A PROPOSAL TO CLASSIFY THE URBAN SETTLEMENTS

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ABSTRACT

Nowadays the metropolitan areas are oriented towards the exclusive use of the car and they have few or inadequate interventions aimed at developing alternative modes such as public transport or pedestrian mobility.
In this paper a method that allows to classify homogeneous zones according to the estimated energy consumption for the annual mobility per capita is proposed. This certification estimates the annual energetic needs of a urban zone and then determines its energetic class identified by a letter from A+ to G. This analysis can improve the energy efficiency of the system influencing both policy and practice. Indeed it influences the user behaviour in two ways. In one way it informs transport system users of how much they will have to spend for mobility if they decide to live in one area of the city rather than in another. Furthermore it forces building firms to choose a building place and to design new settlements more accurately. This method can reintroduce externalities into the building market through the variation of fees and through an indicator that shows clearly to all what is the energy requirements of each area of the town. This prompts citizens, administrators and building firms to better practices.

Keywords: land use, energy efficiency, urban pattern

1. MOBILITY AND ENERGY CONSUMPTION – STATE OF THE ART

Nowadays energy policy is one of the main themes of transport policy. A number of strategies have been designed over the last decades in order to reduce current energy consumption trends in the transport sector. They include fuel taxes, more efficient technologies and changing travel behaviour through demand regulation. But the energy market has a high degree of uncertainty and the effectiveness of those policy options should be assessed. Furthermore, considering the environmental and energetic issues of our days, energy efficiency is the most important aim of each engineering design. For instance, in the building sector progress has been made in order to increase house energy efficiency. In the territory of the European Union the adoption of energy certification of buildings has been particularly successful. The main idea of this certification is that if you classify the buildings by their energy efficiency, you can create a simple indicator that allows everybody to understand the level of efficiency of his home [1]. In this case the aim is to make clear to the citizen the level of energy consumption of a house. It boosts the construction and the acquisition of more efficient houses, and also stimulates the market to increase the performance of the existing buildings. While the energy demand for home heating is only a tenth of the total world consumption, the energy demand for mobility is up to 25% of the total. In the transport sector public aids have been given and technical advance has been made especially in vehicle technology. Recent researches show how only with a correct urban planning it is possible to significantly reduce the energy demand due to the mobility.

Indeed, some studies show that technology progress alone is not able to improve effectively the energy efficiency of the transport system [2]. They conclude their paper asserting that demand regulation measures proved to be more effective than technology investments in terms of energy consumption and environmental criteria, i.e. a reduction in car use brought by demand regulation measures exceeds the effect of more efficient technologies. So to actually reduce the energy consumption it is necessary to implement rules that help the transport mode that needs less energy.

Several studies suggest that modal split can be deeply affected by the urban form. They consider the interaction of urban pattern characteristics – such as population density, settlement size, distance from urban centres and transport networks, jobs and housing balance, local neighbourhood design, public transport accessibility– and socio-economic characteristics – such as income and car ownership, house tenure and attitude to travel.

Moreover, correlational analysis and regression models that provide continuous measures of neighbourhood characteristics can quantify the relation between neighbourhood characteristics and not motorized transport while controlling for either or both individual and neighbourhood socio-demographic variables (e.g., age, income, automobile ownership) known to be associated with walking and cycling. Population density is among the most consistent positive correlates of walking trips. In the 1995 Nationwide Personal Transportation Survey [3], travel by walking/cycling was approximately five times higher in the highest versus lowest density areas. Frank and Pivo [4] found that population and employment density were independent positive correlates of walking rates for commuting and shopping purposes, after accounting for such factors as vehicle ownership, residents' age, and driver's license status. Studies relying on observational measurement of rates of pedestrian and cycling behaviour within selected neighbourhood areas document higher walking/cycling rates in the highest density areas, even after controlling differences in population demographic characteristics. Mixed land use, especially the proximity of shopping, work, and other non-residential land use to housing, appears related to greater walking/cycling among residents. Commuting to work by walking/cycling was higher in areas with mixed land use and where commercial facilities existed nearby (less than 300 ft, or 0.1 km)[3]. Kockelman [5] and other researchers have found that the closer proximity or accessibility of jobs and services is associated with more walking and cycling. In contrast,

long trip distances are negatively related to the likelihood of walking/cycling. Nowadays the metropolitan areas, as a result of an increasing dispersion of residences and activities in the territory, are oriented towards the exclusive use of the car and they have few or inadequate interventions aimed at developing alternative modes such as public transport or pedestrian mobility [6].
The new residential districts have seen the rise of infrastructures designed for passenger cars. Two lane roads separate the buildings so that pedestrian mobility is reduced to the minimum and public transport must adapt to the design created for passenger cars. The use of private vehicles becomes widespread results not only in the increase of distance and time but also in the phenomena of congestion and air pollution [7]. Furthermore, the economic and social costs also increase.
The solution to this problem must be sought by investigating the potential of the characteristics of urban form, usually recognized in the so-called three "Ds" (density, diversity and design) [8], that can influence mobility. So the traveller behaviour is influenced by socio-economic variables and urban pattern.
This behaviour can change over time because the activities can change places and urban form evolves upon time. So politicians and practitioners have to encourage a more efficient way to travel.

2.THE PROPOSAL

In this paper an energy classification of the urban area is proposed. The aim of this procedure is to classify the urban settlements according to their annual energy consumption pro capita for the mobility of their inhabitants and employers. This analysis can improve the energy efficiency of the system influencing both policy and practice. Indeed it influences the user behaviour in two ways. In one way it informs transport system users of how much they will have to spend for mobility if they decide to live in one area of the city rather than in another. Furthermore it forces building firms to choose a building place and to design new settlements more accurately. This procedure can be used to force new settlements to have a minimal parameter of urban efficiency and furthermore to vary the taxation and the charge of construction according to the energy efficiency of the new settlement. This procedure can also be used to have an energetic map of the city and to decide where to redesign the neighbourhood. This prompts citizens, administrators and building firms to better practices. This method can reintroduce externalities into the building market through the variation of fees and through an indicator that shows clearly to all what the energy requirements of each area of the town is. Looking at the success that this policy has had with household appliances and home heating it is simple to imagine the impact that this classification might have on the estate market and accordingly, on the mobility scenario. Until today the attention has been focused on the consumption of the single building or single vehicle. Here the objective is to focus on the relationship between the world of the buildings and the use of vehicle, to inform citizen and the authority about the performance of the planned intervention on the urban pattern for a more informed choice.

Looking at
Fig. 1 it can be concluded that the aim of this classification is to work on the feedback between land use, spatial and temporal changes, activities development and travellers behaviour. As we have just seen in the previous paragraphs, if there isn't any regulation, the time evolution of the system might not achieve the reduction of the consumption because the operator of the real estate market are not interested. With this classification it is possible to lead the urban planning in the desired direction without imposing strict rules.

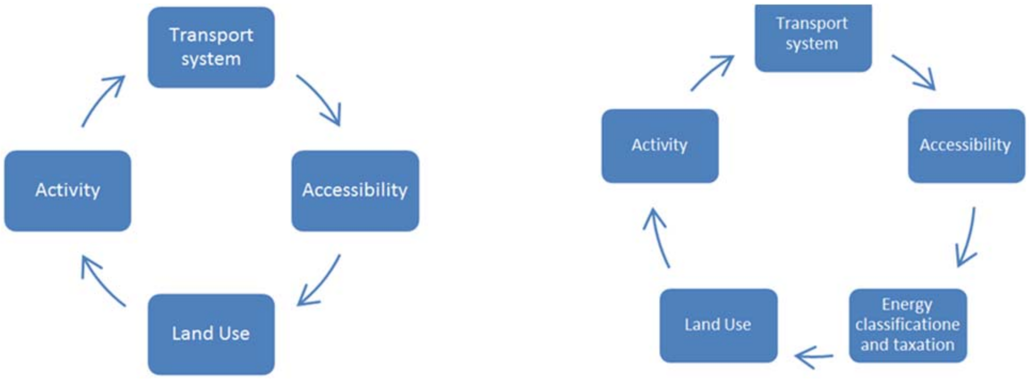

Fig. 1. Link among land use and transport system and the role of the energy classification

2.1 The energy classification

The proposed procedure is articulated in seven steps:
1. Definition of vast area in which the studied area is in;
2. Definition of territorial boundaries of the zone;
3. Calculation of annual pro capita energy consumption of the vast;
4. Definition of threshold that represent transition from one class to another;
5. Calculation of annual pro capita energy consumption of the interested area;
6. Assignation of area to its proper class;
7. Definition of the recommended improvements.

2.2 Definition of the vast area

In this step the territorial boundaries in which most of the impacts taken into account end must be found. To find these boundaries it is necessary to analyze the trips through a traffic model and using a sensitivity analysis of the indicators of the transport system.

2.3 Definition of the territorial boundaries of the zone

This first step is fundamental for the whole procedure. The issue is to understand where one area with homogeneous urban parameters end and another one starts. The following parameters should be considered:

1. Population density;

2. Workers density;
3. Orography;
4. Nodes density;
5. Links length;
6. Presence of rail and metro stations;
7. Presence of green areas.

Each minimal area has to be at least of 500m of radius. Indeed this the conventional distance that is easily to travel on foot. After that the minimal areas are identified will be possible to join close areas that are homogeneous from the point of view of their urban parameters. Obviously there are some areas of a city that cannot be consider in this analysis because they belong to the system of transport. Areas with a specific function as universities, hospitals, parks, etc. will be consider as independent zone to evaluate.

2.4 Calculate the annual pro capita energy consumption of the vast area

The procedure used for this calculation has to be the same used to calculate the energy consumption of each area. This can be made through a common traffic model. Specifically this point is made by the following steps:

1. Description of the supply transport system;
2. Description of the demand transport system;
3. Estimation of annual pro capita energy consumption.

So if target of the whole procedure is the evaluation of the annual energy consumption per capita for the mobility of the users, first of all it is necessary to define how the number of users is calculated. For user is understood anyone who travel from or toward an area for any reason, so are user are: inhabitant, workers, tourist, students, people who come for shopping, etc.. So for each zone that we have identified we have to list each kind of users.
The determination of the zone's users, for a new settlement, is done under the assumption that all the residences and activities are completely used (hypothesis 1).
The supply system is made by two components: the transportation network and all transport modes available by user.
For each vehicles (mode of transport) the characteristics in term of energy consumption for each type of traffic conditions have to be specified. In fact a trip of a certain transport mode and a fixed length can have different energy requirements, so the elements to be taken into consideration are:

1. mass of the vehicle;
2. number of passengers on board;
3. type of engine;
4. presence of a slope on the path;
5. driver's driving style;
6. traffic conditions (interference with other vehicles and users of the transport system).

The combination of all these factors determines a combination of conditions called *j*. As vehicles pedestrian and bicycle are also included. Furthermore it is assumed that the energy consumption for vehicles which required human energy to ride (like pedestrian mode, cycling, etc.) is null (hypothesis 2). To describe the demand system is needed to start from the description of the residence and activity system. The parameters to be used are socio-economic indicator as the real estate value, the building surface, the intended use, etc.. From this data it is possible to do a description of the users of the zone and then classify them according to their socio-economic parameters and meanwhile determine the number of the users after an estimation of the number of trips generated and attracted by the specific zone. Obviously a descriptive aggregate model has to be used. In order to determine the length of each path it is necessary to build up the origin/destination matrix utilizing a descriptive aggregate model too.

To establish the modal split of the transport demand of each zone it has to use a behavioural aggregate model with elastic supply. For the path choice is to be used a classical McFadden behavioural model.

After the transport demand is completely described it is possible to determine the per capita annual energy consumption of certain zone. It is necessary to follow the next steps.

If e_{mkj} is the energetic consumption for length unit of vehicle *m* on the link *k* travelled in the condition *j*, then the energetic consumption of the vehicle *m* to travel on the *h* path made by *H* link is:

$$E_{mh} = \sum_{k=1}^{H} e_{mkj} k_l$$

Where k_l is the length of the link *k*.

If the vehicle is a pedestrian or bicycle or another vehicle with human traction e_{mkj} is conventionally equal to zero (hypothesis 2).

Therefore the energetic consumption of every paths, equal in number to *O*, generated from the zone *z* is:

$$E_{zo} = \sum_{o=1}^{O} \sum_{k=1}^{H} e_{mkj} k_l$$

Likewise the energetic consumption due to the attracted paths, equal in number to *I*, for the zone *z* is:

$$E_{zi} = \sum_{i=1}^{I} \sum_{k=1}^{H} e_{mkj} k_l$$

At this point the total annual energetic consumption of the considered zone is equal to:

$$E_{ztot} = E_{zi} + E_{zo}$$

Obviously the per capita consumption for each user is:

$$E_{zpc} = \frac{E_{ztot}}{U}$$

In this way it is possible to determine the user behaviour and so the energy consumption of each trip. For vehicle characteristics it is possible to refer to an average condition inferred from the existent literature. Obviously the average condition is different in each country or in each vast area that is taken into account. Although it is possible to calculate the energy needs of each vehicle by reference to a generic average vehicle, it's very important to take into account the actual situation of the area. So it's better to make a previous research that investigates the local situation in terms of vehicle features, traffic condition, driving style, load factor and orography. In this way it is possible to know the vehicle consumption per unit of length and divide it for the passengers on board. In this way it is possible to calculate the energy consumption for each trip. Now there are two ways to carry out the analysis: to take into account only the systematic trips or to consider all the trips that are made over the day. So there are four combinations of procedures as shown in
Fig. 2.

Energy needs per kilometres	Type of trips take into account	
	All trips	Only systematic trips
Detailed analysis	1. Detailed analysis and all trips	2. Detailed analysis and only systematic trips
Generic analysis	3. Generic analysis and all trips	4. Generic analysis and only systematic trips

Fig. 2. Different kind of analysis

As shown by the colours, procedure number one is the best. It's possible to follow the other procedures because, although one is more accurate, all of them can lead to an effective result.

2.5 Define the boundary value that represent transition from a class to another

In this paragraph the value of annual pro capita energy consumption that represents the threshold between one class and another are defined. This value cannot be established in absolute. It has to vary according to the vast area consumption. In fact the same area put in a different context might have different energetic needs for mobility. The problem is to create classes that can cover all the situations in the vast. In fact you can use this procedure to map the whole area in the vast and to understand in which zone it's better to make changes. Since there are eight classes, it is established that the upper border of the central class (D) is taken equal to the annual pro capita energy consumption of the vast. The other values are established increasing or decreasing the previous value of the 20%. In this way it results that the minimum and maximum class cover a range from about half to nearly twice the average value. These values are represented in Fig. 3 and
Fig. 4.

A+	A	B	C	D	E	F	G
<0,58	>0,58 <0,69	>0,69 <0,83	>0,83 <1,00	**>1,00** **<1,20**	>1,20 <1,44	>1,44 <1,73	>1,73

Fig. 3. Graph of the ratio between the boundary values of each class

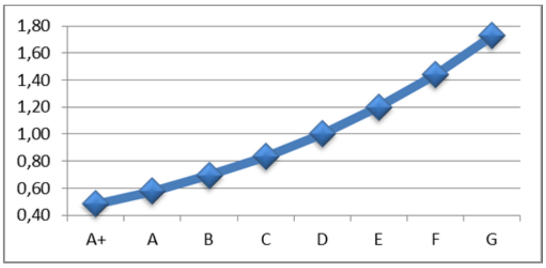

Fig. 4. Graph of the ratio between the boundary values of each class

2.6 Calculate the annual pro capita energy consumption of the interested area

The procedure used for this calculation have to be the same used for calculate the energy consumption of the vast area. In fact this point of the main procedure is made by the following steps:

1. Description of the supply transport system;
2. Description of the demand transport system;
3. Estimation of annual pro capita energy consumption.

The data needed for this analysis are the same sought in paragraph 2.4 and the procedure is the same.

2.7 Assign the area to its own class

This point is quite simple. In fact since was determined the threshold value among a class to another and the annual pro capita energy consumption, it is simple put the area in the right class. If the classification is applied to new planning settlements the classification procedures must outcome almost the C class. The charge due to build can vary according to the efficiency of the area under planning. In this way the builder are enticed to build settlement more efficient as possible.

2.8 Definition of the recommended improvements

After the classification procedure is finished it is necessary to give some recommendations to improve the area efficiency in the future. The recommendations have to be feasible from an economic point of view. In particular their cost have to be amortized within 30 years. The expenses for new infrastructures will be repaid from lower energy consumption and/or lower externalities. So the classifier has to calculate the net present value of the investment. The recommendation designed have to demonstrate the real effectiveness of the interventions provided. To establish the better interventions and their affordability it is necessary to estimate the current cost of the mobility for the zone *z*. This cost can be divided in fixed costs and variable costs. The fix costs are for instance the cost to maintain the infrastructure, to buy a vehicle, to maintain a vehicle, etc.. The variable costs, that depend on ridership, can be estimated utilizing the following expression (BPR link performance function):

$$C_{km} = C_{km}^{0} \cdot \left(1 + \alpha \left(\frac{x_k}{F_k}\right)^{\beta}\right)$$

That represent the cost that the user has to bear to ride on the link *k* with a vehicle *m*, α and β are coefficient of the BPR function; x_k is the flow on link *k* and $F_k$its capacity. For each intervention designed the classifier must indicate the new energy performance and class reached and then the energy performance and class reached of the whole interventions set. This point is shown in Fig. 5.

Recommendation 1	New energy performance	Class reached	Payback time (≤30 years)
Recommendation 2	New energy performance	Class reached	Payback time (≤30 years)
Recommendation 3	New energy performance	Class reached	Payback time (≤30 years)
Implementation of Rec1 + Rec2 + Rec3	New energy performance	Class reached	Payback time (≤30 years)

Fig. 5. Example of recommendation planning with energy performance and class consequently reached with the indication of the payback time

The advices must be oriented to arise the transport modality who required less energy, in order:

1. Pedestrian;
2. Cyclist;
3. Public transport;
4. Private transport.

In the certification they have to explain a method that, with mathematical indicators, shows how they want to improve the classification of the area. The indicators suggested in this paper are indicators of accessibility. In fact the mode that need more sources usually has higher operative cost, so if the user takes it, it is because the total transport time of the other mode are too high. It is due to the lower accessibility of the public transport. The classification of the area focus its attention on this fact and want to point the situation in which the city planning do not encourage the mode of transport that consume less sources. To do this, it is necessary to provide to the user of the transport system alternatives who he perceived as the best in term of total transport time, economic cost and comfort. The classifier has to show that the pedestrian catchment area [9] arise and the impedance to access the public transport are lower. After the improvement measures are actuated the area have to be reclassified and if the energy consumption is lower, the taxation in the area decreases too. So the citizen are interested in the requalification of their zones because their will spend less for mobility, and have a better neighbourhood and more comfortable.

3.CONCLUSIONS AND FURTHER DEVELOPMENTS

The sustainable development is the ability to satisfy the needs of the present generation without prejudice the needs of the following generations. So planners have to ensure the mobility of our days without consume the natural sources necessary for the mobility of the next years. Indeed the best things to do is to reduce consumption for mobility now. There are new kinds of engines but they required whatever oil to ride. And the better solution to achieve this result is to planning neighbourhoods and towns oriented to low consumption mode of transport. The classification result can improve and clarify the feedback between land use and transport system. This can happen because, as the class is an indicator easily understood by all the people, this method will lead local governments and public opinion toward more efficient choices and in order to introduce new design standards. The classification can be applied moreover, in order to compare cities. If the classification result is low it means that the user perceives as not available the mode of transport which are more eco-compatible.

For the new design areas the classification permits to increase or decrease the taxation for buildings according to its result. This action includes the externality due to the mobility into the market. This enhances the rational user to build new settlements taking into account the sources needed for the mobility of its futures inhabitants or employers. Furthermore the semi-quantitative indicator communicates to the potential buyer of a house how much he will have to spend for mobility each year. In a long period this can modify the housing choice in a better way [10]. This creates the retroactive action between the transport system and land use. The fiscal incentives have to be set so that builders prefer to build in a convenient area and in a convenient way. To establish the value of this fiscal incentives it is necessary to study first of all the market situation. Their value has to be able to really influence the choices of the building firm. What is this value is still to be defined. The several transport-land use interaction models could be used to do this. They are often based on the random utility hypothesis that the user’s perceived utility is made by a systematic utility plus a random deviation.

The random utility models based on discrete choice are the most useful expression to represent the user behaviour, and they are used not only to describe the user behaviour in the transport system but also in several software that want to describe the interaction between land use and transport system. They had been proposed by Daniel McFadden. On the bases of these models the user want to maximize his utility among available alternatives. So the taxation has to set in order to modify the user behaviour to achieve the system optimum.

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