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## Carbon Emissions, Transport and Location: a Sustainability Toolkit for Stakeholders in Development

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## **CARBON EMISSIONS, TRANSPORT AND LOCATION: A SUSTAINABILITY TOOLKIT FOR STAKEHOLDERS IN DEVELOPMENT**

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### **Abstract**

This paper reports a tool that ranks work place destinations in accordance with their sustainability based on their location's capacity to minimise transport-generated carbon emissions within the Greater Dublin Area (GDA). To measure the transport-related CO<sub>2</sub> emissions the following datasets were used: (i) Central Statistics Office (CSO) 2006 Place of Work Census of Anonymised Records (POWCAR) and (ii) CO<sub>2</sub> emissions per mode of transport. These datasets were combined in a model with a 250 metre grid square coding of the GDA. The model calculations produced a carbon emissions value for every person travelling to work in each of the work destination grid squares within the GDA. The spatial data analysis was performed with a Geographical Information Systems (GIS) software package - ArcGIS - which conveyed both a visual and numerical representation of the model's resulting calculations. The results reveal a link between the location of workplace destination and the carbon emissions generated per person to travel to that location. It is shown that those destinations within close proximity to public transport options in city centre locations demonstrate a lower CO<sub>2</sub> emissions reading than those in more out-of-town locations without the range of public transport options. This outcome of the model forms the basis of a tool that could potentially assist in the environmental component of decision making for the location of work place developments. The implication of the tool is that it can allocate a ranking to locations based on their sustainability from a transport perspective.

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## 1.0 INTRODUCTION

Over 569,000 people travel to work in the Greater Dublin Area (GDA) every day (CSO 2006). This paper reports a destination based assessment of the carbon emissions associated with these journeys. A model was developed which implements this on a fine-grained basis comprising grid squares of 250 metres by 250 metres to evaluate carbon emissions associated with the journeys. The main purpose of the model is to determine the carbon emissions per person at 250 metre grid square destination level. This is to show the environmental impact of land use at various locations in as quantitative a manner as possible. This scientific indicator can assist in the decision making component of how land is used. This methodology has been researched and implemented such that it can deliver that objective.

Carbon dioxide (CO<sub>2</sub>) is a product of combustion, especially of fossil fuels, and is emitted by engines and power plants that use such fuels. Anthropogenic CO<sub>2</sub> is cited as one of the most significant contributors to global warming. A recent report prepared by the OECD (2009) states that Ireland must take significant steps if the commitment to reductions in CO<sub>2</sub> emissions under the Kyoto Protocol are to be met. The report goes on to state that Ireland's agri-food and transport sectors will be responsible for 70% of all CO<sub>2</sub> emissions outside the emissions trading scheme (ETS) by 2020 (See figure (1) below). The role of locations within the office sector in reducing CO<sub>2</sub> emissions is explored and illustrated in this paper providing planners and developers, in particular, with clear guidance in this respect.

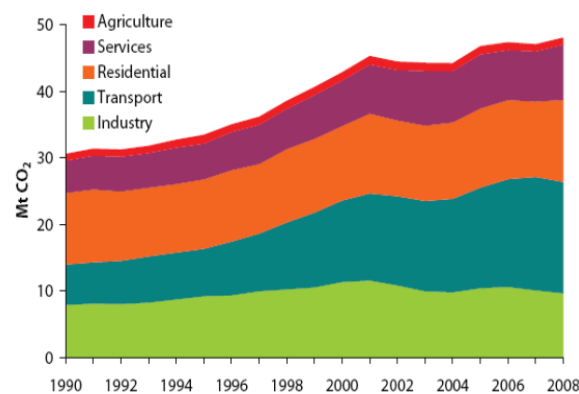


Figure (1): Primary Energy Related CO<sub>2</sub> by Sector 1990 – 2008 (Source: Howley et al. 2009)

## 2.0 LITERATURE REVIEW

Sustainability eco-labelling rating systems for buildings, for example BREEAM (2011), primarily focus on the fabric of the building itself. According to Dixon (2009) there is scope to review these rating schemes and focus on the location of workplace buildings as a benchmark for sustainability. This is upheld by Wyatt (2011) whereby he notes that the environmental performance of a building needs to be measured beyond the operation of the building itself and linked to commuting related energy consumption. In his analysis of this issue Wyatt cites location in relation to potential public transport systems as a means of restricting this type of energy consumption.

Location is central to the real estate industry (Geltner 2007). However, sustainability is not typically factored into the choices being made for the location of the office Dixon (2009). Locational preferences are made based on end user requirements (Hughes 2009). From an urban geography perspective, location is a force that is independent of sustainable development. It is related to where towns and cities develop and proximity to market. Cities are systems of markets “and a fundamental assumption is that locations with good accessibility are more attractive and have a higher value than peripheral locations” (Maguire,

Batty et al. 2005). The most efficient place to locate a business is at the central core of a city, known as the central business district (CBD) according to Christaller's central place theory (Balchin, Bull et al. 1995) and they need to be above a certain minimum size in order to provide both services and the demand for them (Hughes 2009). According to Zoellick (2009) the requirement for optimum sustainable development of cities is "lumpiness" which is focused development of urban centres and compact cities. Dixon (2009) illustrates that end-users in the office market sector rank location of the proposed office building as one of the most important considerations when making their final decision to move or change office space. Proximity to public transport is rated as being a significant factor in selection of office location for occupiers.

The link between population density and types of travel patterns (for instance, mode, distance and travel time) has been demonstrated through a substantial body of research, for example The Swindon Model (Steadman, Holtier et al. 1998). The report produced by ECOTEC (1993) has supported the findings of Newman and Kenworthy (1989; 1999) and Cervero (1996) in their world survey on energy use in cities to demonstrate a clear inverse correlation between urban density and distance travelled in cars. The findings from this research show that low density, more dispersed patterns of development are less efficient from an emissions perspective than more concentrated centralised patterns of growth. This would indicate a consensus for urban compaction in contributing to make cities more sustainable.

The area at the focus of this paper is the Greater Dublin Area (GDA). The more dispersed low dense type of urban form that Dublin characterises has been identified by Carty (2010; Carty and Ahern 2011) as a challenge to achieve any major changes. The research carried out by Carty and Ahern (2010, 2011) demonstrates that the layout of our medium sized city contributes significantly to this transport related energy use. Their view is that the augmented levels of carbon emissions are difficult to control without adopting a different strategy for future development within the GDA. Their analysis took the CSO POWCAR dataset which particularly looks at the place of work patterns of people and combined it with the carbon emissions generated by various modes of transport used in the Greater Dublin Area. The outcome of the Carty Ahern (2011, 2010) papers are that the future transport energy consumption (TEC) can be reduced by encouraging more high density mixed use developments closer to strong urban centres and good public transport links. This approach would lead to reduced transport related CO<sub>2</sub> emissions.

The use of a model to investigate the outcome of differing circumstances and situations in a controlled way in order to be able to make fact based or scientific decisions has been well documented (Steadman 1991; Brown, De la Barra et al. 1998; Steadman, Holtier et al. 1998). This is very appropriate in the area of environmental decision making as it is quantitative and scientific. Wyatt (2011), Banister (2008) and Carty (2011) have assembled data and developed models to illustrate the TEC in both a high density compact city and a more dispersed type urban form. The following are two examples of appropriate models for the methodology in this paper:-

(a) *A transport carbon dioxide emissions vulnerability index for the Greater Dublin Area (Carty 2010; Carty and Ahern 2011).*

This model was created to spatially represent the regional differences in commuting distances and modal shares in terms of transport carbon emissions. In illustrating the TEC they used GIS to show the various CO<sub>2</sub> emissions per mode and combined this with the CSO POWCAR dataset for the GDA.

(b) *Business parks and town centre workplaces in England: a comparative analysis of commuting-related energy consumption Model (Wyatt 2011).*

This Model examined the transport related CO<sub>2</sub> emissions associated with workplace locations in comparison to town and city centre locations. It used 2001 Census Special Workplace Statistics which allowed the distance travelled and mode of travel to be calculated for a sample of workplace locations.

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In order to assess patterns of energy use it is valuable to combine the results of a numerical model with the spatial analysis and visualisation capabilities of a geographical information system (GIS). The advantage of GIS is the ability to be able to communicate to a broad range of experts and non-experts in appealing and comprehensible visual formats (Maguire, Batty et al. 2005). Flowing from the literature on the models, mentioned above (Wyatt 2011 and Carty Aherne 2011) it was evident that the use of GIS in the development of the models has taken advantage of the capabilities of this type of spatial analysis and it served as a support to the decision making function by being able to layer, analyse and manipulate various types of data and information. Urban land use and transportation models are very appropriate candidates for this type of tool in that the data being used to give the outcome is both complex and computationally intensive.

Within general energy labelling rating systems, such as BREEAM (2011), there is already a category to rank locational connectivity as part of the scoring system. Hence according to Wyatt (2011) the location of the premises could also be scored based on its ability to minimise TEC because mandatory energy certification of real estate in England takes the form of Energy Performance Certificates (EPCs) and at the moment takes no account of commuting – related energy consumption. It would appear from the literature review that there is a gap in the research for a more fine-grained model to be created for the GDA. This model could combine both transport and carbon emissions in the context of the GDA. The outcome of the model would aim to provide a CO<sub>2</sub> reading for the various locations in the GDA whereby a ranking of these sites in terms of sustainability would be a very useful outcome.

### 3.0 METHODOLOGY

The key objective of this paper is to assign a transport-related carbon (CO<sub>2</sub>) emissions weighting to work place destinations in the Greater Dublin Area (GDA) based on current commuting patterns in the GDA. A general map of the GDA study area in the context of Ireland is presented in figure (3) below.

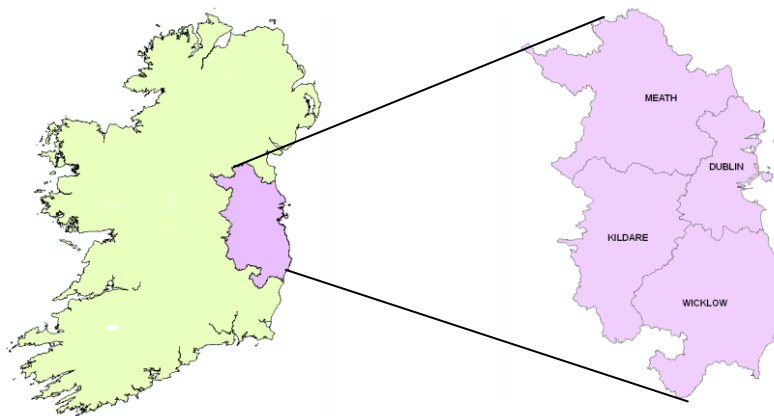


Figure (2): The GDA study area in the context of map of Ireland (Source: Authors)

The CO<sub>2</sub> weighting was computed by creating a model which included the distance from home to work, the mode of transport taken to work, and the CO<sub>2</sub> emissions factor for this mode. Within the model the calculation was repeated for all journeys with a final destination in the GDA. The destinations were aggregated to a 250 metre by 250 metre grid superimposed on a map of the GDA. The model output was then entered into a geographical information system (GIS) to facilitate visualisation and analysis.

The CSO created a dataset that issued with the 2006 census known as the Place of Work – Census of Anonymised Records (POWCAR) which records persons who make commuting trips to work. The POWCAR dataset is available in the form of 250 metre grid squares. This presents an opportunity to carry out a more fine grained analysis of the GDA study area

which is the subject of this paper. In their paper of 2011, Carty & Aherne calculate the CO<sub>2</sub> emissions for the dominant modes of transport in the GDA. These figures are provided in terms of kilogrammes (kg) of CO<sub>2</sub> per person per kilometre (km), for bus, rail, car, car passenger, LUAS (both red & green lines), DART and motorbike. Pedestrians and cyclists are assigned zero emissions. The figure for lorry transport was obtained from a UK source (Davies 2003).

There are 569,565 journeys recorded in the POWCAR dataset, with people travelling to work in 11,811 of the 111,797 grid squares in the GDA. The model was required to calculate the CO<sub>2</sub> generated for all of the journeys to each destination grid square. This required the distance in kilometres (km) to be multiplied by the CO<sub>2</sub> per km associated with the mode of transport taken for each journey, and the sum of all CO<sub>2</sub> generated by journeys to a given destination grid square to be calculated. The CO<sub>2</sub> generated per employee was then calculated by dividing this figure by the number of journeys to that grid square. This determined the carbon emissions per person at 250 metre grid square destination level and the next step was to map these numerical results. The use of GIS for the analysis of this type of spatial and numerical data was very constructive and enhanced the outputs of the model.

The GIS software (ArcGIS®) facilitated the display of multiple outcomes from the newly calculated dataset which included the following:-

1. The working population for each destination 250 metre grid square.
2. The CO<sub>2</sub> emissions per person traveling to each 250 metre grid square.
3. The mode split per person traveling to each grid destination.
4. The total emissions per grid destination.

The quantity of data to be displayed from the above list was quite large so it was necessary to be selective about the actual data displayed and create limitations in order to be more focused on the outcome of the model.

A benefit of using GIS technology in this study is the ability to portray vast amounts of statistical information in a visual and comprehensible manner. Often it is possible to discern trends, patterns and correlations in the data when displayed graphically that were not obvious in the tabular data. The advantages of utilising data at the 250m grid square level compared to data at electoral district (ED) level is clearly demonstrated resulting in a finer grained analysis and closer correspondence to the distribution of the population on the ground. See the following: figure (3) - Population at ED level in GDA; figure (4) - Population at 250 m grid square level in GDA and figure (5) - population at 250 m grid square level for origin and destination.

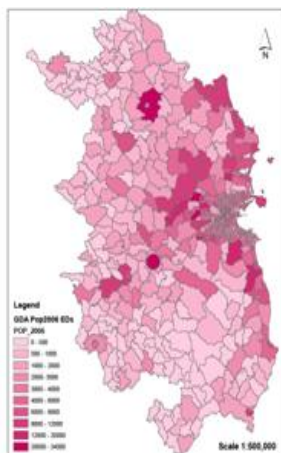


Figure (3)



Figure (4)

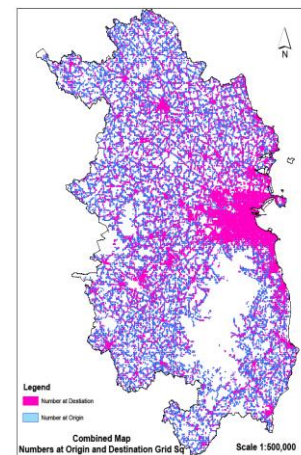


Figure (5)

4.0 RESULTS

A detailed investigation of the output data reveals strong patterns in the CO<sub>2</sub> emissions which provide quantitative evidence that can assist decision making. The key finding is that the CO<sub>2</sub> per employee in city centre locations is up to four times lower than that associated with travel to destinations close to or outside the M50. The model data permits a ranking of the destinations in terms of transport-based CO<sub>2</sub> emissions. In order to interpret the results three test sites were chosen. The test sites were selected to illustrate the variation in transport options to typical work place destinations. The main results of the carbon emissions readings generated through the model analysis are presented in table (1) below.

Table (1) Overall CO<sub>2</sub> emission results for the model at three sample test sites

Test Sites	CO <sub>2</sub> Emissions (kg p.pers.)	Destination Population
City Centre	1.09	4589
M50 Suburban	5.05	393
Outer Suburb	5.97	86

Figures (6) and (7) below illustrate an aerial view of the city centre test site with the grid square circled in yellow. The data for this grid square is taken from the POWCAR dataset and matched up with the relevant CO<sub>2</sub> output from the model for this test site grid square.

Figure (6) Population at Destination 250 m grid square – 4589 persons and Figure (7) CO<sub>2</sub> Emissions City centre - 1.09 kg CO<sub>2</sub> per person



Figure (6)



Figure (7)

Figure (7) Population at M50 destination – average 393 persons and Figure (9) CO<sub>2</sub> Emissions at M50 Destination grid square- average 5.05 kg CO<sub>2</sub> per person

The population travelling to this site in figure (8) is split over two grid square destinations because the office building falls within two grid squares. Hence the numbers presented are an average of the two grid square destination populations circled in yellow – 354 persons and 431 persons.



Figure (8)



Figure (9)

Similarly the CO<sub>2</sub> emissions in figure (9) are representative of the average readings taken from the two grid squares circled where a comparison was made between the modes of transport travelling to both grid squares.

Figure (10) Population at Naas – Outer Urban destination – 86 persons (average) and Figure (11) CO<sub>2</sub> emissions at outer suburban destination – 5.97 kg CO<sub>2</sub> per person (average).



Figure (10)



Figure (11)

## 5.0 CONCLUSION

The overall aim and objective of this paper was to evaluate the link between carbon emissions, transport and location. Through the literature review and the model results it has been demonstrated that there is a clear link between these three factors. Hence it is important to consider environmental performance beyond the operation of the building itself. This may lead to a re-evaluation of the role of out-of-town work place destinations with respect to the higher CO<sub>2</sub> emissions recorded as a result of car generated journeys to these locations.

This paper set out to provide a tool in evidence based decision making in the context of improving the environmental component of the decision. The research has succeeded in this purpose because it is both scientific and quantitative but lends itself to a generally accessible qualitative interpretation. A logical next step would be to run the procedure with the 2011 census data and to extend the model to include data for the entire country.

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