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A spatial application of an opportunity costing methodology for the assessment of the climate value of cycling

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Abstract

Sustainable transportation, especially cycling contributes to mitigation of CO_2 emissions as cycling possesses an intrinsic zero-emission value. Cycling mobility can be seen as a 'CO_2-sink' because each bicycle trip represents potential CO_2 emission when replaced with an alternative motorized transportation mode. Only few studies have been conducted to assess the climate value of cycling and those studies used the a-spatial version of the opportunity costing methodology which gave statistical analysis of the city as a whole. This research aims to use the spatial version of the opportunity costing methodology which assigns a value to a bicycle kilometre travelled based on the stated substitution mode for that trip by the cyclists. The model includes the first and second order effect of bicycle substitution which makes it more complex and accurate. It allows to visualize the spatial distribution of the climate value of cycling per ward and to identify the major contributors to the total climate value for the study area. This resulted in a climate value of cycling of 1,062.4 tonnes CO_2 per year which corresponds to monetary asset between US$ 7,075.9 - 20,994 if traded into the carbon market.

Peer-review under responsibility of IEREK, International experts for Research Enrichment and Knowledge Exchange

Keywords: Bicycle trips, stated preferences of cyclists, Mode shift, Climate value

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1. Introduction

1.1. Unsustainable transport

Transport systems represent a cities economic backbone, as they provide the basic mobility and accessibility options that are crucial to the reasonable functioning of most activities. Many transport systems around the world are beginning to threaten the very habitability of the cities they serve, as vehicle numbers and travel begin to outstrip the capabilities of existing infrastructure systems. The resulting traffic congestion has a direct effect on economic growth, and the level of Greenhouse Gasses (GHG) released to the atmosphere. These problems are particularly acute in the developing world's largest cities, growing incomes and proliferation of cheaper motorized vehicles increases car ownership, requiring large amounts of additional land and energy to supply thus large emission of CO_2 (Folton, 2001).

Urban transportation in developing countries is being affected by fast growing rural to urban migration. This increase of urban population is not accompanied with the distribution of land uses, resulting in a large number of people living far from their daily activities. Those living far from their activities are forced to shift away from cheaper modes, often with zero CO_2 emission suitable for short distances like cycling to motorized vehicles, with remarkable higher cost and higher emission of CO_2 (Kanyama, Carlsson-Kanyama, Lindén, & Lupala, 2004). Hence urban form and urban growth may proof to be important factors causing unsustainable transport. Cycling, urban form and the climate impact of cycling, particularly in Zanzibar, Tanzania, is the topic of this research.

1.2. Background of urban transport in Tanzania

Most of African cities have expanded faster than the capacity of their governments to cope with the growing needs for infrastructure, resulting in incomplete and unconnected road networks. In Dar es Salaam (the largest city in Tanzania), the condition of roads, both paved and unpaved contributes to congestion, reducing the speed, profitability and useful life of public transport vehicles. The coverage of the paved road network, in particular, limits access of bus services in many areas of the city, most can be only reached by two-wheeled vehicles. The total road network is about 1140 km, of which only 445 km is paved (Kumar & Barrett, 2008).

In Zanzibar the road network is composed of 1600 km roads, of which only 85% is paved or semi-paved ("Zanzibar," 2010). Based on census 2002 the total population of Zanzibar island was 984,625 inhabitants and the paved or semi-paved road density per thousand inhabitants was 1268.65m ("Zanzibar Statistics," 2010) which is high compared to Dar es Salaam. According to the UN Millennium Cities Database, such road density for Zanzibar is acceptable since the average of paved road density for developing countries should be close to 1,000 meters per thousand inhabitants (Kumar & Barrett, 2008).

Cycling at Zanzibar is modest with an average of 41% of the modal split. With its relatively small scale (particularly the urban area) its relatively high road density, there is an interest in how current level of cycling perform (as related to other modes) as a sink of CO_2 emission. Particular interest is also how this varies by socio economic group and spatial locations (as a function of urban form).

2. Opportunity costing of Cycling (Methodology)

In trade market there are goods or services, which have no value or price, constructed for them and they are not traded, cycling mobility is one of them. According to Heertje & Polak (2001) value of an object is determined by its production cost or labour sacrificed.

For this research the climate value of cycling is assessed by hypothetical substitution of bicycle trip with the most likely alternative mode, based on the stated preference of the cyclists. The avoided cost for using the alternative mode (CO_2 avoided) determines the value of that cycling. The climate value of cycling has a straight relation between the emission factor of the alternative mode and the Passenger Kilometre Travelled (PKT). The emission factor is the average rate of emission grams of Carbon dioxide (CO_2) released per mega joule of energy produced, it is expressed as number of kilograms of particulate per ton of the material or fuel (Schipper, Cordeiro, & Wei-Shiuen, 2007).

2.1. Model principles

The main principle of this methodology is to assign a value (in this case climate value in terms of the CO_2 emissions) to a bicycle kilometre travelled based on the stated substitution mode (*v*) for that trip by the cyclists. The value of bicycle kilometre travelled corresponds to the CO_2 emitted per kilometre by the alternative motorized vehicle. The higher the CO_2 emitted, the higher the climate value of that bicycle trip.

For that three assumptions were made and are presented as the follow:

1: Each Passenger kilometre Travelled (PKT) used in the model represents a substituted bicycle trip.

2: The model developed takes into consideration the first and the second order effects. The first order effect is to identify the alternative modes in case of bicycle substitution, and the second order effect looks into the new travel time and destinations based on the stated preferences of the cyclists.

3: For bicycle trips which do not change destination means the utility of the activities at destination exceeds the disutility of using the alternative mode

$$Uj > Zijv \quad (1)$$

Where

Uj: Utility at the destination j

Zij_v: Disutility of travelling from i to j by alternative mode v

The opportunity costing is assessed by the substitution of all bicycle trip with the most likely alternative mode (v) based on the stated preference of the cyclist. So it can be stated that opportunity costing of cycling is the difference between the social cost regarding to the actual trip (emission of bicycle trip=0) and the social costs of the trip made by the alternative transportation mode (emission of the alternative traffic>0)

2.2. Modelling approach

Trip making is a result of individual choice. Based on the utility maximization theory, traveler will choose an alternative mode *v* to execute a trip between OD pair *i-j* if the utility at the destination *j* is high than the utility of staying at the origin *i* and disutility of making the trip on the OD-pair *i-j*.

$$N_j - N_i - Z_{ij} > 0 \quad (2)$$

Where

N*j*: utility at the destination *j*
N*i*: utility of staying at the origin *i*
Z*ij*: disutility on the OD-pair *i-j*

For travelers with Z*ij*>0
Trip with the alternative mode doesn't take place, then $PKT_{vij}=0$.
PKT_{vij}: Passage kilometer traveled with mode *m* on the OD-pair *i-j*

For Zij<0

Trip takes place, then PKT_{vij}=Travelling distance between *i-j with* the alternative mode *v*. Different travel pattern can be observed as result of the mode change. Trips for compulsory propose will remain with the same pattern and should be influenced with the infrastructure supply, network links, nodes, capacity, travel speed and other factors of resistance. The distribution of the alternative modes *v* on the OD pairs *i-j*, should take into consideration both behavioral differences and congestion effects.

The model is characterized as following:

Alternative mode choice (v)

Alternative mode choice depends on the available modes and the travel resistance for each mode from origin *i* to destination *j*. The traditional approach to transport planning is the four stage model (Bovy, Bliemer, & Van Nes, 2006). For this study the mode choice is modeled based on the stated information of the cyclist and calibrated based on the socio economic characteristic of the trip maker collected during the survey. The input to the mode choice model in this case is the total demand between each origin and destination OD pairs (Wards). The common approach is to distribute the total travel demand for the given OD pairs over the available modes using the logit mode expression:

$$\beta_{ijv} = \frac{\exp[bV_{ij}^{v}]}{\sum_{w}(\exp[bV_{ij}^{w}])} = \frac{\exp\sum_{k}\alpha_k^{v}X_{ijk}^{v}}{\sum_{w}(\exp\sum_{k}\alpha_k^{w}X_{ijk}^{w})} \quad (3)$$

Where:
β_{ijv}: Proportion of travelers shifting from bicycle to the alternative mode *v* on the OD pair *ij*
b: Variance parameter in logit model
V_{ij}^{v} : Observables part of utility travelling between OD-pairs *i-j* with mode *v*
X_{ijk}^{v} : Explanatory variables for the mode *v* on the OD-pair *i-j* (travel cost)
$\propto_k^{v}$: Weight parameter for the explanatory variable mode *v* on the OD pair *i-j* (eg. The value of time)

Route choice(r)

Generalized travel time on link *a* depends on the traffic flow on link *a*

$T_a = t_a(q_a)$ *(4)*

And

Proportion of trip flow from *i* to *j* via route *r* depend on the behavioral route choice parameter and travel time on the route *r*, thus the route length (l_r) correspond the PKT*v* by the alternative mode *v*

$_{ijv} := \beta_{ijv}(\Theta . t_a(q_a))$ *(5)*

$PKTv = l_r \sim \; _{ijv}(\Theta . t_a(q_a)) \in [0, 1]$ { =1 if route a is chosen from *i* to *j*; =0 otherwise

Then

Climate value of cycling from *i*-*j* on the OD pair is directly proportional to the travel distance of the alternative mode *v* on the route *r* and the amount of carbon dioxide admitted by the mode alternative mode *v*, if *v* is a motorized mode.

$CV_{cycling} = PKTv . EFv$ *(6)*

Where CV: climate value ($KgC0_2$)
PKT*v*: Passenger Kilometer Traveled (km)
EF*v*= Emission factor for mode *v* ($kgC0_2$/km)
v; Alternative modes to cycling

3. Data collection

To construct the opportunity cost of cycling in Zanzibar town, primary data on travel behaviour (in terms of daily trips) and stated preferences of current cyclists is required in addition to secondary data.

3.1. Secondary data acquisition

A major dataset used for the entire study is the outcome of the survey of cyclists. However, the data collected from the secondary sources are used to compliment the primary data to do the research. Notably among these datasets were the road network, land use and the socio-economic data of Zanzibar town. Some of the secondary datasets were given in digital and the rest and others in hardcopies. A table showing the list of all the datasets acquired is provided below;

Table 1: Secondary data acquired

Data	Description	Institution
Traffic count	General information about traffic count conducted in Zanzibar island, gives overview of modal split in entire Zanzibar. This information is from November 2008- hardcopy	Ministry of Communication and Transport
Attraction points (for cyclists)	Were identified 7 attraction points which were: Malindi market (fish market) Darajani market (bus station and principal market in Zanzibar), Michenzani market, Mikunguni market, Magomeni market, Mkunazini market and Mwanakerekwe market (this is out of our study area)	
Demographic information	The 2002 Population and Housing Census (hard copy, softcopy) Urban west District: Census Results in Brief (softcopy- year 2002) Urban west district: population distribution per sex, age, in each ward (excel sheet- year 2002)	Office of chief Government Statistician- Zanzibar
Socio economic information	Household Budget Survey Final report, September 2006 (hard, soft copy) Socio - Economic Survey- 2009 (hard, softcopy) urban district profile (hard, softcopy- year 2002)	
Administrative boundaries	Updated administrative boundaries of urban district- 2010 (hard copy)	
Land use	Shape file	Department of Survey and urban planning

3.2. Primary data collection (Selection of study area)

The initial idea was to take stone town as the study area, but after the first visit and also based on traffic count conducted by Ministry of communication and transport, most cyclists come from or live outside the stone town because there is no or less attraction points for cyclists. This could be because the land use is not that attractive for local residents, mainly this is touristic area.

So, the all strategic approach was changed in place of collecting data in one destination, several points where indentified and the study area extended to cover the urban west district, which also includes the stone town. The wards included in our study area are the following: Amani, Chumbuni, Gulioni, Jangombe, Karakana, Kidongo, Chekundu, Kiembesamaki, Kikwajuni bondeni, Kikwajuni juu Kilimahewa bondeni, Kilimani_u, [†] **Kiponda**, Kisima, Majongoo, Kisiwandui Kwaalamsha, Kwaalinatoo, Kwahani, Kwamtipura, Magomeni, Makadara, **Malindi**, Matarumbeta, Mchangani, Meya, Miembeni, MigombanI, Mikunguni Mkele, **Mkunazini**, Mlandege, Mpendae, Muembe ladu, Muembe makumbi, Muungano, Mwembeshauri, Mwembetanga, Nyerere, Rahaleo, Sebleni, **Shangani**, Shaurimoyo, Sogea, Urusi, Vikokotoni.

[†] Bolded wards – belongs to Stone town

3.3. Sampling design

The design of sample was made in order to intersect as many cyclists as possible in the study area. The survey areas were those were most cyclists were expected to be concentrated. The Ministry of Transport and Communication provided information that was relevant to select the area:

- A traffic count document that was conducted in the city was given.
- Identification of the main roads along which most cyclists are found within the study area.
- Stations or locations where these cyclists converge for their daily activities were selected along these major roads so they could be interviewed. These happened to be the market centres.

Below the list of major attraction points (destinations) numbered as the sequence of the survey:

- 1. Malindi market
- 2. Darajani market
- 3. Mkunazini market
- 4. Michenzane market
- 5. Mikunguni market
- 6. Magomeni market
- 7. Mwanakwerekwe market (out of study area)

The listed markets above were considered as the major attraction points in the study area according to the Ministry of Communication and Transport. So decision was made to visit these markets one after the other (following the numbering sequence) to interview cyclists. During the visits, available cyclists were selected randomly one after the other and interviewed.

The cyclists were asked questions regarding to their socio-economic, and their yesterdays trip pattern. The survey was conducted from Tuesday to Saturday and as early as 7:00AM to 5:00PM. Sundays and Mondays were used to prepare for the survey, because it was predicted that the number of previous trips on these two off- days is minimum as they are not working days.

After visiting all the seven attraction points or centres and conduct survey at the first point, the Centrality Index (CI) calculation was performed to identify the origins of the majority of the cyclists. The origin of these cyclists then became the next batch of attraction points. It was assumed that the probability of finding more cyclists in these areas is higher.

To identify the wards from where most cyclists were originating, the Fuzzy Cognitive Mapping (FCM) was used which gave a possibility to visualize the complex and dynamic interaction of bicycle trips and helped to represent the relationship between origin and destination wards. For this particular case, only the attraction wards have Indegree and Outdegree values, and the rest of the wards have only indegree values.
Outdegree (od): Sum of all bicycle trips with origin outside attraction ward intersected in a certain attraction points.
Indegree (id): Sum of all bicycle trips with the same origin intersected in different attraction points.

After assigning all bicycle trips in OD matrix, all the values were standardized, using maximum standardization. The number of cyclists is considered as benefit, the standardization was done by dividing the score by the maximum score, because FCM allows only values maximum to one. The table below shows the centrality index of all the wards in the study area.

Table 2: Centrality index for all the wards in study area

Identification of wards			
Density	**Hierarchy Index**	**Total Nr. Factors**	**Total Nr. Connections**
0.06714876	deactivated by author	44	130
Ward name	**Outdegree**	**Indegree**	**Centrality**
Amani	0.00	2.50	2.50
Chumbuni	0.00	2.00	2.00
Gulioni	0.00	1.25	1.25
Jangombe	0.00	2.00	2.00
Karakana	0.00	0.75	0.75
Kidongo chekundu	0.00	1.25	1.25
Kiembesamaki	0.00	1.25	1.25
Kikwajuni bondeni	0.00	0.75	0.75
Kikwajuni juu	0.00	1.25	1.25
Kilimahewa bondeni	0.00	2.00	2.00
Kilimani_u	0.00	0.50	0.50
Kiponda	0.00	0.25	0.25
Kisima majongoo	0.00	1.00	1.00
Kisiwandui	0.00	0.00	0.00
Kwaalamsha	0.00	1.25	1.25
Kwaalinatoo	0.00	0.25	0.25
Kwahani	0.00	2.25	2.25
Kwamtipura	0.00	1.00	1.00
Magomeni	5.00	1.50	6.50
Makadara	0.00	1.25	1.25
Malindi	11.25	0.25	11.50
Matarumbeta	1.50	0.75	2.25
Mchangani	0.25	1.00	1.25
Meya	0.00	0.00	0.00
Miembeni	0.00	1.75	1.75
Migombani	0.00	1.50	1.50
Mikunguni	0.00	1.65	1.65
Mkele	0.00	0.25	0.25
Mkunazini	10.75	0.25	11.00

Mlandege	0.00	0.25	0.25
Mpendae	0.00	1.50	1.50
Muembe ladu	6.40	2.00	8.40
Muembe makumbi	0.00	1.25	1.25
Muungano	0.00	0.25	0.25
Mwembeshauri	0.00	0.00	0.00
Mwembetanga	0.00	1.25	1.25
Nyerere	0.00	1.25	1.25
Rahaleo	5.00	1.00	6.00
Sebleni	0.00	1.25	1.25
Shangani	0.00	1.00	1.00
Shaurimoyo	0.00	1.50	1.50
Sogea	0.00	1.50	1.50
Urusi	0.00	1.25	1.25
Vikokotoni	7.50	0.75	8.25

The centrality index (CI) is the sum of the Indegree and the Outdegree values, thus the centrality expresses how large a role of a given variable plays in the system. A high centrality shows a large importance and a low centrality reflects a lesser importance (Kirsten, Wildenbergb, Adamescu, Skov, De Blust, & Varjopuro, 2009). For this study CI, represents the number of cyclists from different wards intersected in a particular attraction point added to the number of cyclists with origin in this attraction point intersected in another attraction points. Connection, sum of all standarized bicycle trips in the study area (Maximum Standarizatyion 0-1)

4. Data analysis

Collected data was organized into a database, including the socio economic characteristics of the trip makers, Origin – Destination (OD) data, their yesterday's trip pattern using bicycle and their alternative mode (trip road table). A unique identity is assigned to individual trip maker (ID), individual activity locations (*OD ID*), and individual road segments (*Road ID*).

The *OD* table contains 17 *fields*: *Trip ID, Person ID, Age, income, household composition, gender, level of education, Origin ID, Origen Name, Destination Name, Destination ID, departure time (time), arrival time (time), Trip Day, Trip Purpose, Travel Time, Activity Duration, route, then their alternative traffic if bicycle is no longer any option is recorded the new trip pattern made by bicycle, such as departure time, destination ID, origin ID, route, purpose.*

Disaggregated data analyses are conducted on GIS based on their Origin or Destination. Avoided emission is calculated based on the emission factor of the replaced transport mode and the climate value of cycling trip is assigned to the origin.

5. Case Zanzibar, Tanzania

Zanzibar, is part of the United Republic of Tanzania, consists of two main islands of Unguja and Pemba and about 50 other small islets. The islands are located 40km off the Mainland coast of East Africa in the Indian Ocean between 5° 6´ South and 39.5° 40´ East. Unguja is the larger of the two main islands has an area of 1,666 km² while Pemba has an area of 988 km² (Zanzibar).

According to the population census of 2002, Zanzibar town had a population of 231.241 people; the average population density was 194 people per square kilometre, distributed in 45 wards. Currently the estimated population for all islands is 1.193 million at population density of 400 people per square kilometre (Zanzibar strategy for growth and reduction of poverty, 2007). This has direct implication on the available resource, settlement development and demand for transportation. The spatial arrangement of the activities determines the travel patterns in the city; during the morning peak hour heavy vehicle traffic is observed towards stone town and in the evening peak hours from the stone town.

The current traffic performance in Unguja Island is composed largely of bicycling 41%, followed by private car 27%, motorcycle 17% and public bus with 13% (DROMAS, 2009). In 2006, based on Zanzibar master in the main town approximately 35300 vehicle trips per day was registered, where public buses carried the highest number of passengers which is around 150000 passengers per day (ZANCON, 2007).

5.1. Construction of Passenger Kilometre Travelled of all modes (PKT)

The PKT is developed based on the sample and assumptions regarding to average speed for each transportation mode. To each mode the clustered trip purpose was added in order to depict the high contributors for the climate value of cycling.
As result of *first order effect of bicycle substitution*; Public bus makes the largest share of modal shift (12656 km), followed by walking (1443 km). Combining with trip purpose HBW has the largest share with 4595 km, followed by HBSH with 3551 km. large number of bicycle trips made for HBOs (72.2%) and HBSs (5.6%) were discarded or not replaced. Based on the utility Maximization theory it means that the disutility of making those trips with the alternative modes exceeded the utility of the trip.

Added trips are the result of the *second order effect of bicycle trip substitution*, where cyclists change their travel patterns, in order to maximize the utility of their trips as result of different opportunities of the new transportation mode; trip makers may change their destinations. For the current study, this mostly occurs for HBSH trips with additional 1501.7km to the existing bicycle trips. See the table 3 for additional information.

Table 3: Aggregated PKT per trip purpose and mode of transportation

Passenger Kilometer Traveled (Km)								
Trip Purpose	Cycling	Walking	Bus	Motorcyle	Private_car	Taxi	(-)Descarted trips/(+)Added	% Descarted trips/Added
HBW	-4407	280.9	4594.6	371.2	123.2	18.3	+981.2	22.2
HBS	-1614.9	298.3	1226.8	0	0	0	-89.8	5.,5

HBSH	-2555.8	287.3	3551	186	33.3	0	+1501.7	58.7
HBO	-2484.6	107.4	507.8	70	5.0	0	-1794.4	72.2
NHBW	-948.5	151.2	1116.8	77.4	30.9	0	+427.8	45.1
NHBS	-245.9	61	180	13.3	0	0	+8.3	3.3
NHBSH	-877.5	130.9	766.8	19.1	0	15.8	+55.1	6.2
NHBO	-711.6	125.7	712.2	71.6	0	0	+197.9	27.8
Overall	**-13846.1**	**1442.7**	**12656**	**808.6**	**192.4**	**34.1**		

6. The climate value of cycling of Zanzibar

6.1. Traffic performance of the alternative modes

Figure 1 below depicts the performance of the alternative modes, also shows that a large part of the sample shifted to public bus (63.5%) followed by walking (31.8%). About 9.5 % (249) of bicycle trips are not executed. One important remark for the huge shift to public bus was due its fare attractiveness. In Zanzibar, unlike other countries or cities bus fare is fixed for a route not by kilometre travelled. For walking mode, the sample reveals to be more attractive for shorter distances, it means when the travel distance increases the frequency decreases.

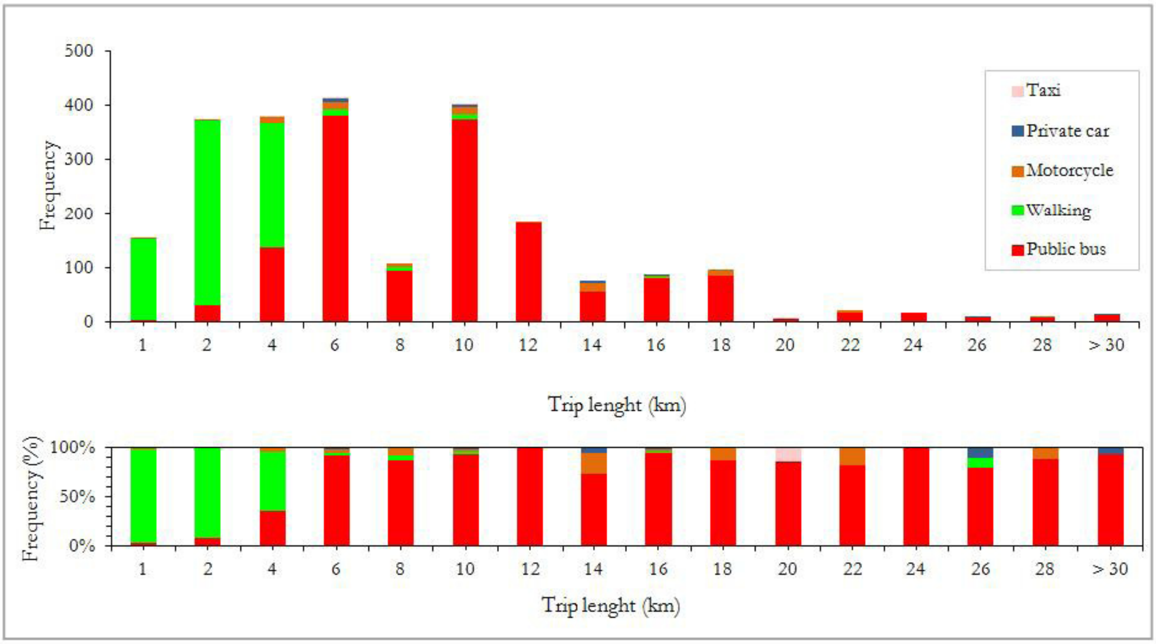

Figure 1: Performance of the alternative modes

6.2. CO_2 avoided per cyclist at ward level (Sample population)

The climate value per cyclist is obtained by dividing the total CO_2 avoided per ward by the total number of cyclists starting trips in that ward. For bicycle trips that were not substituted and those substituted by walking are not included, as they do not participate in the total CO_2 avoided.

The variation of the CO_2 avoided per cyclist at ward level is presented in the figure 2 below. The side graph shows the percentage of bicycle trips belonging to that range and in brackets is the number of wards in that class.

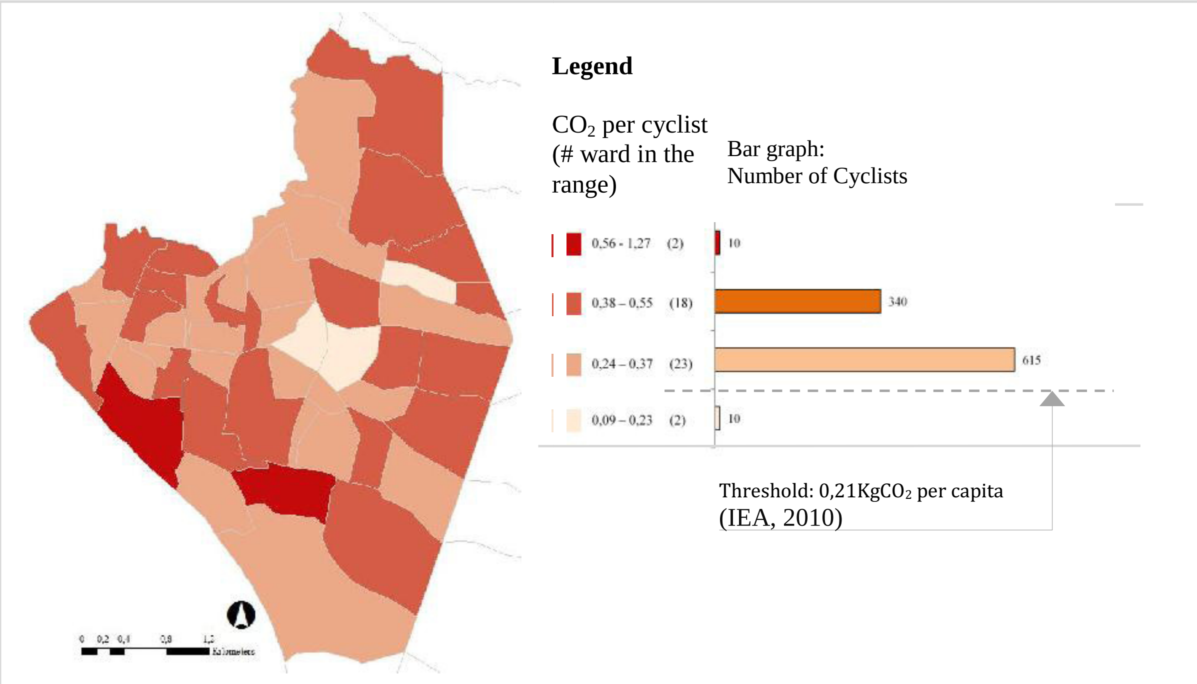

Figure 2: CO2 avoided per cyclist at ward level (KgCO2 per Cyclist)

Mostly, the wards in the central part of Zanzibar town were found to have low CO_2 avoided per cyclist as compared with northern and southern wards. According to IEA (2010), in 2008 the average CO_2 emission per capita for road transport sector in Tanzania was 0,21KgCO_2 per day. Combining this with the results from the sample it was found that 98.9% of the cyclists were above this average. This means if cycling is stopped it will contribute significantly to increase the CO_2 emission.

Wards with low climate value and high per cyclist, meant that the climate value per ward resulted from the substitution of few bicycle trips with motorized modes with high CO_2 emission per PKT.

6.3. Climate value for all population

The results from the calculations showed that the climate value of bicycling in Zanzibar is around **1,062.4 tonnes CO_2 [tCO_2] per year** as disaggregated in the table 4 below.

Table 4: Avoided CO_2 by different transport modes

Transport mode	Person trips daily	Modal shift (%)	Total distance travelled per day (km)	C02 Avoided (tC0$_2$/year)
Walking	2994	31.4	93.4	0
Public bus	5865	61.5	379.6	723.6
Motorcycle	451	4.7	309.1	40.9
Private car	222	2.3	125.8	295.6
Taxi	4	0.05	34.1	2.2
Overall	**9536**	**100**	**942.2**	**1,062.4**

Public buses and private cars provide the largest share of avoided CO_2 emissions. The share of public buses is logical due the number of shifts to this mode and the total travelled distance for this mode was 379.6km. For private car the larger CO_2 share is explained by the fact that the emission factor (CO_2 per PKT) of this mode is relatively high, compared with the public bus it is almost five times higher.

To give an indication on how this climate value is distributed, figure 3 presents the spatial distribution of the climate value of cycling; the higher climate value is depicted in the wards located far from the main centre. This is what was to be expected as most of the trips are heading to the attraction locations, which are mostly located in the centre, and because of the distance cycling is replaced by motorized transport.

In the table 5, all the wards were clustered according to the CO_2 avoided class. This shows that the climate value per ward is directly influenced by the number of bicyclists (1), number of the replacement for motorized vehicle (2) and the travel distance (3). Most of wards were within lower class (22 wards) and they contributed with almost 13 % of the total CO_2 avoided in the study area. Wards within high CO_2 avoided class had almost three times more cyclists compared with lower class, were composed of only 8 wards and contributed with 57% of the total CO_2 avoided in the study area. These are the most suitable wards to assign resources to promote or preserve cycling, because investing there can benefit many cyclists and avoid many others to shift to motorized vehicles.

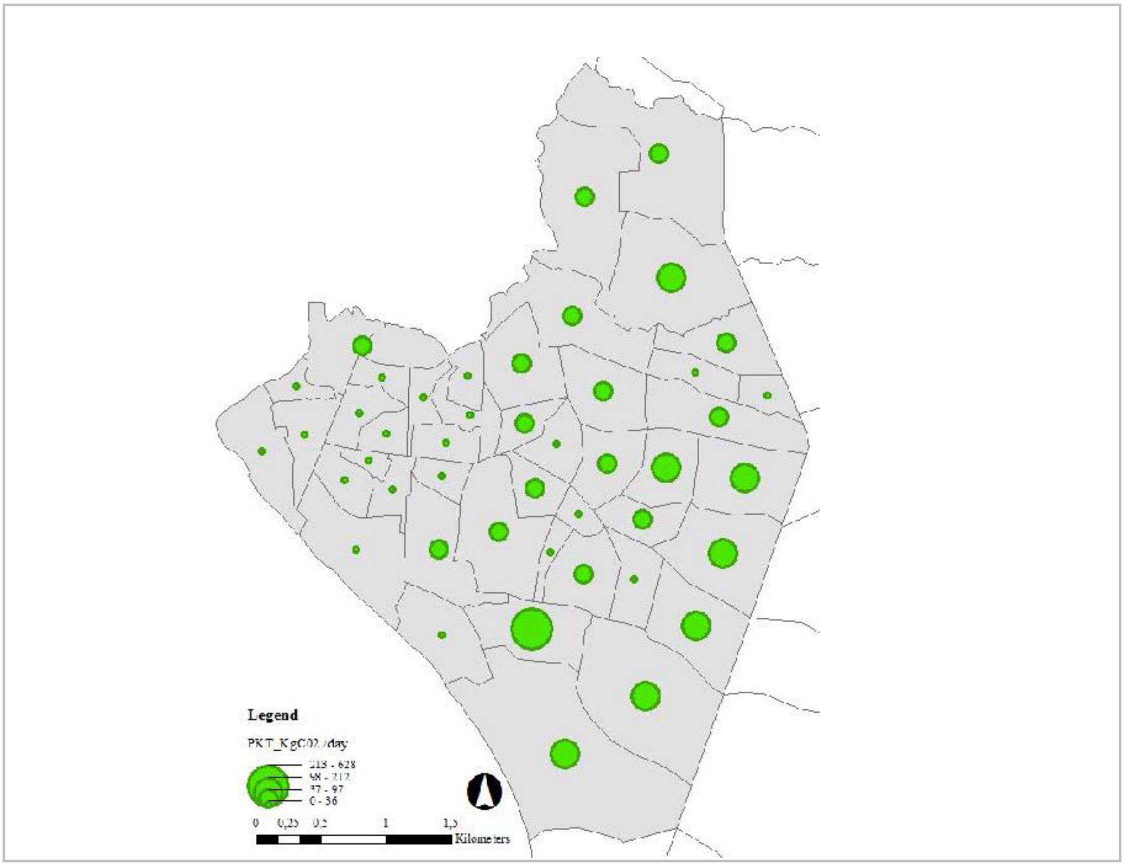

Figure 3: Spatial distribution of the climate value of cycling for the total cyclists (Population)

Table 5: Factors explaining the avoided CO2 emission

CO_2 class ($KgCO_2$/day)	# wards	# bicyclists	# shifts to motorized vehicle	% shift to motorized vehicle	Avarage travel distance	Total CO_2 avoided per day	% CO_2 avoided
0-36	22	2566	1270	19.4	7.5	397	13.6
37 - 97	15	3481	2447	37.4	8.6	864	29.7
> 97	8	3533	2825	43.2	8.8	1649	56.7
Total	**45**	**9580**	**6542**	**100**		**2910**	**100**

7. Opportunity for carbon finances

The avoided $C0_2$ by bicycle mobility can be traded as carbon credit in the carbon market. Motivated by the Kyoto protocol this emission saved can be traded in different market programs like Clean Development Mechanism (CER) or Voluntary Offsets Markets (VCI) as presented on the table 6.

For the purpose of this study, the carbon price from Clean Mechanism Development (CER) was considered from the average from August 2008 to April 2009. The average price was €14.95 equal to US$19.76 (BlueNext, 2010). The prices were converted to US$ to fit with the prices in VCI market. For that the values was converted using the rate of $1= €1.321 (Thomas Reuters, 2011). For the Voluntary market (VCI) the average prices for tCO_2 in equal period of time is US$6.66 with (Sjardin & Marcello, 2009). This calculation was done to indicate the potential monetary value of cycling in the study area.

Table 6: Monetary value per different transportation mode

Modal shift	Climate value tCO_2/year	Climate Value (VCI[‡]) ($/year)	Climate Value (CER[§]) ($/year)
Public bus	723.7	4819.8	14300
Motorcyle	40.9	272.5	808.6
Private car	295.6	1968.8	5841.2
Taxi	2.2	14.8	44.1
Total	**1,062.4**	**7,075.9**	**20,994**

The annual amount of money expected from the carbon market is US$ 20,994 if sold in CER and US$ 7,075.9 if sold in VCI. This amount could be invested in bicycle infrastructures and thus induce more shifts to this mode and will increase the climate value of cycling and adds to sustainable urban transport.

8. Conclusions

Opportunity costing methodology is an economic concept which allows value for goods which do not have intrinsic zero value, for this study the avoided CO2 emission is given value. The climate value of each bicycle trip is accessed based in the stated preference of the cyclists and calibrated by their socio economic characteristic. Stated preference of the cyclists provided a means to study the choice for hypothetical (not yet existing) alternative transportation modes. Analyzing the choice made by the cyclists helped to estimate the potential share of trips for public buses and it provided important information for transport planners to know the potential market share of the existing public buses.

The inclusion of the second order effect of bicycle trip substitution was found as a powerful component of the spatial application of the opportunity costing model since it includes all trips made with the alternative modes resulting in very accurate outputs.

[‡] VCI price (Sjardin & Marcello, 2009): US$: 6.66
[§] CER price (BlueNext, 2010) : US$:19.16

The disaggregated climate value of cycling per ward provided information about the spatial variations of the climate value over the city and areas with high climate value, which can be depicted. Climate value per cyclist explains how the travel patterns and choice of the alternative modes influences the total CO_2 per ward. When this avoided emission is traded in carbon market it results in monetary value which can be used to promote cycling.

For technical aspect, the combination of the stated preference of the cyclists, transport models and GIS (ArcGIS) provided a strong platform to understand the transport system in Zanzibar. The use of appropriated techniques and software helps planner and decision makers to have a future vision, and identify places to assign resources to promote or preserve cycling. To conclude, it was found that the existing cycling in Zanzibar represented a sustainable transport mode as 68% contributed to avoid CO_2.

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