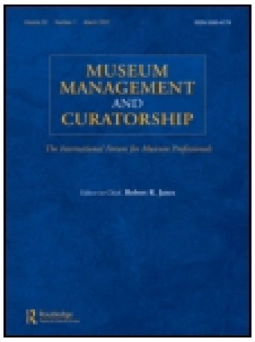

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MANAGEMENT

The carbon footprint of museum loans: a pilot study at Amgueddfa Cymru – National Museum Wales

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By using carbon footprints, museum staff can manage the impact of their loan programs on climate change. To measure the environmental impact of loan activities, a new carbon footprinting methodology has been developed. The methodology includes an *Environmental Impact of Loans* performance indicator, encouraging museums to set and achieve efficiency targets for loan activities. The methodology was developed using data from the Art Department of Amgueddfa Cymru – National Museum Wales. Based on this experience, evidence-based recommendations have been formulated to help museums reduce their impact on global warming.

Keywords: sustainability; climate change; carbon footprint; collections mobility; collections management; museum loans; museum registration; museum management; museums and social responsibility

Introduction

Global awareness of climate change is on the rise and a growing number of sectors are being engaged – including museums. The museum sector in the United Kingdom (UK) has begun to expect improvements in the environmental friendliness of the exhibitions industry (Mellor 2008; National Museum Directors' Conference 2009), and its professionals are asking for tools to measure sustainability (Museums Association 2009, 8). In the years to come, this demand is likely to extend worldwide as museums recognize their responsibility to limit the collateral effects of their activities on the environment.

The 'carbon footprint' is a simple metric that shows how an activity contributes to climate change. It takes into account carbon dioxide (CO_2) and other greenhouse gases (GHGs) such as methane and nitrous oxide. A museum's complete carbon footprint should reveal how all its operations affect climate change. It is reasonably easy for museums to measure on-site activities, such as gas and electricity use, by using online tools or specialized auditing agencies. However, this represents only part of their impact. Little information exists to help museums measure off-site, complex operations such as loans.

The aim of this article is to suggest a new carbon footprinting methodology designed specifically for museum loan activities. It also includes a performance indicator for the *environmental impact of loans* (*EIL*) to encourage museums to balance their environmental responsibility with the growing demand for increased

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access and collections mobility. To design the methodology, initial data were collected at the Art Department of Amgueddfa Cymru – National Museum Wales.

Carbon footprinting and museums

The European Union is committed to reducing its production of carbon emissions[1] by at least 20% of 1990 levels by 2020 (European Union 2009). In the UK, this commitment has extended to sectors that are not large energy consumers (Department of Energy and Climate Change 2010). Although museums may not be the largest carbon producers, setting a positive example can have a ripple effect among the general public (Brophy and Wylie 2008; Museums Association 2008). Museums can also mitigate climate change directly by managing and containing their own carbon footprint. Carbon footprinting is not yet a requirement in the museum sector, but the sooner carbon accounting is integrated into decision-making processes, the more prepared museums will be to justify the value of their activities, while demonstrating environmental leadership and corporate responsibility.

Carbon footprinting

The unit of measurement

A carbon footprint indicates the expected effect of an activity on global warming, spread out over a 100-year period. To make it easier to add up the effect of different GHGs, they are assigned relative values, enabling comparisons with carbon dioxide – the most important (Intergovernmental Panel on Climate Change [IPCC] 1996). For this reason, carbon footprints are expressed in metric tons of carbon dioxide equivalents (tCO_2e).

GHG protocol

The *Greenhouse Gas Protocol Corporate Standard* (World Resources Institute [WRI] 2004) is the primary international reference for company-level GHG accounting and reporting, and is accompanied by several peer-reviewed calculation tools.[2] Given its widespread acceptance, the Protocol was used to design the museum loan carbon footprinting methodology, along with the British Standard Institute's *Publicly available specification for the assessment of the life cycle greenhouse gas emissions of goods and services* (British Standards Institute 2008).

Defining boundaries

To ensure the relevance of a carbon footprint, it is important to define the elements it includes and those that are left out. To help organizations identify and implement emission reductions, the *Greenhouse Gas Protocol* recommends using the 'control approach' (WRI 2004, 21). This helps narrow down the footprint to the operations that can be controlled or managed by the organization. The other approach, 'the equity approach', focuses on profit and ownership. The control approach will be used in the loan carbon footprinting methodology.

Emission sources are generally classified according to their origin (Figure 1). For official mandatory reporting, it is always necessary to count emissions produced by an organization's own activities (sources 1 and 2), but it is optional to count those produced by third parties that support its activities (source 3) (WRI 2004). In the case of museum loans (nonmandatory reporting), even source 3 emissions should be counted to ensure that the carbon footprint remains representative of this activity, as several third parties are involved.

GHG conversion factors

In most instances, it would be impractical to measure the carbon emissions resulting from loan activities directly at the source. A simpler way of doing this is by using 'GHG conversion factors'. These numbers enable 'activity data' (amount of energy used, distance traveled or quantity of materials produced) to be converted into quantities of carbon dioxide (WRI 2004, 42).[3]

It is important to remember that carbon footprinting is not an exact science. Even if great care is taken to collect the most accurate activity data, GHG conversions themselves contain many uncertainties. As indicators of climate change, carbon footprints are useful management tools, but they should not be confused with exact quantities of carbon emissions released into the atmosphere.

Carbon footprinting methodology for loans

An eight-step carbon footprinting methodology for museum loans, which focuses on reducing carbon emissions without downsizing activities, is presented below (Figure 2). It is then applied in the following section on a case study. This case study includes the loan of two-dimensional works (paintings and paper) and some

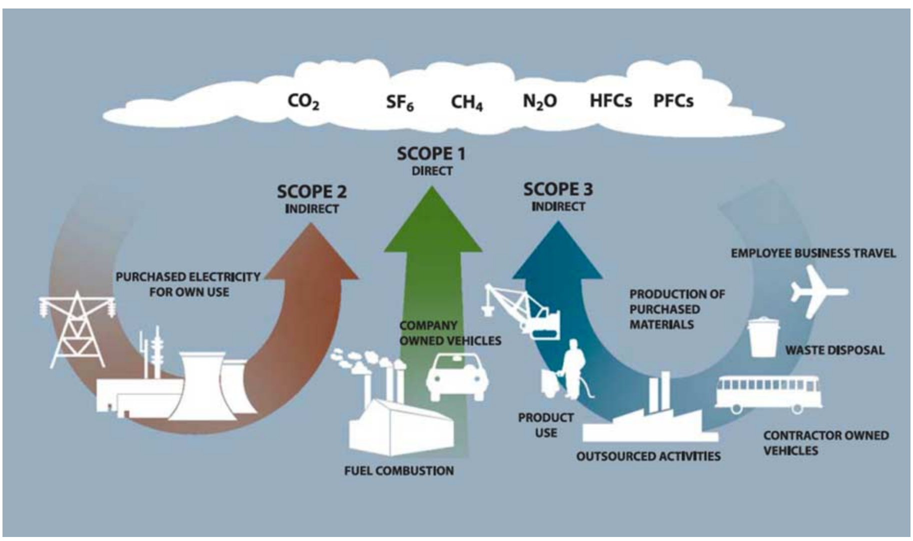

Figure 1. Emission sources. Source: WRI (2006), copyright of the New Zealand Business Council for Sustainable Development. Reproduced with permission.

Figure 2. Eight steps of the loan carbon footprinting methodology.

three-dimensional works grouped under 'applied art' (ceramics, sculpture, etc.), but it could be applied to other types of collections.

To better understand how the carbon footprint is distributed, it is useful to divide loans into four loan components: wrapping materials, packing cases, transport and couriers. These reflect different areas of responsibility in the loan process, which is consistent with the control approach.

Step 1: define the objective

The statement of the carbon footprint assessment's objective should clarify its context and boundaries. It should express the base year (the year to which all future assessments will be compared) and indicate how the results will be used and by whom.

Step 2: express who manages GHG emissions

A complete museum loan includes an outward journey from the lending institution, all intermediate journeys between exhibition venues and the final inward journey back to the museum. A single loan can comprise one or several objects. Lending institutions exert managerial control over their own objects through policies, legal title, procedures and conditions of loan. When arranging inward loans, they no longer have this control. Although borrowers initiate loans, lenders approve them and specify operational requirements. In keeping with the control approach, lending institutions manage carbon emissions arising only from outward loans (and not inward loans).

Step 3: map operations

To simplify data collection, it is useful to divide loans into destination categories (i.e. national, regional, international, etc.), as many museums establish different conditions of loan or travel specifications based on distance. As a guide, it may be helpful to make practice explicit by mapping a typical loan operation, one step at a time, for each destination category.

Step 4: define exclusions and assumptions

To ensure that all future carbon footprints following the initial one can be compared with each other, defining what is included in the calculations is a crucial step. If measuring certain elements is impossible or impractical, estimation approaches can be used – as long as these are clearly explained (WRI 2004, 31). Transparency is key – this will ensure that results are reproducible. For instance, whenever loan documentation is incomplete, the museum can use the data from a similar, well-documented loan as long as this is openly disclosed.

Temporal boundaries are also required when calculating loan footprints, as objects may remain on loan for several years. For consistency, the authors suggest counting all loans that left the museum in a given year as part of that year's carbon footprint. Accordingly, intermediate and inward journeys are counted in that year's footprint, even if they occurred later.

Wrapping materials

Calculations of the environmental impact of wrapping materials depend on quantities used and on whether they are reused. Since it may be impractical to measure the quantities of wrapping materials used for every object, a simple estimation equation based on the size of the objects can be developed (see *Step 4: Wrapping Materials* on page 11).

Packing cases

Calculations for the environmental impact of packing cases depend on what they are constructed from, their life expectancy and how they are initially delivered to the lending institution. It would require disproportionate effort to count materials used in the construction of each individual case; so it is advisable to standardize a few case types and determine which materials are replaced and how frequently. Then, an estimation equation can be developed based on the size of the objects and of cases, and the frequency of replacement of certain elements (see *Step 4: Packing Cases* on page 11).

Transport

Since calculations for the environmental impact of transport require distances, it is important to select a simple and consistent method to collect these data. To avoid the time-consuming task of gathering exact distances traveled from transporters, these can be calculated with online calculators (see *Online Distance Calculators* on page 22) using all known locations on loan itineraries.

In addition to distance, calculations for airfreight emissions require the weight of the cargo. However, packing cases are not always weighed individually by airport personnel and may be grouped with the cases of other institutions. If this is the case, couriers supervising these operations can ask airport personnel to weigh cases individually. Otherwise, the case weight estimation approach described in the *Transport* section (page 12) can be used.

Whenever trucks are boarded onto trains or ships, calculations for rail and sea freight require the weight of the entire truck (including cargo). Since exact truck weights may not be available, museums can establish an average truck weight by examining the most frequent types of vehicle used and obtaining their gross vehicle weights (GVWs) from transport agents. This value can be used every time loans travel by rail or sea.

Research in the food industry has shown that climate control during the transit of freight trucks certainly increases environmental impact (Tassou, De-Lille, and Ge 2009). For the transport of museum loans, this impact would likely be lower since the temperatures are not as low. Nonetheless, the international exhibition industry is now encouraging museums to consider relaxing climate specifications for loans to lower carbon footprints (National Museum Directors' Conference 2009). Although it was not possible to include the impact of climate control in transit here, museums can do this by establishing a 'climate control factor' to be multiplied by the distance traveled. This can be done by making a few test journeys with climate control 'on' and 'off' and noting the differences in fuel consumption – possibly at different times of the year.

Couriers

Calculations for the environmental impact of couriers are most influenced by how staff travel, where they stay and what they eat. When accompanying airfreight, museum couriers generally travel in Business Class. When accompanying road freight, couriers can either travel inside the vehicle or in a car following the vehicle. Nonaccompanying couriers generally travel in Economy Class.

Where staff travel with the loans by road, their journey can be ignored because, contrary to air travel, an empty seat would not significantly reduce carrying efficiency of the vehicle. Distances for passenger travel can be estimated using the same online tools as for freight transport, but additional passenger car journeys must be counted between

- warehouses and hotels;
- exhibition venues and hotels, railway stations or airports;
- the courier's home and the lending institution.

For simplicity, these distances can be standardized by fixing a typical distance per journey (see *Step 4: Couriers* on page 12). To calculate accommodation and food consumption, many museums stipulate the amount of hotel nights and *per diem* allowances to be provided for their couriers in their conditions of loan.

Step 5: select GHG conversion factors

Ideally, museums should use GHG conversion factors that are specific to their country. As carbon accounting has not developed at the same pace everywhere, it is likely that country-specific conversion factors do not exist. Until they are available, the ones suggested in this study can be used.

Conversion factors for wrapping and packing case materials used here include emissions in the product's life up until only it leaves the factory gate – 'cradle to gate' (Hammond and Jones 2008). When available, conversion factors that consider the entire life cycle of a product's life ('cradle to grave') would be preferred.

To select conversion factors for freight and passenger transport, museums must consider the characteristics of the vehicles used, including fuel type, weight and load. It is advisable to limit the number of vehicle categories considered to avoid complicating the data collection process – for example, one 'average' freight truck and one passenger vehicle. All available conversion factors worldwide have been integrated into the regularly updated *Greenhouse Gas Protocol tool for mobile combustion* (WRI 2008). At the time of writing, country-specific transport conversion factors are available only for USA and UK; all other countries must use those provided by the IPCC.

The conversion factor for hotel accommodation was calculated by multiplying the average electricity consumed per night in European hotels (SQW Consulting 2007), by the UK grid rolling conversion factor (Department for Environment, Food and Rural Affairs [DEFRA] 2009). The conversion factor for food consumption was sourced from the Web site of Carbon Fund, a US-based, nonprofit organization. For simplicity, a selection of GHG conversion factors is presented in Appendix 1 and has been included in the standalone calculation spreadsheet (Appendix 4).

Step 6: calculate the footprint

Museums must find a practical balance between the desired level of precision and the resources needed to record data, keeping in mind that carbon footprints are inherently not very accurate. A first pilot assessment can be used to determine what information can be collected feasibly. To help in the reconstruction of itineraries, it can be useful to map the various elements on paper (destination categories, modes of transport, distances, hotel nights and food days). For clarity, the example shown (Figure 3) was created using a computer, but those used for the actual assessment were hand-drawn.

Step 7: evaluate environmental performance

Performance indicator for environmental impact

Although indicators have been used for 20 years by UK museums to report performance to central government, they are sometimes criticized for inducing management-by-numbers and encouraging quick fixes to improve scores (Keene 2002, 38, 185). Regardless, performance indicators are widely used in the public sector and offer interesting possibilities for measuring environmental impact. Given the current trend in the museum sector for improved environmental friendliness and collections access, there is value in a new performance indicator to monitor these issues.

To ensure loan programs achieve their desired social outcomes, the carbon emissions arising from these activities should contribute to increasing public access

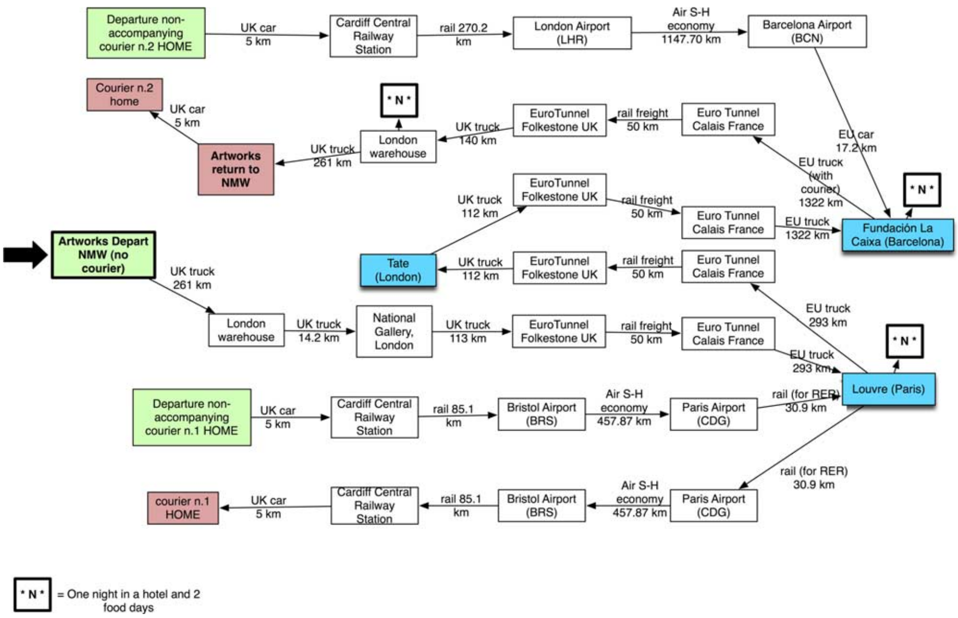

Figure 3. Example of a loan process map for three borrowing venues – Paris, London and Barcelona (Lambert 2009).

to a museum's collection. Although the authors are not aware of specific data correlating loan numbers to increased access and public benefits, it has been asserted that increasing the mobility of museum collections encourages the dissemination of knowledge, international cooperation and cultural dialog (National Board of Antiquities, Finland 2006, 1). To account for the inherent social value of loans and encourage museums to balance environmental costs with access requirements, this methodology includes a performance indicator for the *EIL*. As an efficiency ratio, the *EIL* shows how many objects a museum is able to send out on loan for every ton of carbon dioxide it emits (objects/tCO_2e). Because the most efficient loans will contain more objects, the *EIL* is based on the number of objects rather than the number of loans.

$$EIL = \text{no. of objects} \div \text{carbon footprint}$$

It should be noted that the inverse (tCO_2e/objects) is a productivity ratio that shows the carbon emissions embodied in each object. Using this metric may lead to reducing the footprint by reducing activities, which would go against current priorities. To reflect the diversity inherent in loan operations, the *EIL* should be separated by destination category (national, regional, international, etc.), indicating as many qualifiers as are relevant to the museum's operations. If destinations were grouped together, the *EIL* would be biased toward short-distance, national loans. By measuring the environmental performance of loan programs, museums can develop time-bound targets for improved access and lowered environmental impact.

Improving environmental performance

In theory, to achieve environmental performance targets for loans, museums have three options:

(1) Reduce the carbon footprint maintaining the same level of access (no. of objects);
(2) Increase access (no. of objects) maintaining the same carbon footprint;
(3) Offset carbon emissions.

Option 3, carbon offsetting, is the 'neutralizing' of carbon emissions by participating in activities that have an equal but opposite impact, e.g. planting trees. Offsetting has been severely criticized by Smith (2007) as inducing a 'business-as-usual' attitude and negative effects on consumption patterns. Museums should focus on improving the efficiency of their activities (options 1 and 2) before they consider offsetting. Financial savings would also accompany the first two options, as cost is closely linked to the carbon footprint (i.e. fuel consumption and use of materials).

Step 8: report findings

All stakeholders, i.e. parties likely to affect or be affected by the results, should feel engaged by the carbon footprint assessment process. This can be achieved through a carefully planned communication strategy. The carbon footprint report should be evidence-based and concise, but should provide detailed data tables, glossary and references as appendices. The report will be most meaningful if it clearly shows the relative impact of each loan component, and how changes in practices affect the footprint over time.

Art Department of Amgueddfa Cymru – National Museum Wales: pilot study

Background information

Data from a real loans program were used as a pilot study to design the loan footprint methodology. Amgueddfa Cymru – National Museum Wales has eight different sites throughout Wales, but this study focused on the loans of one department (Art) at one of these sites (National Museum Cardiff). In 2006, the chosen base year, the Art Department approved 29 outward loans for a total of 216 objects (Figures 4–6). This year was selected based on the completeness of the loan documentation available.

Carbon footprint methodology applied to Amgueddfa Cymru – National Museum Wales

Step 1: define the objective

For this study, the objectives were to

- calculate the Art Department's 2006 loan carbon footprint and evaluate its environmental performance;
- identify the relative impact of each loan component;

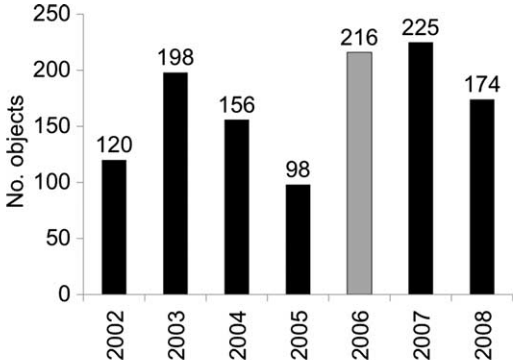

Figure 4. Number of objects loaned out annually by the Art Department (Lambert 2009).

- determine how current loan practices are contributing to reducing or increasing its footprint;
- formulate recommendations for reducing the loan carbon footprint.

These objectives were achieved by applying the eight-step loan carbon footprinting methodology (detailed below) and the *EIL* performance indicator, which shows the carbon efficiency of loan activities.

Step 2: express who manages GHG emissions

Based on the rationale discussed previously in Step 2: Express who manages GHG emissions section (page 4), it was established that the Art Department manages the GHG emissions arising from outward loans. Although road transport and couriers are frequently shared between institutions, all road transport emissions were assigned to the Art Department because of the type of GHG conversion factors that were used (Lambert 2009).

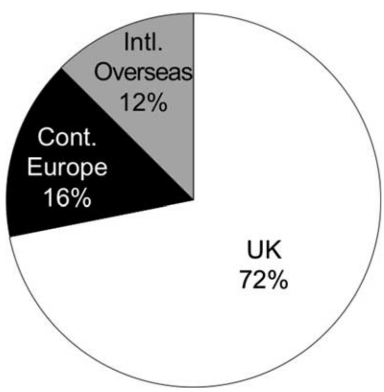

Figure 5. Geographical proportion of exhibition venues in 2006 (Lambert 2009).

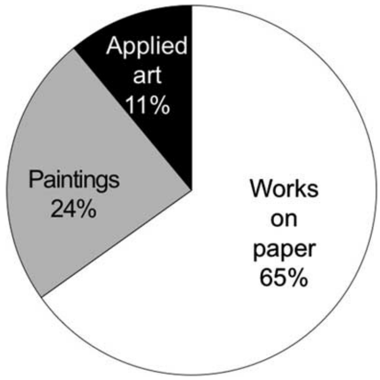

Figure 6. Proportions of loaned objects in 2006 (Lambert 2009).

Step 3: map operations

Outward loans were divided into three destination categories: UK, Continental Europe and International Overseas. The Art Department insists that a courier should accompany all loans traveling by road. However, it often uses couriers of other institutions on intermediate journeys between venues. Most of the packing cases come from Kent Services, a company specializing in packing case rentals for museums and galleries.

Step 4: define exclusions and assumptions

Wrapping materials. Paintings loaned out are usually wrapped in clear polyethylene sheeting of 100 µm thickness. Works on paper are mounted in standard-sized frames and travel unwrapped inside slotted cases. Applied art objects usually travel unwrapped, with supportive wads of acid-free tissue. Since the quantities of tissue paper and tape used are small, only polyethylene sheeting used for paintings was considered in the calculations. An equation was used to estimate the quantity of polyethylene sheeting (Q_{PES}) for each painting based on its dimension. This equation assumed that paintings were wrapped with an amount of sheeting equivalent to three times the surface of the painting itself (see Appendix 1). Any other method can be used, as long as it produces a final quantity expressed in kilograms.

Packing cases. The side panels of cases used by the Art Department are made of plywood and strengthened with softwood battens. The interior is lined with polyethylene foam and fitted with polyurethane cushioning foam. These cases have a considerable life span. A group of 37 cases built 20 years ago is still in circulation today. While polyethylene foam linings practically never need to be replaced, about 35% of polyurethane foam cushioning is replaced every year (K. Amey and J. Roffey, personal communication).

As carbon footprints refer only to one year's activities, the impact of packing cases was small enough to be practically irrelevant over such an extended lifespan. In fact, the yearly impact of one of these cases (excluding the polyurethane foam) is about 3.5 kg of carbon dioxide (see Appendix 2). This is equivalent to about a third of the footprint of a month's incoming emails (Berners-Lee 2010, 15). Thus, except for polyurethane foam, case construction materials were omitted from the footprint calculations. Museums using single-use, purpose-built, packing cases should include all construction materials in their footprint.

Overall, the quantity of packing materials depends on two variables that can be retrieved easily from the documentation: the outer dimensions of the case and the dimension of the object it contains. All packing materials physically lie somewhere between these two dimensions.

In the Art Department pilot study, the quantity of polyurethane foam (Q_{PUF}) was estimated by subtracting the object's volume from the inner volume of the case (excluding the thickness of the outer shell and of the inner polyethylene foam lining; see Appendix 1). Whenever other materials must be accounted for, a similar approach can be used for each layer of the packing case (outer shell, polyethylene lining, etc.). Any other method can be used, as long as it produces a final quantity expressed in kilograms.

Transport. To simplify the selection of GHG conversion factors, all freight trucks were assumed to have the same characteristics: average GVW and average load, diesel-fuelled and rigid (nonarticulated). Whenever the weight of trucks was required, it was assumed to be 5 metric tons (Lambert 2009).

Since packing cases traveling by road are not weighed by the Art Department, an average density was used. This made it possible to assign an indicative weight value for any full case using its outer dimensions. The known weight and dimensions of 54 full cases from other years were used to calculate an average density of 0.1273 tons per cubic meter. Whenever case weights were required and were unknown, this value was simply multiplied by the case's volume (m^3).

Ideally, museums should weigh their cases by filling them with different types of objects. This will help them develop indicative density values for different types of collections.

Couriers. For the pilot study, it was assumed that two journeys of 2 km were made daily (between hotels and warehouses or exhibition venues), with an additional 5-km travel to work (Lambert 2009).

Step 5: select GHG conversion factors

To convert quantities of wrapping and packing case materials, and distances traveled, into quantities of carbon dioxide, conversion factors from various sources were used. These are listed in Appendix 1, along with conversion factors for other commonly used materials and vehicles.

Step 6: calculate the footprint

A user-friendly data collection sheet has been prepared to help couriers, collections managers and/or registrars gather all useful data on a single sheet (Appendix 3). Afterward, the quantities of wrapping materials and packing cases are calculated using the equations for Q_{PES} and Q_{PUF} (Appendix 1). Then, the standalone carbon footprint calculation sheet (Appendix 4) is used to compile the activity data and convert it into quantities of carbon dioxide equivalents. Based on this format, museums can develop a spreadsheet to automate the calculations and update the GHG conversion factors.

In 2006, the Art Department's outward loan carbon footprint was 53 tons of carbon dioxide equivalents (Table 1). The transport of objects had the largest impact on the environment, producing 52% of the total footprint (Figure 7). Couriers are close behind at 45% of the total footprint. Figures 8–10 show a breakdown of the impacts of the various elements within each loan component. It is significant that transport (freight and passenger) represents 95% of the Art Department's environmental impact. Therefore, improving the carbon efficiency of transport is essential to reducing its impact.

By way of comparison, 53 tons of carbon dioxide is equivalent to only about 20 return flights in Business Class between London and New York (DEFRA 2009), to the personal annual carbon footprint of six UK residents (DEFRA 2008, 7) and to the hourly operation of the UK postal service (Royal Mail 2008, 2009). Closer to museums, the transport emissions alone of a traveling exhibition organized by the Smithsonian Institution (USA) amounted to 38 tons of carbon dioxide (Warden 2007). Thus, 53 tons seems like a large amount of carbon dioxide, but placing it in context with other activities reveals how society readily accepts activities that are far more carbon-intensive.

Step 7: evaluate environmental performance

The pilot study showed that overall, 4.1 objects were loaned out for every ton of carbon produced (Table 2). Based on its situation, the Art Department's *EIL* performance was divided into four destination categories: 'UK only', 'Continental Europe only', 'Continental Europe & UK' and 'International overseas'. Based on the results, a hypothetical environmental performance target for loans could be that by 2015, the Art Department would raise its International (Overseas) *EIL* by 0.4 points

Table 1. Summary table of the Art Department's carbon footprint for 2006.

	Total activity data	Total tCO_2e
Wrapping materials		
Polyethylene sheeting	12.4 km	0.021
Packing cases		
Polyurethane foam	151 kg	0.453
Case deliveries	1368 km	1.097
Transport		
Road freight (all)	29,601 km	23.000
Air freight	73,540 km	3.562
Rail freight	500 km	0.080
Sea freight	484 km	0.938
Couriers		
Road-passenger	4071 km	0.917
Air-passenger	117,677 km	19.998
Rail-passenger	12,725 km	0.777
Hotel accommodations	75 nights	2.265
Food	143 days	0.179
Total carbon footprint		52.904

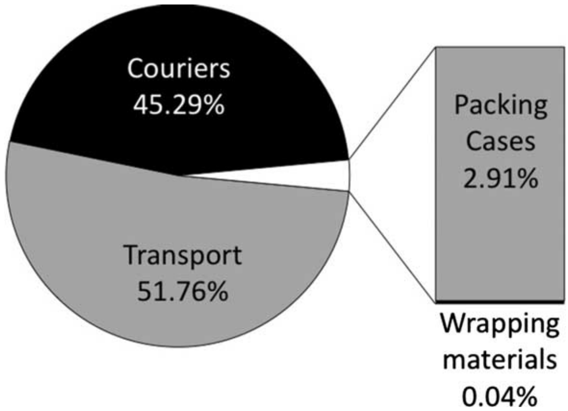

Figure 7. Breakdown of the Art Department's total carbon footprint for 2006, by loan component.

and its National *EIL* (United Kingdom) to 22. To do this, it would have to increase its loan activities and/or reduce its environmental impact. The section *How to Reduce the Carbon Footprint of a Loans Program* (below) offers suggestions on how this can be achieved.

Step 8: report findings

A comprehensive report including targeted recommendations to reduce the Art Department's carbon footprint and improve its *EIL* rating was submitted to the Sustainability Forum of Amgueddfa Cymru – National Museum Wales. The Art Department now has an evidence base to integrate carbon footprinting into decision making.

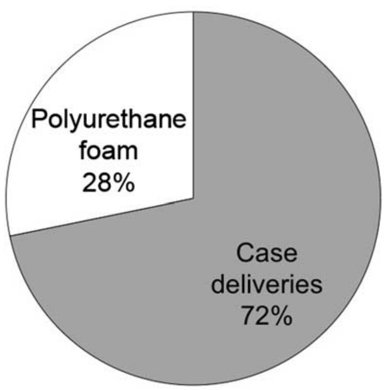

Figure 8. Breakdown of the Art Department's carbon footprint for 2006 (packing case component only).

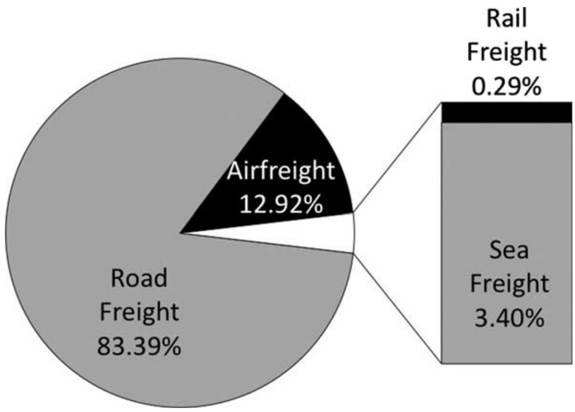

Figure 9. Distribution of the Art Department's carbon footprint for 2006 (transport component only).

How to reduce the carbon footprint of a loans program

Reuse wrapping and packing materials

The New Museum Registration Methods (Freitag and Smallwood 1998, 137) states that polyurethane foam 'must not be re-used'. Although polyurethane foams are chemically unstable and long-term contact with objects should be avoided, there is no evidence to suggest that wrapping and packing materials cannot be reused several times for loan purposes if they still offer proper protection for objects. Because Kent Services reuses all its foams, the Art Department saved about 840 kg of carbon dioxide in 2006.

Lease packing cases or refit old ones

It is rather alarming that in a group of 85 major museums worldwide, as many as one fifth do not reuse any of their packing cases (Mellor 2008). By using a case leasing service instead of commissioning newly built cases and disposing of them, the Art Department saved 5.161 tons of carbon dioxide from materials, an additional 13 kg of carbon dioxide equivalents from landfill decomposition (WRI 2005, 34) and 6.6

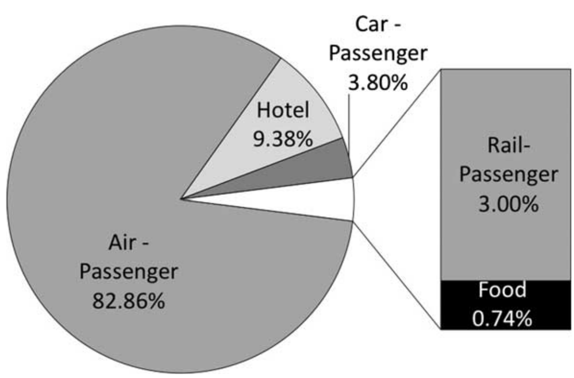

Figure 10. Distribution of the Art Department's carbon footprint for 2006 (courier component only).

Table 2. EIL performance indicators for the Art Department's outward loans for 2006.

Destination category	No. of objects	Carbon footprint (tCO_2e)	EIL (objects/ tCO_2e)
National (UK only)	189	10.026	18.9
Regional (Continental Europe only)	12	4.538	2.6
Regional (Continental Europe and UK)	11	11.255	1.0
International (overseas)	4	25.988	0.2
All destinations	216	52.904	4.1

tons of solid waste. Where leasing is not yet viable, museums should keep and refit their cases as much as possible.

Use sea freight and rail freight, whenever possible

For international loans, using sea freight has clear environmental benefits. On a hypothetical loan from London to Sydney, carbon emissions could be reduced 37 times if sea freight were used instead of airfreight. The greatest inconvenience, however, would be the duration of the journey (increase from 21 h to 35 days), possibly affecting the use of accompanying couriers.

For national loans, using rail instead of road transport can reduce carbon emissions significantly. Since rail freight is not a door-to-door service, it requires transshipment by truck – this would affect logistics and somewhat lengthen the shipping time. Even so, emissions can be reduced considerably, with road transport creating 7.5 times the emissions of rail freight for a typical UK-based journey (Lambert 2009).

The use of rail transport is discouraged due to elevated shock and vibration levels (Marcon 1991). Nonetheless, frequently cited sources refer to data that were collected in 1971 (Marcon 1991) and 1987 (Ashley-Smith 1999). Since then, high-speed rail technology has required rail beds to be leveled and new studies may yield different results. Interestingly, these same studies show that the shock and vibration levels encountered in sea transport were generally lower than in air transport. Saunders (1991) has shown that extreme climatic variations could be encountered in air transport, as much as in sea transport. Perhaps the time is ripe to generate new evidence and revalue alternative modes of transport.

Set upper limits for the number of objects in ground-shipped loans

There are at least two thresholds for significant increases in carbon emissions arising from road freight:

(1) the maximum number of cases that can fit inside a truck;
(2) the maximum number of cases that can be supervised by a courier.

Large loans may require a larger, heavier truck and/or an additional courier, thus increasing the environmental impact. The maximum number of packing cases that can fit inside a truck is difficult to quantify because of the variability in case and truck sizes, and because of the sharing of transport with other institutions. Nonetheless, museums could set formal limits based on these two thresholds to lower their environmental impact, minimize costs to the borrower and use their own staff effectively. For example, they could decide to approve only those loans that do not require more than one courier.

Share couriers and use them only when justified

Sharing couriers saves passenger carbon emissions, especially on international loans. In 2006, the Art Department saved nearly 10 tons of carbon dioxide equivalents on air and rail emissions by not sending a courier to accompany loans on intermediate journeys (between exhibition venues). Museums already share couriers with other institutions, and a recent survey shows that 78% of museums would use another institution's conservation staff as couriers (Mellor 2008). Museums can develop well-defined, transparent criteria to assess their courier needs, based on risk or specific object requirements. The International Exhibitions Organizers (2009) group produced revised courier guidelines, urging accompanying couriers to be used sparingly. This group would be ideally positioned to develop an international courier accreditation scheme to encourage sharing and the building of trust between institutions using existing courier guidelines.

Avoid hand-carrying objects if an extra seat is required

When objects are hand-carried inside the passenger cabin, they require an extra seat or an extra row of seats to fasten the case next to the courier. On a return journey between London and New York, for example, about 3 tons of carbon dioxide equivalents can be saved per extra seat not purchased if a small case is checked in as cargo instead of being hand-carried. Unless cupboard storage will be available inside the cabin, it is recommended that hand carriage of objects be avoided.

Insist that couriers travel with ground-shipped loans

Because of scheduling or staff availability, couriers are sometimes sent to borrowing venues separately from road shipments. If a courier is deemed necessary at any point in the loan process (even if only at installation), he or she should always be present inside the vehicle and not travel by other means of transportation. This will help reduce passenger transport emissions.

Encourage transport agents to measure fuel efficiency

In 2009, the International Convention of Exhibition and Fine Art Transporters (2010) adopted environmental guidelines to help its members lower their environmental impact. Many of the transport agents consulted for this study described how they were reducing their environmental impact by submitting their fleet to regular check-ups to improve fuel efficiency. To effectively integrate environmental performance into decision making, museums should put pressure on their agents to produce sustainability reports.

Introduce a sustainable procurement policy

Through their purchasing decisions, museums can influence the practice of their suppliers. In this instance, museums could encourage transportation companies to consider alternatives to fossil fuel or factor in the life cycle assessment of packaging materials (De Silva and Henderson 2011).

Plan exhibitions strategically and geographically

Warden (2007) recommended that exhibitions should be planned according to geography. In fact, loans often travel great distances back and forth because itineraries are planned based on openings in the individual borrowers' exhibition calendars. Even though lending institutions may not necessarily have a say in the planning of an exhibition's itinerary, they could try to persuade borrowers to consider the environmental (and financial) impact of itinerary planning holistically when the loan conditions are being negotiated.

Benchmark performance

Following their first assessment, museums should create their own internal benchmarks by monitoring yearly carbon reductions or increases, or by demonstrating how the loan footprint relates to that of other museum functions. It is useful to remember that any carbon reduction is a step forward to making outreach activities more environmentally sustainable. It is not necessarily possible, and may actually be misleading, to define what constitutes an 'acceptable loan footprint'. Further research is required into what impact can be expected from 'average' loan programs that ensure a good level of access on a reasonably low footprint.

Museums may already be following many of the above-mentioned recommendations to save resources. Financially motivated decisions can be accompanied by environmental benefits. Museum managers can make a positive difference by integrating concerns for their carbon footprint into everyday decision making, in loan policies and procedures.

Discussion

While interest in minimizing environmental impact is increasing in the museum sector, so does the pressure to improve collections mobility (European Commission 2007; Museums, Libraries and Archives Council 2009). At the same time, the current economic climate may be threatening the capacity of museums to deliver these services (Kaufman and Bailey 2009). Instead of reducing total activity to reduce the carbon footprint, this assessment shows the importance of aiming for environmental efficiency while still allowing the museum to create socially and economically attractive activities, such as loans. Carbon footprints address only one of the three pillars of sustainability (environmental, social and economic). Museums wishing to assess their overall sustainability should find meaningful ways of integrating environmental impact into a wider matrix of social and economic impacts.

The methodology described within this paper offers a relatively simple way to calculate the environmental impact of museum art loans, including a performance indicator to correlate activities to benefits. However, it does require a commitment to collect and interpret data, and to act upon these findings. Many museum professionals already feel that they are being asked to carry out an increasing multiplicity of tasks with decreasing resources. The authors provide a tool to help museums better understand how their activities affect climate change and how to minimize this impact. It is for the profession to gauge its importance and priority. Is monitoring environmental impact an unwelcome distraction or an essential step in ensuring the relevance of museum practice in society?

Conclusion

The generous participation of Amgueddfa Cymru – National Museum Wales in the pilot study has made it possible to test the eight-step carbon footprinting methodology and refine the data collection and calculation sheets to allow any museum to conduct its own carbon footprint assessment. Based on the methodology used, the Art Department's outward loan footprint for 2006 was 53 tons of carbon dioxide equivalents – 95% of which resulted from freight and passenger transport. It is impressive that its current environment-friendly practices have contributed to savings of more than 15 tons of carbon dioxide equivalents, and encouraging that the review of transport practices could save even more.

Museums in general should reexamine couriering practices and policies, transport operations, exhibitions itinerary planning and the reuse of materials. This study considered outward loan activities from one lending institution to several venues. A further extension of this work will be to use the methodology to determine the total impact of traveling exhibitions, including a component for visitor travel. According to the UK Museums Association's fifth draft sustainability principle, museums must 'make the best use of energy and other natural resources and minimize waste, setting targets and monitoring progress towards them' (Museums Association 2008, 6). By using this tool, museums worldwide can formulate informed strategies for loan programs while serving the diversity of established aims for access. To grow sustainably, museum loan activities in the twenty-first century should aim to balance environmental, social and economic concerns, and the *EIL* is offered to contribute to this vision.

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Notes

1. In this article, 'carbon' is used as shorthand for all other GHGs associated with global warming.

2. The Greenhouse Gas Protocol is based on guidelines and accounting principles defined by the IPCC (1996) and is the basis of International Standard 14064 (International Standards Organization 2006).
3. For utilities and transport, GHG conversion factors (also called 'emission coefficients' or 'emission factors') are calculated using energy and fuel efficiency statistics, technical characteristics and use patterns of sources (DEFRA 2009). For manufactured products, emissions arise from a variety of sources along a complex chain, and therefore, 'embodied carbon dioxide coefficients' are used; these are specific to each country and industry sector (Hammond and Jones 2008).

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Online distance calculators by mode of transportation

Air: http://www.airrouting.com/content/TimeDistanceForm.aspx.

Road and rail: http://maps.google.com.

Sea: http://www.searates.com/reference/portdistance.

Appendix 1. Summary of equations and coefficients:

Equations to calculate a quantity of polyethylene sheeting (Q_{PES}) and a quantity of polyurethane foam (Q_{PUF})

All measurements entered into the equation (x, y, z, …) must be expressed in cm.

Q_{PES}	$x \times y \times 3 \times 0.01 \times 0.925 \div 1000$	Area multiplier: 3 PES thickness: 0.01 cm PES density: 0.925 g/cm^3 (ASTM 2000) Constant to give result expressed in kg: 1000 x = Length of frame (cm) y = Height of frame (cm)

Example: $70 \times 150 \times 3 \times 0.01 \times 0.925 \div 1000 = 0.29$ kg PES

Q_{PUF}	$[(a - 11) \times (b - 11) \times (c - 11)] - (x \times y \times z) \times 0.35 \times 27.5 \div 1000000$	Wall thickness: 11 cm New PUF used: 35% (0.35) PUF density: 27.5 kg/m^3 Constant to give result expressed in kg: 1,000,000 a = Length of case (cm) b = Height of case (cm) c = Width of case (cm) x = Length of frame (cm) y = Height of frame (cm) Z = Width of frame (cm)

Example: $[(100 - 11) \times (200 - 11) \times (30 - 11)] - (70 \times 50 \times 10) \times 0.35 \times 27.5 \div 1000000 = 5.90$ kg PUF

GHG conversion factor for wrapping and packing case (after Hammond and Jones 2008).

Material	Function	GHG conversion factor (kgCO_2/kg)
Low-density polyethylene	Wrap paintings (PES)	1.7
Fine paper	Protect delicate frames, wrap unframed mounted works on paper, pack ceramics and small sculptures	1.5
Polyurethane	Case cushioning and insulation	3
Plywood	Plain outer shell	0.81
Softwood, sawn	Battens	0.45
Synthetic rubber	Waterproof seals	4.02
Stainless steel	Hardware	6.15
Medium-density fiberboard (MDF)	Side panels	0.59

GHG conversion factors used for freight transport and passenger transport.

Freight	Region	Description, as written in published sources	GHG conversion factor	Unit	Source
Road	UK	Heavy goods vehicle (rigid) engine size unknown	0.8020	$kgCO_2e/km$	DEFRA 2009[a]
Road	USA and other	Heavy duty vehicle (rigid) diesel–year 1960–present	0.7154	$kgCO_2/km$	WRI 2008
Air	All	Long-haul international	0.6008	$kgCO_2e/(t{\cdot}km)$	DEFRA 2009
Air	All	Short-haul international	1.4183	$kgCO_2e/(t{\cdot}km)$	DEFRA 2009
Rail	All	Diesel	0.0319	$kgCO_2e/(t{\cdot}km)$	DEFRA 2009
Sea	All	Large RoPax Ferry	0.3875	$kgCO_2e/(t{\cdot}km)$	DEFRA 2009

Passenger	Region	Description, as written in published sources	GHG conversion factor	Unit	Source
Road (car)	UK	Passenger: average petrol car	0.2078	$kgCO_2e/km$	DEFRA 2009
Road (car)	USA	Passenger: gasoline, 2005–present	0.245	$kgCO_2e/km$	WRI 2008
Road (car)	Other	Passenger: gasoline, 2005–present	0.2375	$kgCO_2/km$	WRI 2008
Air	All	Passenger: domestic 'average'	0.1728	$kgCO_2e/km$	DEFRA 2009
Air	Europe	Passenger: short-haul economy	0.0946	$kgCO_2e/km$	DEFRA 2009
Air	All	Passenger: short-haul business	0.1419	$kgCO_2e/km$	DEFRA 2009
Air	All	Passenger: long-haul economy	0.0827	$kgCO_2e/km$	DEFRA 2009
Air	All	Long-haul business	0.2399	$kgCO_2e/km$	DEFRA 2009
Rail	All	Passenger: National Rail	0.0611	$kgCO_2e/km$	DEFRA 2009

Activity	Region	Coefficient description	GHG conversion factor	Unit	Source
Hotel	All	Average European hotel	30.2	$kgCO_2e/(guest{\cdot}night)$	SQW 2007; DEFRA 2009
Food	All	Average nonvegetarian diet	1.25	$kgCO_2/(person{\cdot}day)$	Carbon Fund

Emission coefficients used for hotel accommodations and food, with source.

[a]The emission factors published by DEFRA and US Environmental Protection Agency (EPA) account for the impact of N_2O and CH_4, but those from the IPCC do not.

Appendix 2. Environmental impact of a 'typical' painting case (excluding the polyurethane foam)[a]

Packing case element	Carbon footprint ($kgCO_2$)	Carbon footprint distributed over 20 years ($kgCO_2$)
Polyethylene foam lining	10.66	0.53
Plywood side panels	33.85	1.69
Softwood battens	12.54	0.63
Metal hardware (stainless steel)	12.30	0.62
Total	69.35	3.47

[a]To calculate the footprint, it was assumed that the painting frame measured 103 × 114 × 10 cm, and the case's outer dimensions were 158 × 130 × 32 cm. This implied the following material quantities: polyethylene foam: 6.26 kg; plywood: 41.79 kg; softwood: 27.86 kg; stainless steel: 2 kg.

Appendix 3. Activity data collection sheet
Use one sheet per loan, focusing on sections 4 and 5.

1. LOAN INFO	Number of objects	Object information
ID No.		Inventory No., dimensions, weight (if avail.)
Venues (name & post code)		

2. WRAPPING MATERIALS (approx. quantity per object)				Notes on wrapping
Polyethylene sheeting:	☐ __________	Tissue paper:	☐ __________	
Bubble film:	☐ __________	Other:	☐ __________	

3. PACKING CASES	(type 1, quantity)	(type 2, quantity)	(type 3, quantity)	Number of cases
Polyurethane Foam	☐ __________	☐ __________	☐ __________	
Polyethylene Foam	☐ __________	☐ __________	☐ __________	Case dimensions
Plywood	☐ __________	☐ __________	☐ __________	
Softwood	☐ __________	☐ __________	☐ __________	
Metal:__________	☐ __________	☐ __________	☐ __________	
Plastic:__________	☐ __________	☐ __________	☐ __________	
Other:__________	☐ __________	☐ __________	☐ __________	

4. TRANSPORT (if unknown, indicate "?")				Venues
Road Freight	rigid☐ art.☐ 3.t☐ 7.5t☐ 18t☐ 33t☐	fuel:______	case wt: ____t	______________
	rigid☐ art.☐ 3.t☐ 7.5t☐ 18t☐ 33t☐	fuel:______	case wt: ____t	______________
	rigid☐ art.☐ 3.t☐ 7.5t☐ 18t☐ 33t☐	fuel:______	case wt: ____t	______________
	rigid☐ art.☐ 3.t☐ 7.5t☐ 18t☐ 33t☐	fuel:______	case wt: ____t	______________
Air Freight	gross wt: ____t (cases) Arpt Codes: _____ to _____	gross wt: ____t (cases) Arpt Codes: _____ to _____	gross wt: ____t (cases) Arpt Codes: _____ to _____	
Rail Freight	gross wt: ____t (cases/truck) venues:____________	gross wt: ___t (cases/truck) venues:____________	gross wt: ___t (cases/truck) venues:____________	
Sea Freight	gross wt: ____t (cases/truck) venues:____________	gross wt: ___t (cases/truck) venues:____________	gross wt: ___t (cases/truck) venues:____________	

5. COURIERS					
Road	Car☐ Taxi☐ fuel: ______ Dist.:_____km	Car☐ Taxi☐ fuel: ______ Dist.:_____km			
	Car☐ Taxi☐ fuel: ______ Dist.:_____km	Car☐ Taxi☐ fuel: ______ Dist.:_____km			
	Car☐ Taxi☐ fuel: ______ Dist.:_____km	Car☐ Taxi☐ fuel: ______ Dist.:_____km			
	Car☐ Taxi☐ fuel: ______ Dist.:_____km	Car☐ Taxi☐ fuel: ______ Dist.:_____km			
Flights	Econ☐ Business☐ Domestic☐ Short-haul☐ Long-haul☐	Arpt Codes: ______ to ______			
	Econ☐ Business☐ Domestic☐ Short-haul☐ Long-haul☐	Arpt Codes: ______ to ______			
	Econ☐ Business☐ Domestic☐ Short-haul☐ Long-haul☐	Arpt Codes: ______ to ______			
	Econ☐ Business☐ Domestic☐ Short-haul☐ Long-haul☐	Arpt Codes: ______ to ______			
Trains	Dist.:______km	Dist.:______km	Dist.:______km	Dist.:______km	Dist.:______km
Ferries	Dist.:______km	Dist.:______km	Dist.:______km	Dist.:______km	Dist.:______km
Hotel (post codes & number of nights):					
Food days:					

Appendix 4. Carbon footprint calculation spreadsheet
Use one sheet per loan.

Loan ID No:								
	Total activity data (kg, km, etc.)	Uplift	×	Wt (t)	GHG conversion factor	=	$kgCO_2e$	Observations
WRAPPING MATERIALS	kg							
Polyethylene Plastic film			×		1.7	=		
Tissue paper			×		1.5	=		
PACKING CASES	kg							
Polyurethane Foam			×		3	=		
Polyethylene Foam			×		1.7	=		
Plywood, plain			×		0.81	=		
Plywood, veneered			×		1.54	=		
Softwood, sawn			×		0.45	=		
Synthetic rubber			×		4.02	=		
Stainless steel			×		6.15	=		
MDF			×		0.59	=		
TRANSPORT	km							
Road Freight (UK)			×		0.802	=		
Road Freight (US & Other)			×		0.7154	=		
Air Freight – Long-haul		× 1.09	×		0.6008	=		
Air Freight – Short-haul		× 1.09	×		1.4183	=		
Rail Freight (Euro-tunnel)			×		0.0319	=		
Sea Freight (Ferry)			×		0.3875	=		
COURIERS	km, etc.							
Car - Passenger (UK)			×		0.2078	=		
Car - Passenger (US)			×		0.245	=		
Car - Passenger (Other)			×		0.2375	=		
Air - Passenger - Domestic		× 1.09	×		0.1728	=		
Air - Passenger - S-H Econ.		× 1.09	×		0.0946	=		
Air - Passenger - S-H Busn.		× 1.09	×		0.1419	=		
Air - Passenger - L-H Econ.		× 1.09	×		0.0827	=		
Air - Passenger - L-H Busn.		× 1.09	×		0.2399	=		
Rail - National			×		0.0611	=		
Hotel nights			×		30.2	=		
Food days			×		1.25	=		
	TOTAL:							÷1000= tCO_2e