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Towards more circular office fit-outs: a socio-technical descriptive framework of office fit-out processes

Casas-Arredondo M., Croxford B. and Domenech T.

The Bartlett School of Environment, Energy and Resources, University College London, London, UK

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Abstract

The built environment is the most resource intensive sector of the economy, accounting for a significant share of the extracted materials and the total waste generated. Within the built environment the most recurrent replacements of building materials and components take place during fit-outs, which are the process of installing interior fittings, fixtures and finishes. These materials and components are frequently replaced in non-domestic buildings.

Non-domestic building fit-outs are therefore responsible for a significant consumption of materials and a large source of waste. However, they tend to go unnoticed and unmeasured in the research about sustainable buildings. The present work aims to study this research gap and analyse the potential for fit-outs to become more sustainable. The approach of this project ties in closely to the concept of circular economy, where materials are kept at their most useful state for as long as possible.

This paper provides a socio-technical descriptive framework of fit-out processes in office buildings. This descriptive framework contains a qualitative analysis of the roles and interactions of involved stakeholders regarding the material flow (based on interviews), and a quantitative material flow analysis (MFA) throughout the downstream supply chain (based on a fit-out case study). The mixed methodology used includes on-site observations, cross-examination of the corresponding design specifications or waste reports, and semi-structured interviews with the involved stakeholders.

The aim of this research is to provide a grounded perspective that allows the identification of process and design improvements that support the transition towards more "circular" fit-outs. It is concluded that there are potential areas of improvement as fit-out practices show a predominantly linear tendency both for decision making and material flows.

Introduction

The built environment is the most resource intensive sector of the economy, accounting annually in the European Union for 50% of all extracted materials, 35% of carbon emissions (European Commission, 2011), and 32% of total waste generated, approximately 830 million tonnes (EEA, 2012). Within the built environment the most recurrent replacements of building materials and components take place during fit-outs, which are defined as the process of installing floor, wall and window coverings, partitions, doors, furniture, equipment, and sometimes mechanical and electrical services (Cole and Kernan, 1996; Forsythe, 2010). In offices, these components can be replaced every 3-10 years (Trucker and Treloar, 1994; Roussac et al., 2008; Forsythe and Wilkinson, 2014). In addition, an outgoing tenant may remove the fit-out (de-fit) and the new tenant will reinstall all these fittings, fixtures, and finishes (re-fit). Accordingly, fit-outs account for a significant amount of wasted resources, and associated embodied carbon emissions throughout the lifecycle of a building.

Office building fit-outs tend to go unnoticed and unmeasured in the debate about sustainable buildings (Forsythe and Wilkinson, 2014) but this is beginning to change. Building fit-out certification methods, such as SKA Rating, BREEAM or LEED exist, but have a low uptake and do not fully cover the circular economy concept. Growing environmental concerns and the gradual increase of UK's landfill tax (Seely, 2009) certainly encourages stakeholders to pursue waste recycling instead of landfilling. However, most fit-out waste gets downcycled, since the original materials or components are generally not designed with recycling or reusing in mind (McDonough and Braungart, 1994).

In order to identify key areas of improvement in the fit-out process and in the use and management of resources, it is pertinent to understand key materials used and waste generated, as well as the destinations of waste streams.

This paper analyses fit-out projects within UCL and London, tracing outgoing waste streams and incoming building materials and components. The roles and responsibilities of different stakeholders within the supply chain are analysed in order to assess which actors have the highest impact on components specification and waste management.

The objective of this work is to set out a socio-technical descriptive framework of office fit-outs from a material flow perspective. The aim being to identify potential improvements in the fit-out process and the design of building components, reflecting on the possible benefits for main stakeholders involved and for society as a whole.

Background

Circular economy

The environmental consequences of using the biosphere to dispose of waste are becoming critical, such as climate change, loss of biodiversity and natural capital, land degradation, and air and ocean pollution. So the circular economy is a model proposed to replace the current 'take-make-dispose' attitude and to decouple environmental pressures from economic growth. The four sources of value creation in a circular economy to achieve this decoupling are (EMF, 2013): 1) Minimising material use over a product's lifespan. 2) Maximising the number of consecutive use cycles 3) Diversifying reuse across the value chain and across industries. 4) Using higher quality input materials.

Non-domestic building fit-outs

There is large potential to integrate circular economy characteristics in building fit-outs processes. Buildings can be seen and analysed in different layers, depending on function and replacement rate. Brand (1994) proposes six different layers: Site, Structure, Skin, Services , Space plan and Stuff. These layers have increasing rates of replacement, from the Site being permanent to the Space plan and Stuff being replaced every three years or so. Fit-outs relate to the most frequently replaced layers: Services (sometimes), Space plan and Stuff. Brand (1994) demonstrates that in a 50-year cycle, the changes within a building cost three times more than the original building. Multiple authors state that, the embodied energy of fit-outs eventually outweighs that used to construct the building (Cole and Kernan, 1996; Zabalza et al, 2009).

Non-domestic buildings, represent 26% of the total EU building stock floor area, where 6% of the total are offices and 4% education buildings (Economidou, 2011). Non-domestic buildings may have 30 to 40 fit-outs during their lifecycle, accounting for an estimated 11% of UK construction spending (RICS, 2016).

The Construction Resources and Waste Platform (2009) carried out a study based on fit-out waste data contained in the SMARTWaste tool. Based on four UK office fit-out projects, the average rate of waste generation is reported to be 6.4t per 100m2 of gross internal floor area (GFA).

The Better Building Partnership et al. (2015) used a fit-out case study in Sydney, Australia to record the types and amounts of waste generated. A rate of waste generation of close to 10t per 100m2 of GFA was found, and 63% of this waste was diverted from landfill. The materials that were not able to be recycled were ceiling and carpet tiles, timbers, office furniture, and paint.

The Institute for Sustainable Futures (2014) performed a series of interviews in Sydney to identify the main waste contributors during fit-outs. The same few materials were consistently nominated: plasterboard, ceiling tiles, carpet, packaging, office furniture (particularly workstations) and the resultant MDF (medium-density fibreboard) and particleboard. It is stated that although some issues can be solved systematically, each material stream needs to be tackled specifically.

Hardie et al. (2011) interviewed twenty-three experts in commercial refurbishments in Sydney to find out the average rate of reuse and recycling. They report that building materials and components such as aluminium, structural steel, steel reinforcing bars, bricks, and concrete, are subject to a high level of recycling, however, little recovery is made from the removal of most internal fittings and finishes during the fit-out process.

Methodology

A mixed methodology approach is taken composed of specific methods to answer specific research questions. All research outcomes are then concatenated to provide a socio-technical descriptive framework of the building fit-out process and its material flow.

1) In order to map out the stakeholders within the fit-out supply chain who determine the specification of building components and the management of waste, exploratory interviews were conducted using chain-referral (snowball) sampling. Twelve people related to the fit-out industry were contacted and interviewed. The interview data was cross-checked to lead to an objective interpretation.

2) To describe the function of actors at each stage in the fit-out process and to define the relationships among them (evaluating their impact on the material flow), semi-structured interviews and/or questionnaires were carried out with the stakeholders identified in research objective 1. Three further fit-out experts were interviewed. The key aims in the interviews and questionnaires were to describe the fit-out process in-depth, to identify the roles and interactions of the supply chain actors for each stage, and to define the main drivers and barriers to improved circularity in the fit-out process. The data from interviews and questionnaires was qualitatively analysed to lead to an objective conclusion.

3) In order to define how material flow occurs in fit-out projects, from incoming components to outgoing waste streams, four waste contractors and three managers at recycling facilities were contacted and interviewed. Also,

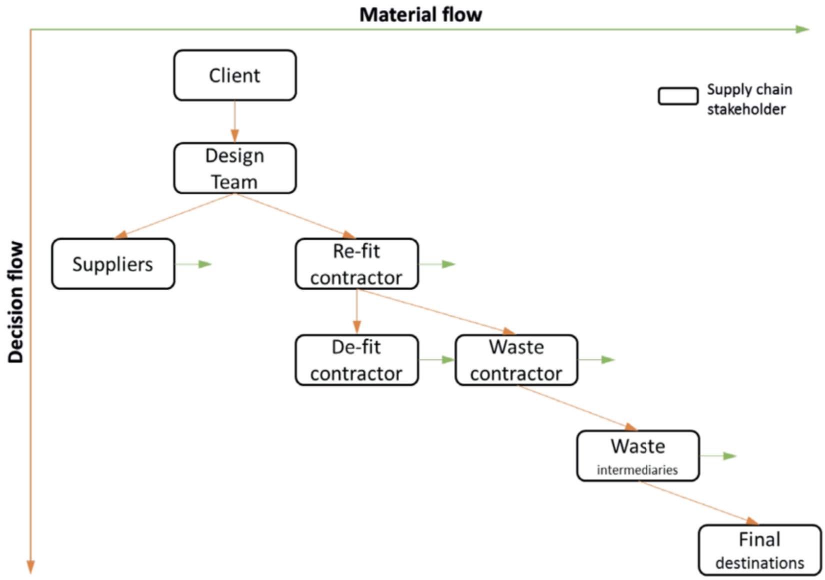

Figure 1. Generic fit-out supply chain stakeholders and structure.

an office building fit-out was selected as a case study to carry out a material flow analysis of the waste streams generated during the project. Material flow analysis was performed using data from stakeholders' reports, such as fit-out specifications, site waste management plans (SWMPs) and Recycling Reports. Also, site observations were carried out during and after fit-out.

Fit-out descriptive framework

Fit-out supply chain structure

Several stakeholders within the fit-out supply chain were interviewed including policy makers and stakeholders collaborating in the design team, as well as fit-out contractors, waste contractors and employees in recycling facilities.

From these interviews, it can be concluded that fit-out processes in the area of study are very similar to each other. Thus, a generic fit-out process is considered and described next.

The Client choses whether to pursue a sustainable fit-out or not and whether to use an assessment method as guideline. The Client also hires the Design Team. The Design Team is usually comprised of an Architect, Project Manager(s), M&E (Mechanical and Electrical) Engineer(s), Quantity Surveyor(s), and sometimes includes a Sustainability Consultant. The Design Team potentially has the highest impact on the decision making within the project, covering decisions such as the specification of building materials and components and the management of waste.

Once the project brief is developed by the Design Team (including project specifications, times and budget), the Project Manager sends out an invitation to tender. Any Fit-out Contractor can then submit a tender, i.e. offer their services to carry out the fit-out works, stating how they would perform the job and how much it would cost. The Fit-out (Re-fit) Contractor who gets the job will be in charge of all the on-site process and they may sub-contract other actors, such as Strip-out (De-fit) Contractor or Waste Contractor. Likewise, the main Fit-out Contractor normally has within their team another Project Manager, M&E Engineer, Quantity Surveyor and a Sustainability Manager.

The assigned Waste Contractor will be in charge of collecting the waste arising from the de-fit and re-fit stages to then take the waste to a transfer site, where it usually gets sorted into different waste streams.

The different waste streams are then sent out to different material recovery facilities (MRFs) or Waste Collectors where they deal with thousands of tonnes of one or several waste streams. The respective Waste Collectors further sort and grade the waste streams for onward delivery, potentially to their respective Final Destinations. These destinations may include recycling within the original industry (closed-loop) or in another industry (cascade), as well as incineration for energy recovery or landfill.

Figure 1 shows the generic structure of the fit-out process. The decision flow is represented in the diagram with a vertical descending orange arrow and the material flow is represented with a horizontal green arrow. It can be appreciated that both the decision and the material flows have a linear tendency.

The Suppliers produce and market the building products, and the Design Team selects from the available offer. The De-fit and Re-fit contractors install and remove the products, respectively. The Waste Contractor collects the waste and sorts it, to then hand over the different waste streams to the corresponding Waste Intermediaries who further sort and grade the waste before sending it to the respective Final Destinations.

During this study, it was found that the Design Team and the Fit-out Contractor(s) generally have negligible knowledge about the Final Destinations of components and materials, whereas the Waste Contractors and the people in charge of the Final Destinations generally have negligible influence on the specification of these components. It can be suggested that the linear tendency of the decision flow is a barrier for the circularity of the material flow, or in other words, a linear decision flow leads to a linear material flow. However, more analysis and case studies are required to support this supposition.

Fit-out materials and components

Table 1 presents a list of the common fit-out materials and components along with the corresponding European Waste Code (EWC), where available. These materials and components are consistently considered in the literature review and in fit-out SWMPs.

Element	EWC
MATERIALS	
Asbestos	17 06 05
Fines (soil)	17 05 04
Glass	17 02 02
Gypsum (incl. plasterboard)	17 08 02
Hardcore	17 01 07
Metals -Ferrous	17 04 05
Metals -Non-ferrous	17 04 01*
Mixed waste	17 09 04
Paint, adhesive, etc.	20 01 27
Paper & Cardboard	20 01 01
Plastics (including packaging)	17 02 03
Textiles	20 01 11
WEEE	20 01 36
Wood (including fibreboard)	17 02 01
COMPONENTS	
Appliances	N/A
Batteries	20 01 33
Carpet	N/A
Electrical socket	N/A
Fire alarm	N/A
Fire extinguisher	N/A
Insulation	17 06 04
Light -Fluorescent tubes	20 01 21
Light -Other	N/A
Office furniture	N/A
Raised access floor tiles	N/A
Suspended ceiling tiles	N/A

Table 1. Common fit-out materials and components (Author generated, 2017).

Element	Weight [t]	Share [%]
Gypsum (plasterboard)	72.59	31.8
Mixed waste	66.25	29.0
Metals	32.84	14.4
Wood (including fibreboard)	25.06	11.0
Glass	13.02	5.7
Hardcore/Soil	11.90	5.2
Paper & Cardboard	6.18	2.7
WEEE	0.32	0.1
Light -Fluorescent tubes	0.30	0.1
TOTAL	228.46	100.0

Table 2. Weight and share for each material stream collected, for the first quarter of 2017 (Waste Contractor's report, 2017).

Fit-out waste generation

A major waste contractor in London was contacted in order to find out the top material streams or waste streams generated during fit-out projects (Table 2). Over 90% of the waste they collect comes from building fit-outs. Figure 2 shows the share or percentage (by weight) for each material stream relative to the overall waste collection, for the first quartile of 2017

Material flow in an office fit-out case study

The fit-out took place in London during 2016, and is considered a best-practice fit-out in the UK. The fit-out gross internal floor area (GFA) is 162m2 and the project value is £60k.

The information presented here was provided (and cross-checked) by the design team, the fit-out contractor and the waste contractor.

Outgoing waste

The total waste generated (considering de-fit and re-fit) is 3.81t, with a landfill diversion rate of 99.5%. The rate of waste generation is 2.35t per 100m2 of GFA, which is 63% lower than UK average (6.4t / 100m2 GFA).

Table 3 shows a breakdown of the waste streams generated during the de-fit stage. The waste during this stage (2.82t) accounts for 74% of the total waste generated.

Table 4 shows the waste stream breakdown for the re-fit stage, which accounts for only 26% of the total waste.

Table 5 presents waste stream breakdown combined for both the de-fit and re-fit stages. For this case study, gypsum (including plasterboard) accounts for the largest share (34.0%), followed by mixed waste (31.9%), wood (17.0%), office furniture (9.9%), and insulation (0.2%).

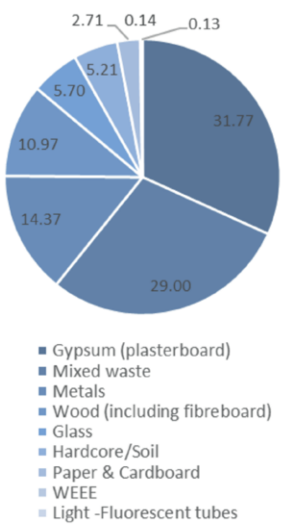

Figure 2. Share (by weight) for each material stream relative to the overall waste collection, for the first quarter of 2017 (Waste Contractor's report, 2017).

De-fit waste			
Element	**Weight [t]**	**Recycled [t]**	**Disposed [t]**
Gypsum	0.96	0.96	0.00
Mixed waste	0.90	0.88	0.02
Wood	0.48	0.48	0.00
Office furniture	0.28	0.28	0.00
Insulation	0.20	0.20	0.00
Total [t]	**2.82**	**2.80**	**0.02**
Percentage [%]	**100**	**99.3**	**0.7**

Table 3. Waste generated during de-fit (fit-out SWMP, 2016).

Re-fit waste			
Element	**Weight [t]**	**Recycled [t]**	**Disposed [t]**
Gypsum	0.72	0.72	0.00
Mixed waste	0.27	0.26	0.01
Total [t]	**0.99**	**0.98**	**0.01**
Percentage [%]	**100**	**99.0**	**1.0**

Table 4. Waste generated during re-fit (fit-out SWMP, 2016).

All waste			
Element	**Weight [t]**	**Recycled [t]**	**Disposed [t]**
Gypsum	1.68	1.68	0.00
Mixed waste	1.17	1.15	0.02
Wood	0.48	0.48	0.00
Office furniture	0.28	0.28	0.00
Insulation	0.20	0.20	0.00
Total [t]	**3.81**	**3.79**	**0.02**
Percentage [%]	**100**	**99.5**	**0.5**

Table 5. Waste generated during de-fit and re-fit (fit-out SWMP, 2016).

Waste stream final destinations

The Fit-out Contractor (and the upstream stakeholders) tend to sub-contract a Waste Contractor that can ensure a high rate of landfill diversion. This is generally driven by environmental reasons whether or not a certification assessment is followed.

Another important reason for landfill diversion is the gradual increase of landfill tax, as handing the waste to a Waste Contractor is normally cheaper than landfilling. The 'gate fee' refers to the price that the Waste Contractor charges per tonne for each waste stream. The gate fee for Mixed waste is generally the highest, so it is advisable for the Fit-out Contractor to segregate waste on-site. In fact, some segregated waste streams are collected free of charge or even paid for (negative gate fee), as is the case for segregated Metals, Plastics, and Paper & Cardboard.

Figure 3 shows the generally linear waste stream among the downstream stakeholders for the office fit-out case study. Note that 15% of gypsum is closed-loop recycled. Although 99% of the waste was diverted from landfill, all material streams diversify into multiple Final Destinations that require a lower grade of material quality.

In this case, Wood is sent to Belgium, mixed Metals generally end up in Spain or Turkey (or other countries depending on the offered price), and Plastics are sent to China. All other Final Destinations are located within the UK.

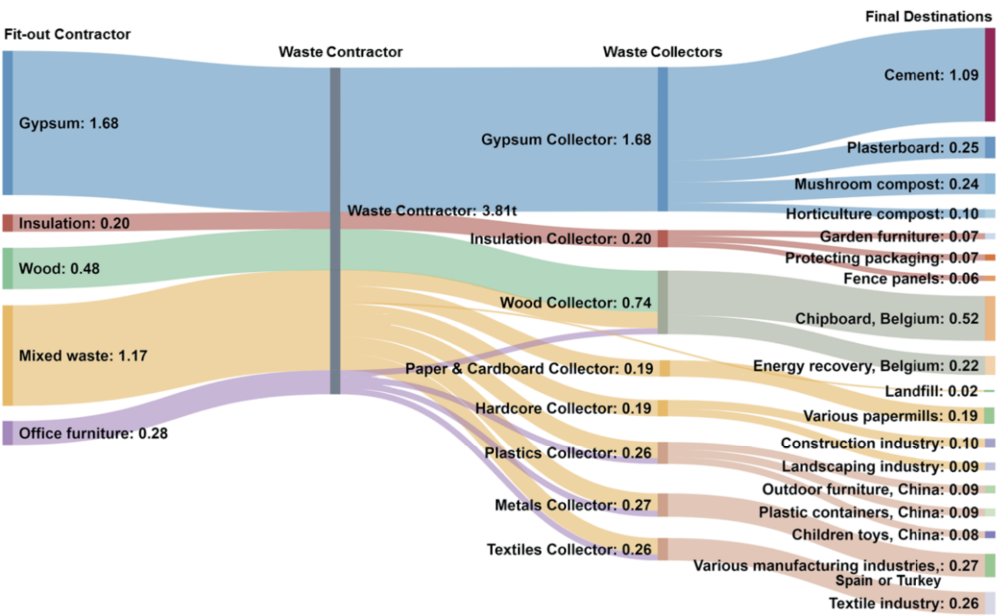

Figure 3. Waste streams flows in tonnes for an office building fit-out.

Conclusions

Given the emerging socio-technical descriptive framework of office fit-outs, it is clear there are several areas that can be improved.

It is found that the office (and non-domestic) fit-out supply chain has a generic structure in which both the decision and material flows have a predominantly linear tendency. The stakeholders in this supply chain with the highest impact on the specification of materials and components and the decisions on waste management are generally the client and the design team.

Currently, good-practice fit-out projects (and the corresponding assessment methods) pursue high recycling percentages for the generated waste streams. However, this study found that the stakeholders in the supply chain are generally unaware of the waste streams' final destinations, i.e. what the different waste streams get recycled into or used for.

In order to be able to design more 'circular' fit-outs, the stakeholders involved in the supply chain should have more effective communication. That is to say, the suppliers and the design team should understand what happens with materials and components at the end-of-life. Accordingly, the actors in charge of the final destinations of these components and materials should provide a systematic feedback to the suppliers and the design team.

In the office fit-out case study, it is found that the rate of waste generation was 2.35 tonnes per 100m2 of gross internal floor area (GFA), which is lower than the UK reported average of 6.4. However, the fit-out project analysed in this paper is considered best-practice. On the other hand, the top wastes generated during this case study were gypsum, mixed waste, and wood, which coincides with the data provided by the interviewed waste contractor.

Further studies on building fit-outs are required in order to confirm the findings presented here, and further investigate the share and final destinations of each waste stream. Likewise, it would be useful to carry out a Life-Cycle Analysis (LCA) for the building components most commonly found in fit-out projects.

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