to the subway with the introduction of escalators was also determined based on a hedonic price model, allowing concluding that the capture of two thirds of this recovery finances all of the escalators segments offered throughout the lifecycle.

Keywords: Urban Mobility, Assisted Itineraries, Feasibility Analysis

INTRODUCTION

Pedestrian mobility was forgotten for many years as a mode of transportation that requires planning care and a prominent place in cities organization [1] as its integration with other modes was not always ensured [2]. The arrival of automobile has brought benefits to individual mobility but also disadvantages that cannot be ignored, for example the occupation of large amounts of space to circulate and parking, preventing many elements dedicated to social and cultural activities take shape in this space [3]. This occupation affects the quality of life in cities on many aspects, reducing spaces to stop and gathering outside to enjoy the pleasures of life in society. This may not seem important before the imperatives of transport but the necessity of meeting is what leads people to live together and not alone [4]. The priority given to motor traffic has reduced mobility options in the city since at this point walking is uncomfortable, cycling is dangerous and bus proves to be slow especially at the peak-hours. For the captive users of public transport there is no alternative and for the automobile users there are no attractive solutions. This vicious cycle must be ended and the correct way is to recognize the pedestrians as a central element of urban mobility and the public space as the essential infrastructure. The goal is not to eradicate the car but find a balance that ensures to citizens the right to choose [5].

Walking is the basic method of travel and also the healthiest one. Allows great freedom of movements and the use of various routes for the same origin-destine pair, easy changes in direction and speed, stops at any desired point, the required space is minimum when compared with other modes and pedestrians have a great versatility to adapt their march to paths' conditions. However, presents important limitations such as the speed which assumes different values depending on the age and circumstances of the trip, the scope of this mode is reduced and pedestrians are at the mercy of weather conditions and terrains characteristics, factors that may reduce the willingness of move on foot [6]. Pedestrian infrastructures must meet a series of quality criteria. They should be functional, linking different transport modes and the main focuses of travel without unnecessary detours, safe with regard to the interaction between vehicles and pedestrians and for antisocial behaviors, comfortable to move presenting moderate slopes and protection against weathering, with the appropriate materials in the floor

and urban furniture, attractive working as a promotional tool of social, cultural and recreational services. The proper location and accessibility are also key factors to the success or failure of a pedestrian area [7].
The use of mechanical means in cities with huge slopes to aid in pedestrian movements enhances walking, reducing the physical wear and the discomfort of people [8]. The most common mechanical means to support pedestrian movements are escalators, conveyors, funicular, elevators and cable cars. Each system has different characteristics and strengths which allow choosing the best solution for each case depending on the local circumstances [9]. There are several examples of successful integration of these systems such as escalators in Toledo (Spain) and Barcelona (Spain), conveyors in Victoria-Gasteiz (Spain) and an elevator in Teruel (Spain).
Given the initial required investment and the operating cost of these systems, before the decision to plant it in a certain area of the city, it is necessary to estimate the levels of demand in order to ensure that pedestrian flows and the attractiveness of the infrastructures in the study area justify the investment. It is also important to examine ways to finance these systems. When people shift the time spent travelling for leisure or work, positive changes happen in their welfare. There are several examples of people's willingness to pay to see their time on trips reduced. It is thus evident that the saving in travel time has an associated value but its determination is not simple and requires aspects of economic thought [10]. This could be a way to finance the referred mechanical means since they allow a saving in travel time. Accessibility has an important role on location of services and housing choice. An area with good accessibility is quite popular so the cost of real estate is high [11]. The installation of escalators generates substantial improvements in accessibility which causes an enhancement of properties in the surrounding area and the dwellings in the vicinity of this system will be closer to much more parts of the city. This value should be captured at least in two thirds of his total for the local administration, responsible for the installation and management of this mechanism. It is also possible to use advertising as a contribution renting spaces for advertisers on the sides of escalators and its steps, increasing the budget available to fund these systems.

OBJECTIVES AND METHODOLOGY

The aim of this work is to study the feasibility of escalators introduction in three areas of Lisbon that allow access to *Campo dos Mártires da Pátria* (CMP) which is located on a hill. Figure 1 shows a digital terrain model where it is possible to observe the level at which CMP is.

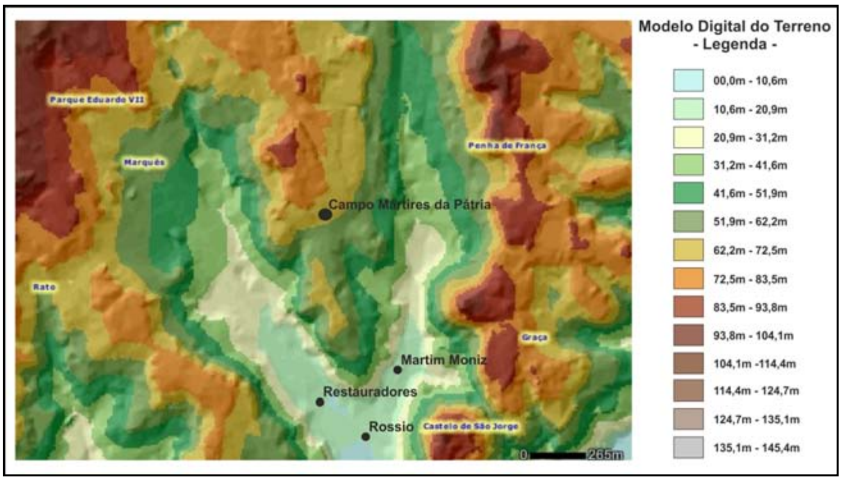

Figure 1 - Digital terrain model of the study area [12]

CMP presents itself as an area primarily for residential use but also some trade and services which are example a hospital and the Rectorate of Technical University of Lisbon. It is a pleasant place that has a garden at its center and rehabilitated buildings that hold the historic facades with a high proportion of young population who has economic power. Along the hill there are a significant percentage of elderly people struggling to walk through the winding streets that connect their homes to downtown. In downtown it is possible to find a large number of shops and services as well as theatres, museums, subway and railway stations among others.

Current Situation

The paths most currently used by pedestrians were determined and their characteristics analyzed with regard to traffic conditions and coexistence between different modes of transport. Figure 2 shows a map where the six analyzed paths are marked with different colors.

Figure 2 – Map with the six analyzed paths marked

Path 1 (leftmost in figure 2) presents motor traffic from the base of the hill to CMP and mostly narrow sidewalks with a high flow of pedestrians. The length is about 450 meters with an altitude difference of 40 meters. Path 2 has motor traffic just in a small part (street that leads to CMP) and a high flow of pedestrians. This path has the peculiarity of possessing one funicular (the *Lavra* Funicular) that transports users until roughly halfway. For those who do not want to spend money on the funicular it is necessary to climb over than 150 steps. Sidewalk is very narrow in the first 90 meters and in the last 150 meters is mostly occupied by parked vehicles. The length of this path is similar to the first and the altitude difference is the same. Path 3 presents an altitude difference of almost 65 meters in the first 200 meters of length which is mostly covered by several steps totally dedicated to pedestrian traffic (*Beco de São Luís da Pena*). In the last 300 meters the altitude difference is only about 5 meters and motor circulation arises only in this part which has sidewalks with acceptable width. Also on path 4 the altitude difference in the first 200 meters of length is almost 65 meters through streets that pedestrians and vehicles share with very narrow sidewalks. Like the first path this one has some shops in the streets. Path 5 has approximately 500 meters long, begins in an area called *Martim Moniz* and its total altitude difference is about 70 meters. In this path the motor traffic is intense and sidewalks are extremely narrow in the first 300 meters, hardly able to support a pedestrian safely. Path 6 presents high pedestrian and motor flows during all day and the altitude goes up gradually throughout the length.

Given the current situation it was decided to intervene in the three following areas: *Lavra* Funicular, *Beco de São Luís da Pena* and *Martim Moniz*. The objective of these interventions is the improvement of pedestrian mobility reducing the discomfort associated with these paths due to physical wear and large travel times. After an analysis of local conditions and also the characteristics of the support systems available to help in pedestrian movements, it was decided that escalators corresponded to the most viable option since that all areas already have stairs. For each area were set one, two or even three proposals for the escalators installation depending on the local specifications. Intervention area 1 (near *Lavra* Funicular) has two alternative proposals with escalators in both directions (*Jardim dos CTT-Jardim do Torel* and *Calçada do Lavra+Jardim dos CTT-Jardim do Torel*) due to the higher pedestrian flows. Intervention area 2 (*Beco São Luís da Pena*) has just one proposal for upward. Intervention area 3 has three proposals, all for upward, where proposal 2 (*Travessa do Colégio+Calçada Nova do Colégio*) is an upgrading of proposal 1 (*Travessa do Colégio*) and proposal 3 (Travessa do Jogo da Pela+*Calçada Nova do Colégio*) is an alternative to the others.

Feasibility Analysis of Escalators Installation

The methodology used to analyze the feasibility of the escalators installation in the three intervention areas is divided in two parts: one in which the number of trips necessary to make the system viable is determined and another where the appreciation in real estate with the escalators introduction is estimated (with the aspiration of capturing part of this amount to finance the system).

First Part – Escalators Viability

In this part the goal is to determine the number of necessary trips during a day to cover escalators costs. To achieve this end, the analysis starts by measuring the current travel time on places where the escalators will be and for which the altitude difference between the beginning and the end is known. Hereafter the journey time using escalators was estimated based on a linear relationship, using the time measured on *Baixa-Chiado* subway station escalators to which altitude difference was known. The costs of each escalator segment were determined considering the installation, maintenance and cleaning portions. These portions values are based on information courtesy of an entity that manage outdoor escalators [13] and also from other sources. The values are shown in table 1.

Portions	Observations	Value
Installation Costs	For commercial reasons it was not possible to obtain this true value so the used one is based on projects developed in Barcelona and Lisbon	160.000,00 €
Urban Arrangements Edge	5% of the Installation costs	8.000,00 €
Maintenance Costs	Sum of the annually updated maintenance costs until 2025 considering an increase of 5% of the initial cost (based on [13]) in last 5 years	104.502,77 €
Cleaning Costs	Sum of the annually updated costs until 2025 (2 persons, EUR 7 per person per hour, 2hours per week)	13.950,26 €
	TOTAL (for one segment in the entire lifecycle)	**286.453,03 €**

Table 1 – Values of each portion of cost for escalators

With Barcelona *Ayuntamiento* was possible to define a range for the installation cost of each escalators section. Based on the cost of installing escalators in Portugal, informally investigated since the contact with some companies proved fruitless, the decision was to use the minimum value of the range (still superior to Lisbon values) and add a margin of 5% to reflect the cost of urban arrangements. In the maintenance costs amount was considered a 5% increment in the last five years of the lifecycle due to wear of the material. The cleaning costs were estimated since the true value was not possible to determine.

Since escalators lifecycle is fifteen years [13], it was necessary to update their costs based on equation 1.

$$Updated\ Cost = \frac{Cost}{(1 + Discount\ Rate)^t} \qquad \textbf{\textit{(1)}}$$

In this equation, *t* represents the actualization time in years and the discount rate used was 5%. This is an indicative value which was chosen with the attempt to portray the current and future situation.

The determination of the necessary trips that makes the system viable, or in other words the number of trips required to generate a monetary benefit equal or above the escalators' costs, is based on multiplying the value of each unit time (in Euros per minute per trip) by the time saved on each trip (in minutes per trip). The considered time value was taken from an European study which aims to standardize the determination of costs in transport projects on European Union [14]. The values for work trips on bus and non-working trips also on bus for Portugal are presented in table 2.

	Passenger Working Trips on Bus	Passenger Commute Non-Working Trips on Bus	Passenger Short Non-Working Trips on Bus
$€_{2002}$ / Passenger / Hour	15,52	4,81	4,03

Table 2 – Time Value for Passenger trips on Bus in Portugal [14]

Non-working trips are divided in two categories: short and commute. Bus travel time values were chosen for being the most suitable although not conforming to walk (which is expected to be lower) since that the options were train, plane and car travel time values which are much bigger. The time value adopted corresponds to non-working trips inasmuch as the nature of most trips is not known and working trips time value is substantially higher than the chosen value, so a conservative posture analysis was taken. As the time value in the European study was for 2002, it was necessary to update it to current year (2010) and then throughout escalators lifecycle based on equation 2. In this equation, the discount rate used was 3%. This value intends to reflect the increased value of time over the years due to rising wages and living conditions of citizens.

$$Updated\ Value = Value * (1 + Discount\ Rate)^t \qquad \textbf{(2)}$$

The following is the explanation of the methodology adopted to assess the feasibility of each proposal to install escalators in the three intervention areas:

1) Time saved with the introduction of this system was determined by subtracting the estimated time in escalators to the current travel time;
2) The annual maintenance costs were updated annually until 2025 (end of lifecycle) taking into account that for the last five years it was assumed a base value 5% higher. This update was based on equation 1 with a discount rate of 5%;
3) It was assumed that one hour of cleaning has a cost of EUR 7 per person and based on this, the annual cost of the cleanup was determined and subsequently annually updated until 2025 according to equation 1 with a 5% discount rate;
4) Proceeded to the sum of maintenance and cleaning costs, updated every year, with installation costs plus 5% (urban arrangements margin), and then divided the obtained value for 15 which is the lifecycle number of years. This allowed to find the annual costs of an escalator segment;
5) Then proceeded to the division of the value obtained in the previous point by 365, number of days in a common year, and next divided by 14, number of hours that the system will be daily operational (between 7h30 and 21h30) in order to determined the hourly cost of operating an escalator segment which is shown in table 3;
6) The updated time value for 2010 (in Euros per hour) was updated annually until 2025 based on equation 1 and then all of these values were sum. This sum was divided by 15 to obtain the average value for the time period under analysis and further divided by 60, to convert to Euros per minute. The result is presented in table 3;
7) Finally, based on the number of escalators segments that take place in each one of the proposals, the total cost per hour was defined which results from multiplying the hourly cost of a segment obtained in point 5 by the number of considered segments. Then the number of trips required during an hour to monetize the system was determined. This number of trips results from the integer that allows multiplying the value of one minute (table 3) by the saved minutes with the escalators introduction, achieving an equal or a higher value than the hourly total costs of the escalators in each proposal.

Second Part – Value Capture in Real Estate

As mentioned earlier, one possible way of financing the escalators throughout its lifecycle is capturing the appreciation introduced by them in buildings. To quantify this value generated it was used a study that focuses on the effects of transportation accessibility on residential property values using hedonic price model [15]. This study examines the relationship between proximity to transport infrastructure and property values of Lisbon urban area, reflecting the influence of structural characteristics of buildings (number of bedrooms, built year, etc.), neighborhood attributes (level of education, mixture of land uses) and accessibility attributes. Although this study allows estimating the price of a property based on the analysis of the accessibility to the train and to the road network, modifications and considerations will only be done about Lisbon subway accessibility. On structural and neighborhood attributes are also not made any changes.

Escalators reduce travel times approaching pedestrians to services and spaces in the city, helping to increase the influence of subway stations on the uptake of users. Considering these facts, the influence areas of some subway stations in the study area were delineated and knowing the travel time on foot to access these subway stations before and after escalators introduction, the appreciation in real estate is determined.

<u>Delineation of the Subway Stations Influence Areas</u>

The subways stations considered that belong to the study area are four: *Avenida*, *Restauradores*, *Rossio* e *Martim Moniz*. *Avenida* and *Restauradores* stations belong to one subway line, *Rossio* and *Martim Moniz* stations belong to another line.

The delimitation of the influence areas was based on *Network Analyst* extension of the geographical data treatment software *ArcGIS*, which allows the definition of service areas based on travel times for one or more

origin points [16]. Geographic information[1] met several features with all city streets and travel time on foot of the most relevant ones for this analysis and also contains characterization of the Base Geographic Information Referral (BGRI) in the study area which includes structural properties data (such as the number of houses and rooms) and statistical properties data (number of inhabitants, etc.). It was considered that the maximum time that a pedestrian is willing to walk to access a subway station is 10 minutes. This value allows defining the maximum limit of the influence areas and also the scope of this study. There have been several attempts to contact the Lisbon Subway for the purpose of corroborate or refute this limit but this has proved unsuccessful.
In first place, travel times in *ArcGIS* were checked in order to confirm if they were in agreement with those measured in the field. They were very similar to the obtained in most cases but corrections were necessary in a few streets. Finally, based on the *Network Analyst* tool the influence areas were drawn for 5, 7 and 10 minutes away from each subway station.

<u>Appreciation in Real Estate due to the Escalators</u>
As mentioned before, the appreciation in real estate with the introduction of escalators is based on a hedonic price model. It was considered a continuous decreasing function of impedance of proximity to subway entry points to measure accessibility of each BGRI and to model this continuous impedance, an inverse logistic function was used (equation 3) [15].

$$Y = \frac{1}{1 + \exp\big(a - b\ (Xmax - X)\big)} \qquad \textbf{(3)}$$

In this equation, *Y* is the value of accessibility and varies between 0 and 1. First value corresponds to the situation of null accessibility and the second to the "does not need to walk to the site" situation. The parameter *X* represents the time of access to transport infrastructure in minutes and *a* and *b* parameters were calibrated considering two different points in the curve (e.g., *X* = 5 min walking distance – *Y* = 0.90, and *X* = 15 min walking distance – *Y* = 0.10). *Xmax* is a specific parameter of each public transport. For the subway accessibility, the author of this model built equations 4 and 5 which calculate the accessibility to one subway line (*Y1*) and two subway lines (*Y2*), respectively, based on equation 2 [16].

$$Y1 = \frac{1}{1 + \exp\ (6{,}812 - 0{,}659(17 - X))} \qquad \textbf{(4)}$$

$$Y2 = \frac{1}{1 + \exp\ (4{,}394 - 0{,}439(20 - X))} \qquad \textbf{(5)}$$

In these equations *X* represents the time in minutes to reach the subway station. In the first case (*Y1*) to the nearest allowing access to one subway line and in the second case (*Y2*) the nearest allowing access to other line.
Once mapped the influence areas of subway stations, the BGRI that they intersect were determined counting both those which presented themselves fully or partially contained. This was done based on an automatic tool of *ArcGIS* program, counting 196 BGRI in total. For these BGRI, the value of each one as well as the accessibility values to one and two subway lines were provided[1]. Before evaluating the appreciation with the escalators introduction, it was necessary to determine new values for the subway accessibility in each BGRI and also its new monetary value in the current situation, since the origin accessibility values do not take the streets slope into account so travel times to access one or two subway lines are not correct. Thus, the current value of each BGRI was determined based on equation 6, where *Vcurrent* represents the current value of each BGRI without considering the escalators, *Voriginal* is the original value of each BGRI, *Y1original* and *Y2original* represent the original accessibility values to one and two subway lines, respectively. β1 and β2 are coefficients determined by the author of this model for accessibility to one and two subway lines, respectively, and β1 is equal to 0.0652 and β2 is equal to 0.0916. The accessibility values to one and two subway lines taking into account the actual travel times are represented by *Y1current* and *Y2current* and were calculated based on the access times presented in *ArcGIS* software.

$$Vcurrent = \exp\ (\ln(Voriginal) +\ \beta 1\ (Y1current - Y1original) +\ \beta 2\ (Y2current - Y2original)) \qquad \textbf{(6)}$$

[1] Information courtesy of [16] author.

Then, the access times to one and two subway lines of each BGRI considering the escalators were determined using equations 4 and 5 with the new travel times in order to calculate the value of each BGRI due to escalators introduction based on equation 7.

$$Vfinal = \exp\left(\ln(Vactual) + \beta 1\,(Y1final - Y1actual) + \beta 2\,(Y2final - Y2actual)\right) \quad \textbf{(7)}$$

In this equation, *Vfinal* represents the value of each BGRI obtained with the escalators introduction, *Vcurrent* the corrected current value of each BGRI without considering the escalators, β1 and β2 are the same coefficients of equation 6 and is worth 0.0652 and 0.0916, respectively. *Y1final* represents the value of accessibility calculated for one subway line for each BGRI in the escalators scenario and *Y2final* identical but for two lines.

RESULTS AND DISCUSSION

Here are the results obtained in the feasibility analysis (first part) and the determination of appreciation in real estate with the escalators introduction (second part).

First Part – Escalators Viability

Table 3 shows the determined hourly cost for an escalator segment and the updated time value.

Total costs of a escalator segment during its lifecycle (15 years)	286.453,03 €
Hourly cost of operating a escalator segment (14 hours)	3,74 €/hour
Time value	0,08 €/minute

Table 3 – The determined hourly cost for a escalator segment and the updated time value used on the analysis

Table 4 presents the results obtained for each proposal of the three intervention areas.

Study Areas	Proposals	Current time	Time with escalators	Time savings	Escalators Segments	Cost/h	Savings	Required trips/h	Required trips/14h
1	1	7,55 min	1,88 min	5,67 min	2	7,48€	0,46€	34 (both directions)	476 (both directions)
	2	7,55 min	2,07 min	5,48 min	4	14,96€	0,44€	51 (both directions)	714 (both directions)
2	1	7,00 min	2,05 min	4,95 min	4	14,96€	0,40€	38	532
3	1	2,20 min	0,62 min	1,58 min	1	3,74€	0,13€	30	420
	2	4,30 min	1,25 min	3,05 min	2	7,48€	0,25€	31	434
	3	4,25 min	1,23 min	3,02 min	2	7,48€	0,24€	31	434

Table 4 – Results for the required trips of each proposal

Pedestrians were counted at morning (between 8 am and 10 am) and afternoon (between 5 pm and 7 pm) peak-hours on the streets where it is proposed to intervene and in some cases also in the adjacent ones, in order to understand whether the existing number of trips is similar to the required to enable the system.

For proposal 1 (which has escalators in both directions crossing two gardens) in the intervention area 1, the required 17 trips per hour in each direction are quite tangible even outside the peak periods and also does not foresee any difficulties in securing over 14 hours of operation the 238 trips in each direction. Although for proposal 2 (which also has escalators in both directions but in the same place) the number of necessary trips is higher than proposal 1, it does not foresee difficulties in achieving it. Intervention area 2 has just one proposal and for this one the required 532 trips over the 14 hours of operation are not possible to reach with current pedestrian flow in the intervention street. However, the escalators installation will attract more pedestrians to this street from the surrounding ones. It is therefore important to do a study on the attractiveness of this proposal prior to its rejection. For proposals 1 and 2 in intervention area 3, the 420 and 434 required trips, respectively, are quite tangible at present due to the high pedestrian flow that leads to the hospital served by these proposals. But given that the hospital will close this flow can only be maintained if the use of this land is attractive to pedestrians. For that reason proposal 3 was created and it is understood that it is possible to satisfy the 434 required trips but outside of peak periods (in morning and afternoon) is difficult to be sure.

The relationship between the costs of each escalators segment and the number of segments must be confirmed with the supplier to verify if this is linear proportionally as supposed. It is probably that these costs can be

reduced. The fact of considering the costs of four escalators segments in proposal 2 of intervention area 1, for example, requires a higher number of trips that in proposal 1 which has only two escalators segments. It is important to examine the advantages and disadvantages of choosing fewer segments thereby reducing costs and the feasibility of the number of chosen segments.
The chosen discount rate for costs (5%) significantly influences the costs value obtained for each piece of escalators. If this was 7%, for example, the total costs of an escalators' piece along the system's lifecycle would become EUR 271,816.61 instead of EUR 286,453.03, which represents a reduction of nearly EUR 14,500.00 in costs. Also the discount rate assumed for the time value (3%) may not characterize the future situation and need to be increase or even decreased, although this scenario is less likely.
The fact that it was considered only the non-working passenger trips value makes the time value much less than it actually is since there are certainly people moving for professional reasons. However, it was not possible to know the percentages of people in each category of travel and for that reason a more conservative posture was adopted since working trips has a higher time value. It is also important to note that the time value used corresponds to commute trips on bus and time value on foot is expected to be lower.

Second Part – Value Capture in Real Estate
In this second part, the results for the delimitation of the influence areas of four subway stations in the study area and the calculation of the real estate appreciation with the escalators introduction will be presented separately.

<u>Delineation of the Subway Stations Influence Areas</u>
In figure 3 it is possible to observe the influence areas of the four subway stations (green polygons) without escalators and in figure 4 the same but in escalators scenario.

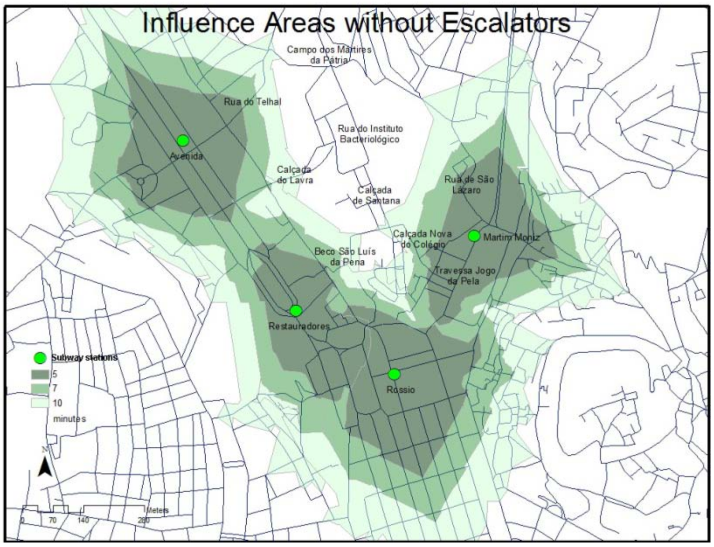

Figure 3 – Subway stations influence areas without escalators

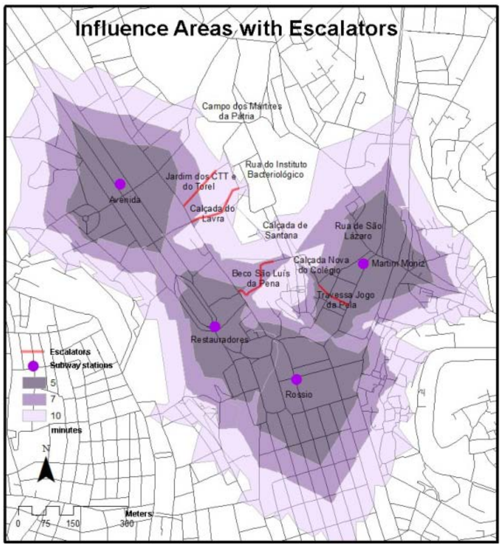

Figure 4 - Subway stations influence areas with escalators

In figure 3, for the study area (hill surrounded by drawn areas), *Avenida* station (far left) presents the influence area that goes on over the hill, reaching the beginning of the street that follows *Rua do Telhal* and about half of the *Calçada do Lavra* but not enough to reach CMP. The influence area of *Restauradores* station reaches almost all of the *Beco de São Luís da Pena* but not *Calçada de Santana*. *Rossio* station influence area serves the beginning of the *Calçada de Santana* but is the *Martim Moniz* influence area that serves up about half of this street and even much of the *Rua São Lázaro*.
In figure 4 it is represented the proposal 2 in intervention area 1 and proposal 3 in intervention area 3. The route in red leftmost does not currently exists. Compared with the situation without escalators there are significant changes. The influence areas increased, now covering all the steep streets of the study hill with just one exception (street below the word "Campo") coming even close to *Rua do Instituto Bacteriológico* whose slope is zero and leads directly to CMP. The introduction of escalators on *Calçada do Lavra* takes the influence area until the beginning of *Rua Júlio de Andrade* (street that starts where the leftmost red line ends) which in turn allows to reach CMP and shows no slope. With the escalators installation in the three intervention areas, CMP is now less than 15 minutes to four subway stations simultaneously and also all the services and stores in these areas, instead of the current 20 minutes.

Appreciation in Real Estate due to the Escalators

From 196 BGRI only 51 had changes in their accessibility values to one or two subway lines, or both, with the escalators introduction. In 17 BGRI the accessibility to one and two subway lines improved simultaneously, in 33 the accessibility to the second subway line increased and in 1 BGRI just the accessibility to one line improved. This increase corresponds to a decrease in travel times, resulting in properties approaching to the subway which encouraging walking and the use of public transport. The placement of escalators in the three intervention areas generates a total recovery in the 51 BGRI of EUR 4,445,353.73. Even if only two thirds of this recovery is caught, this amounts to EUR 2,963,569.15 which allows fully cover of the estimated costs for ten escalators segments throughout its lifecycle since these costs were estimated in EUR 286,453.03 per segment.

The 51 BGRI have 4354 housing units according to used data. Since the 10 escalators segments that are intended to install have a total cost of EUR 2,864,530.3 throughout their lifecycle, this would require that tax collection in the 51 BGRI ascend to EUR 3,744.5 per year which means that each housing unit contributes about EUR 0,86 per year over the Municipal Tax on Immovable Property (IMI). Although the value seems high, considering each housing unit this proves to be insignificant.

CONCLUSIONS

Escalators have the disadvantage of not allow access for wheelchairs and babies strollers. The use of conveyors solves these limitations but in most cases do not constitute an option since that the maximum tolerated slope is low. Under these circumstances the most logical option seems to be the funicular which allows its use by people in wheelchairs and babies strollers and shows no special tilt limitations. However, this system requires the consumption of more public space and impact on the landscape is far superior to the systems mentioned above, especially the escalators which are usually installed in places where already are stairs so public acceptance is positive. Funiculars landscape impact can be reduced with his installation below the surface.

The viability analysis is very important to understand the profitability of the escalators since its installation is based on public funds which are scarce. Based on the actual number of trips during peak-hour periods (morning and afternoon), proposals 1 and 2 in intervention area 1 (*Jardim dos CTT-Jardim do Torel* and *Calçada do Lavra+ Jardim dos CTT-Jardim do Torel*) do not show any difficulties in achieving the minimum users number per day in each direction. Since proposal for intervention area 2 (*Beco de São Luís da Pena*) requires a high number of pedestrians against the currently circulating there, many questions and doubts rise about this proposal's viability. In intervention area 3 (*Travessa do Colégio*, *Calçada Nova do Colégio*, *Travessa do Jogo da Pela*), proposals 1 and 2 does not raise serious doubts concerning the number of required trips due to the large influx of people to the hospital that these two proposals serve. However, the demobilization of the hospital creates an uncertainty that will depend on this land's destination. In these circumstances proposal 3 seems to be the more plausible although it is not possible to ensure the minimum amount of required daily trips outside peak-hours.

The escalators introduction improves accessibility to one and two subway lines in 51 BGRI, valuing this EUR 4,445,353.73 in total. If two thirds of this value is captured it means that EUR 2.963, 569.15 will fund the ten escalators segments that are proposed (considering proposal 1 in intervention area 1 and proposal 3 in intervention area 3) over the 15 years of the lifecycle. But there are other ways to fund these systems, for example the rent of spaces for advertising. It is intended that the system should be free to use for pedestrians, i.e. without any associated fee. These systems generate a high social benefit, a huge contribution to improving the quality of pedestrian mobility and significant regeneration of many areas of the city and therefore management of these systems should be funded in other ways already mentioned such as value capture in real estate or rental of space for advertising. It should be noted that the escalators introduction does not only improves accessibility to the subway: train and bus service also sees their accessibility values improved although this has not been considered in the analysis.

The introduction of escalators simultaneously in the three intervention areas allows CMP to be less than 15 minutes to four subway stations and all the services in these areas instead of the current 20 minutes. The 5 minutes reduction permits an approach between people and services resulting in an increased availability of pedestrians to travel between these points in the city which encourages not only pedestrian movement but also commerce. It is important to enhance that the travel time reduction with the escalators installation also means a mitigation of physical fatigue and pedestrian discomfort caused by sweat. Especially in an area like this with a high percentage of elderly people, escalators allow to increase the mobility of these people offering more opportunities to move and better life conditions. An escalator generates benefits that were not measured but which are extremely relevant in the advantages and disadvantages analysis. The installation of these systems increases the availability of pedestrian to traverse difficult paths, enhances walking in addition to increasing the social and cultural activities in the city, generates health benefits because of moderate physical exercise that requires and fights sedentary modern lifestyle. There is an extremely high social benefit that seems to justify these systems introduction almost by itself making cities more competitive due to life quality increasing.

ACKNOWLEDGMENT

This work was developed in my thesis to obtain the Master degree in Civil Engineer on Instituto Superior Técnico (Lisbon Technical University) under the guidance of Professor Maria do Rosário Maurício Ribeiro Macário and Professor Paulo Fonseca Teixeira.

REFERENCES

1. Schaufelberger, E. (1992). *Les Piétons: Réseaux et Aménagements - Cahier TEA nº 5.* Lausanne, Suisse: EPFL-ITEP.

2. Câmara Municipal de Lisboa. (2005). *Lisboa: o Desafio da Mobilidade.* Lisboa: Colecção de Estudos Urbanos XXI.

3. Fruin, J. J. (1987). *Pedestrian Planning and Design.* Mobile, Alabame, USA: Elevator World, Inc.

4. Cullen, G. (2006). *Paisagem Urbana.* Lisboa: Edições 70 - 3ª Edição.

5. Gouveia, P. H. (Setembro de 2005). Peões Precisam-se? *Jornal Arquitecturas nº 4.*

6. Pita, F. J. (2003). *Estratégias e Planeamento da Mobilidade e Segurança dos Peões - Dissertação para obtenção do grau de Mestre em Transportes sob a orientação do Doutor José Manuel Caré Baptista Viegas.* Lisboa: UTL-IST.

7. Menezes, J. T., & Farinha, J. M. (1983). *O Papel das Áreas Pedonais na Renovação Urbana.* Lisboa: LNEC - Laboratório Nacional de Engenharia Civil.

8. Bieber, A. (1994). *Les Transports à Courte Distance Mecanisés - Les déplacements de personnes a courte distance: rapport de la 96ème table ronde d'économie des transports.* Paris, France: CEMT.

9. Richards, B. (2001). *Future Transport in Cities.* London: Spon Press.

10. IER. (2006). *Developing Harmonised European Approaches for Transport Costing and Project Assessment - Deliverable 5: Proposal for Harmonised Guidelines.* Stuttgart, Germany.

11. Lari, A., Levinson, D., Zhao, Z. J., Iacono, M., Aultman, S., Das, K., et al. (2009). *Value Capture for Transportation Finance - Technical Research Report (CTS 09-18).* Minnesota, USA: Center for Transportation Studies - University of Minnesota.

12. Plataforma Lisboa Interactiva. (s.d.). Obtido em Junho de 2010, de Câmara Municipal de Lisboa: http://lisboainteractiva.cm-lisboa.pt.

13. Barcelona de Serveis Municipals, S.A. (2010). *Escaleras Mecánicas Parc Montjuïc - Barcelona.* Barcelona, España.

14. IER. (2006). *Developing Harmonised European Approaches for Transport Costing and Project Assessment - Deliverable 5: Proposal for Harmonised Guidelines.* Stuttgart, Germany.

15. Martínez, L. M., & Viegas, J. M. (2010). *Effects of Transportation Accessibility on Residential Property Values - Hedonic Price Model in Lisbon Metropolitan Area, Portugal.* Lisboa: CESUR-IST.

16. ESRI Portugal. (2008). *Introdução ao ArcGIS (9.2) - Nivel I e II: Slides do Curso.* Lisboa