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HOW TO REDUCE THE CARBON COST OF ACADEMIC AIR TRAVEL?

A QUANTITATIVE ANALYSIS OF THE AIR TRAVEL BEHAVIOUR AT GHENT UNIVERSITY

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Sarah Van Acker

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List of abbreviations

AAP	Assisting Academic Staff
ADEME	Agency for the Environment and Energy Management
Admin.	Administration
ATP	Administrative and Technical Staff
CA	Administration
CO_2	Carbon Dioxide
DFIN	Department of Finances (Ghent University)
DI	Faculty of Veterinary Medicine
DPO	Department of Personnel and Organisation
EB	Faculty of Economy and Business Administration
EPFL	L'Ecole Polytechnique Fédérale de Lausanne
EU	European Union
FW	Faculty of Pharmaceutical Sciences
FWO	Research Foundation Flanders
GE	Faculty of Medicine and Health Sciences
GHG	Greenhouse Gas Emissions
GUGC	Ghent University Global Campus
ICAO	International Civil Aviation Organisation (United Nations)
IPCC	Intergovernmental Panel of Climate Change
LA	Faculty of Bioscience Engineering
LW	Faculty of Arts and Philosophy
NASCERE	Network for Advancement of Sustainable Capacity in Education and Research in Ethiopia
Non-EU	Not part of the European Union
Postdoc	Postdoctoral researcher
PP	Faculty of Psychology and Educational Sciences
Predoc	Predoctoral researcher
PS	Faculty of Political and Social Sciences
RE	Faculty of Law and Criminology
TW	Faculty of Engineering and Architecture
UBC	University of British Columbia
VAT	Value Added Tax
VLIR-UOS	Network that supports partnerships between universities and university colleges, in Flanders and the South
WE	Faculty of Sciences
WP	Research staff
ZAP	Professorial Staff

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Chapter 1

Introduction

It is still not too late to act. It will take a far-reaching vision, it will take courage, it will take fierce, fierce determination to act now, to lay the foundations where we may not know all the details about how to shape the ceiling. In other words, it will take cathedral thinking.

Greta Thunberg

Climate change is described as a wicked problem, a problem where policies that only involve one actor or individual will not suffice as the solution (Reardon & Marsden, 2016). Effective solutions need cross-domain thinking that considers the interdependencies with various elements of our society. In the words of the young climate activist Greta Thunberg, climate change needs a far-reaching vision, it needs cathedral thinking. Policies related to academic air travel are no exception (Hopkins et al., 2016). In recent years, multiple higher education institutions and organisations have tried to address the travel behaviour of their employees in multiple ways. A very recent example is the sustainable travel policy introduced by the Research Foundation – Flanders (FWO) in January 2020 (FWO, n.d.). Since then, the FWO asks young researchers to use alternative methods, e.g. telecommunication or travel by train, if their trip would take less than 6 hours. Furthermore, CO_2 contributions are now also recognised as an eligible cost within FWO projects. However, higher education institutions often face the dilemma between strategic (international) targets and their sustainability goals, meaning reducing related CO_2 emissions and thus their air travel (Janisch & Hilty, 2017). This interdependence of targets exposes the wickedness of the academic flying problem.

A 2018 study on the global emission impact of Ghent University has shown that air travel accounts for approximately 14% of the total emissions of the organisation, making it the third-largest contributing sector (Holemans, 2018). Any comprehensive plan to reduce the overall emissions of the university should therefore include measures to address air travel pollution. With the approval of the document entitled "*First steps into sustainable travel policy"* at their Executive Board in 2018, Ghent University took its first steps towards implementing such a central policy aimed at reducing their air travel emissions. An essential element of this policy is the collection of air travel data of all employees of Ghent University, performed by the travel agency Uniglobe Smart Travel (Ghent University, 2018a-b). This collection of data serves as a way of implementing, adjusting and most importantly improving the existing air travel policy. Thus, this element of the sustainable air travel policy forms the framework for this thesis.

1.1. Research question

This research serves as an in-depth study towards possibilities of reducing air travel emissions at Ghent University based on the data from Uniglobe Smart Travel that became available by the aforementioned air travel policy. What are the characteristics of the current air travel behaviour, and how can Ghent University leverage this knowledge to effectively improve its current air travel policy?

To arrive at valid policy recommendations, a thorough analysis of the existing data is performed in this work via a two-step approach. First, the air travel behaviour of individual Ghent University employees is characterised based on single properties that are relevant to policy-makers. Secondly, the determinants that are shown to lead to significant differences in flying behaviour in the previous part are included in a newly-constructed regression model, from which policy recommendations are subsequently extracted.

However, it needs to be clear that this thesis does not aim to provide a global roadmap to reduce air travel emissions, as the impact of e.g. current alternatives to flying available at Ghent University such as teleconferencing are not evaluated. The scope of this research is limited to the registered flying behaviour of employees, and as such aims to expand on the existing research and policies at Ghent University, like the theses of Irene Govaerts and Mieke Burrick (Burrick, 2018; Govaert, 2019).

1.2. Air travel policy at Ghent University

The introduction of the central air travel policy at Ghent University had a large build-up and can partially be attributed to multiple grassroots initiatives at the university that promoted both newly-created and existing solutions for more climate-friendly mobility policies (Ghent University, 2018a-b). For example, the organization *De Groene Locomotief* introduced a decision tree[1] during a pilot project, and organised both sticker campaigns and debates on campus to raise awareness for sustainable travel options. D'Urgent, a student association focused on sustainability, promoted more sustainable mobility choices for Erasmus students.

Furthermore, various departments already had an air travel policy established before Ghent University introduced its central plan. The Departments of Political Sciences, Biology, Literature, History, Innovation and Entrepreneurship, as well as the Environment Office and the INTEC research group, worked out practical guidelines ranging from promoting travels by train or bus, compensating CO_2 emissions and assigning a yearly limit for international travel.

[1] A decision tree is a visual tool for helping an employee make the decision on whether or not to fly with a emphasis on not flying.

The travel policy adopted by Ghent University imposed several new regulations. The most relevant measures for this thesis are listed below:

- A first measure is the construction of a central dataset that describes the travel mobility of its employees. Since 2017, Ghent University is affiliated with the travel agency Uniglobe Smart for its international trips. However, booking via this travel agency was not mandatory and therefore a complete dataset did not yet exist. The new air travel policy of UGent made booking via this travel agency mandatory, which therefore marks the start of a complete, analysable dataset, that is the foundation for this research.
- A second important measure is the establishment of the system of a green and yellow list of cities: The green list consists of cities that can be reached in less than 6 hours and travel by plane is no longer an option. The yellow cities are cities that can be reached in less than 8 hours. When booking a trip to a yellow city, bus and train are suggested as the preferred modes of travel. This thesis will evaluate the success of this introduction as well as explore possibilities for expanding these lists.
- Thirdly, Ghent University introduced mandatory CO_2 compensation for every air travel trip. The CO_2 compensation of €10 (plus 21% VAT) is added to the ticket price of every trip by Uniglobe Smart Travel. CO_2 compensation, also called carbon offsetting, is presented as a way of compensating the greenhouse gas emissions made by a certain action, e.g. travelling. This financial compensation is subsequently used to invest in projects that reduce or optimize emissions. Before the adoption of the travel policy, CO_2 compensation was already possible but remained voluntary.

Uniglobe uses the company CO2logic to calculate the specific greenhouse gas emissions that need to be compensated, as well as what projects to support with this compensation (Govaert, 2019). CO2logic developed the CO_2 calculator Greentripper. Ghent University currently supports two projects via CO2logic: efficient cookers in Uganda and water filters in Kenya. These projects are both certified by Gold Standard, which takes implementation difficulties into account.

An evaluation of this calculator and the amount of compensation has already been performed by Govaert, and will therefore not be a part of this thesis. The majority of analyses included in this thesis use the CO_2 calculator developed by Greentripper. However, unlike Govaert, this thesis can consider the accurate data on the actual compensations, as these are provided by Uniglobe Smart Travel. Therefore, it is possible to calculate the total CO_2 compensation of Ghent University, while also performing additional simulations for different hypothetical compensation scenarios.

1.3. Methodology and structure

While this thesis initially aspires to perform a quantitative study of air travel behaviour at Ghent University, it is necessary that the first part of the work comprises a literature study in Chapter 2. This research fits into the broader context of academic flying, and a thorough analysis of existing studies allows this work (i) to put the obtained results into perspective, (ii) to give hypotheses for observed differences, and (iii) to benchmark the empirical findings to those of similar organisations. Furthermore, the problem of academic flying requires an interdisciplinary approach, and this work would be remiss not to mention research on e.g. the individual and institutional motivations to pursue academic flying. Therefore, this thesis gets to opportunity to add value to the existing debate by connecting previously held in-depth interviews or surveys to empirical results, allowing correct hypotheses to be introduced in the empirical analyses in the second part of this work.

To perform the desired quantitative analyses, this work does not limit itself to the data provided by Uniglobe Smart Travel, but (i) enriches it with relevant staff-related data (gender, faculty, job function,…) provided by Ghent University to construct additional variables, and (ii) modifies the enriched dataset to make it suitable for the desired analyses. This procedure is described in Chapter 3. Properties relevant to individual Ghent University staff member's air travel behaviour are subsequently described in Chapter 4 via both univariate and bivariate analyses. Here, special attention has to be given to the distribution of several important variables, such as the CO_2 emissions which do not follow a normal distribution. Therefore, the analyses in this part are performed via non-parametric tests, such as the Kruskal-Wallis rank-sum test as the non-parametric equivalent of the one-way ANOVA test.

Chapter 5 uses the insights from the previous chapters to expand on the work of Irene Govaert to investigate different scenarios for the mandatory CO_2 compensation, from a financial point-of-view. What opportunities do different kinds of compensation schemes offer?

While previous chapters focused on the determinants of the flight behaviour of individual staff members, Chapter 6 focuses on the aggregated departmental level. In this chapter, the findings from previous chapters are combined to introduce a multivariate analysis in the shape of 1-level regression models at the departmental level. Different regressions models are introduced, validated and compared.

The final chapter, Chapter 7, contains the proposed policy recommendations based on the findings of the previous chapters. As a large part of the work involved data cleaning due to complications with the considered datasets, this chapter is not limited to flight-related policy proposals, but also includes recommendations for improvements to the data collection by Ghent University and Uniglobe Smart Travel.

1.4. The relevance of the research

This thesis adds to the existing research in several ways. First of all, specifically for the University of Ghent, previous research on Ghent University travel behaviour or the associated policy measures did not have access to a complete dataset. The research of Mieke Burrick, student Master of Science in Business Administration, was limited to data provided by the Financial Department as well as the data provided by Uniglobe Smart Travel, at a time where booking via the travel agency was not yet mandatory (Burrick, 2018). The thesis of Irene Govaert, student Master of Science in Environmental Sanitation and Management, focused primarily on CO_2 compensation, using data obtained from a survey among the Ghent University employees (Govaert, 2019).

Compared to research on academic air travel in other higher education institutions or research institutions, this research again has the advantage of using an extensive dataset, whereas other researchers often have to resort to surveys or rely on data provided by their institution's financial department. For example, a study from the University of British Columbia had to conduct research on the business air travel data of only 8 of the 26 units of the university, which had to be supplemented by a survey over all the faculties to construct a complete and comprehensive dataset (Wynes & Donner, 2018). Similarly, a study on the emission impact of the University of Montreal only had access to a survey, and therefore could only analyse the trips of 703 participants.

While the dataset used throughout this work has several issues, it does allow a much more thorough analysis of the variables. Analogous to this research, L'École Polytechnique Fédérale de Lausanne (EPFL) had a partnership with a travel agency, and was therefore able to analyse a comprehensive dataset. However, this study focused primarily on the inequalities in air travel behaviour within the research field. Finally, most studies limit themselves to purely descriptive analyses. In contrast, this research includes a chapter on multivariate analyses, attempting to give an additional layer to the interpretation of the results, further taking the interdependencies between variables into account.

Chapter 2

Literature overview

Before discussing the results of the empirical data analysis and accompanying policy recommendations in later parts of this thesis, this chapter first delves into the existing literature around academic flying. Hence, it is possible to see where this thesis is located within the broader academic research and debate. First, the general concept of academic flying is introduced and discussed. Where does the discussion about researchers flying come from, and why is it important to devote a thesis to this subject? Secondly, this chapter analyses the different scales from which to approach this research topic: starting from the individual level to the university level as well as the larger research community level. The final part of this overview then gives a summary of several tools proposed in the literature that can help reduce academic emissions from air travel.

2.1. The concept of academic flying

Although there is scientific debate about the specific timing and impact of global warming, there is a clear consensus among scientists that climate change will have a severe, pervasive, and irreversible impact on our society (IPCC, 2014, 2007; National Research Council, 2011, Jiang et al., 2016). Scientists, academics, and policymakers agree that a 2 degrees Celsius man-made warming is considered the absolute upper limit to global warming, to avoid considerable damage to society (Jiang et al., 2016; Nevins, 2014). To achieve this goal, a drastic decrease in greenhouse gas emissions is vital, which for the advanced economies of the western world generally translates itself into an 80-95% reduction emissions compared to the 1990 baseline (Le Quéré et al., 2015).

However, emissions from aviation, one of the most polluting modes of transport, have not reduced despite widespread technological and efficiency improvements (Le Quéré et al., 2015). On the contrary, the number of passenger-kilometres in worldwide civil aviation has increased at an average rate of 5% per year. The corresponding carbon dioxide (CO_2) emissions increased by 2% per year on average (Ciers et al., 2019). This results in a 2-3% share of the global emissions, a fraction that might be considered small, but is alarming for numerous reasons (ICAO, 2016; Wynes et al., 2019).

First of all, this 2-3% share of global emissions only considers the direct effect of CO_2 emissions. Seeing as aviation is also responsible for indirect non-CO_2 effects on global warming, the complete effect from airlines on the greenhouse effect is larger (Murphy et al., 2018). However, there is no complete scientific certainty on the exact effect, which means that this global impact of aviation differs depending on the research (Govaert, 2019). Besides this indirect effect, aircrafts also need supporting infrastructure at the airports themselves, for example, aircraft auxiliary power units (APUs) and ground support equipment (GSE), further increasing the number of emissions (Yim et al., 2013).

When talking about the biggest contributors to these aviation emissions, the western academic community often falls in the category of high aviation emitters and therefore contributes to the crisis many of its members try to diminish (J. Higham & Font, 2020; Pasek, 2019). In the survey of the Tyndall institute, a European research centre in integrated ICT, respondents had a yearly average of 2,3 flights (Le Quéré et al., 2015). A similar survey of the Norwegian Institute for Air Research reports that their employees, mostly researchers, flew 3 times per year on average (Stohl, 2008). For comparison, the average number of flights for a Belgian inhabitant was 0,99 in 2015 (*Passenger Traffic by Air / Countries of the World*, n.d.).

There are several reasons for both researchers and universities as to why they should reduce their flying emissions. First of all, the emissions from air travel increase annually and show no trend of delay. The World Tourism Organization (UNWTO) predicts that in 2030 1,8 billion individuals will travel internationally, an increase of 59 % compared to 2015 (Govaert, 2019). Although criticism towards the airline industry has been raised within the western countries, this is not the case for new emerging markets like China, India or Vietnam. There, air mobility is considered a symbol of success and consequently, it is widely believed that much of the future growth of the air travel industry lies in these emerging markets (J. Higham & Font, 2020).

Geographers James Higham and Xavier Font as well as Anne Pasek state in their research that there is a huge inequality in the global distribution of emissions. Only five countries are responsible for half of the total global tourism emissions, 53% to be exact (Lenzen et al., 2018). This global phenomenon applies to the research community as well. As Higham, Font and Pasek point out, the researchers in developing countries do not always have the same travel opportunities, creating unequal knowledge production and distribution within the research community. However, as the travel industry is rising in those developing countries just maintaining the status quo as western researchers and universities will not suffice to countervail the rising demand.

Secondly, if universities aim to reduce their emissions and therefore uphold the climate commitments in their climate policy documents, it is hard to disregard the emissions produced by academic air travel. Over recent years, the sustainability of higher education institutions has increasingly been in the public spotlight (Hopkins et al., 2016). AlshuwaikhataI and Abubakarb point out that universities should be regarded as small cities, given their rising size, population, as well as their various complex activities on campus. Therefore, speaking about their share in the global emissions is not only relevant in comparative terms, but is even relevant in absolute terms.

Several studies show that (air) transportation contributes a tremendous fraction of the total amount of emissions produced at universities. For example, the research of the Pacific Institute for Climate solutions that investigates the greenhouse gas emissions of business-related air travel at the University of British Columbia (UBC), reports that the air travel is responsible for 63 - 73% of the total annual emissions (Wynes & Donner, 2018). In absolute emission numbers, this translates to 26.333 - 31.685 ton CO_2 equivalent each year. In other studies, the share in the total emissions is lower but remains significant. In a study of the air travel emissions of L'École Polytechnique Fédérale de Lausanne (EPFL), researchers quantified the amount emissions linked to air travel and found that those comprise one-third of the total emissions of EPFL (Ciers et al., 2019). A 2009 report of the English higher education institutions reported similar findings: emissions arising from both student and employee mobility accounted for 37% of total institutional emissions in 2006 (Hopkins et al., 2016).

Thirdly, even if the absolute numbers of an institution are not significant enough to have a severe impact, several researchers argue that universities have a moral obligation to do their part in combatting global warming. Highams and Font, two researchers active in the field of tourism studies, argue that their research field has a responsibility in showing leadership. However, their article goes on to state that this greater responsibility also holds for the research community as a whole, not just the tourism studies (J. Higham & Font, 2020). Caset, Boussauw and Storme state that the public expects a pioneering role of academics, especially because researchers are perceived, although this is not always the case, to have the time and flexibility to consider other options besides air travel like travelling by train. The article of ethnomusicologist Catherine Grant focuses on her personal experiences and the ethical personal issues that academic flying raises. Her research field often reports on climate change and as a researcher as well as person, she feels that emitting such a great amount of emissions is ethically difficult to reconcile. Therefore she makes the personal decision to cut back drastically on her air transportation (Grant, 2018).

Producing a high amount of emissions can even be damaging for results that the research community reports, in particular those on climate change (Nevins, 2014). In 2016, an interdisciplinary study by Attari, Krantz and Weber performed two large-scale surveys that measured the credibility of climate researchers that provided advice on reducing energy use by e.g. flying less or conserving home energy (Attari et al., 2016). They randomly assigned specific environmental behaviour to the climate researchers, both to their energy usage and air travel. They documented a large effect on the participants, both on those who believed in climate change and on those who did not. The behaviour of researchers even affected that of the participants themselves. When the climate researcher had high emissions in the assigned behaviour, participants reported a lower intention to use public transportation.

The above-described concerns gave rise to a recent and growing body of literature that calls for a critical view on established hypermobility lifestyles, often going so far as to call it climate hypocrisy (Le Quéré et al., 2015). With his critical piece in *Nature*, Grémillet is often attributed to being one of the first academics to address the irony of academics attending international conferences, that so often call out for action concerning climate change (Caset et al., 2018; Storme et al., 2017; Grémillet, 2008). [2] The oceanographer raises the question whether or not the carbon dioxide added by the conferences that he and his colleagues attend outweigh the environmental benefits of their findings and lobbying. However, at the end of his piece, he concludes with the following quote: "Industry would be all too pleased if we did not attend distant meetings because we refuse to board aeroplanes." (Grémillet, 2008, p. 1175).

This expanding research field has in the recent past decade grown beyond merely raising critical questions about the polluting transport modes of the academic community, and is now actively investigating different sub-questions related to academic flying:

- Calculations of the total emissions of:
    - Scientific meetings (Bossdorf et al., 2010; Desiere, 2016; Jäckle, 2019; Orsi, 2012; Spinellis & Louridas, 2013);
    - A research project (Waring et al., 2014);
    - A single university (Arsenault et al., 2019; Burian, 2018; Ciers et al., 2019; Glover et al., 2017; Larsen et al., 2013);
- Reasons why researchers rely on face-to-face meetings (Anderson, 2013; Glover et al., 2016; Nursey-Bray et al., 2019; Sheller & Urry, 2016; Storme et al., 2017);
- Providing a policy roadmap to universities to reduce their aviation emissions (Janisch & Hilty, 2017; Le Quéré et al., 2015).

[2] Higham and Font have called not Grémillet, but the 2001 article by Hoyer and Naess, the first to raise critical questions about conferencing.

2.2. Reasons and incentives for individual and institutional academic flying

The concept of academic flying can be studied from multiple points of view. Initially one can consider only the viewpoint and the responsibility of the consumer, in this case, the researcher. However, this problem can also be considered from the point of view of either the conference meeting itself or the universities as institutions that try to reduce their overall emissions. Therefore, this subchapter considers those different viewpoints, and more importantly the constraints they place on each other. On the one hand, universities strive for excellent research, of which internationalisation is often considered a key factor. The university is therefore also partly dependent on how researchers act and how they think they can perform best. On the other hand, the researcher has to operate in this highly demanding environment that the university creates. Furthermore, even if they would want to operate on their own, is still dependent on the university because of funding and prospects for career advancement. Authors like Tom Storme state that to be able to recommend successful policy changes, these multiple viewpoints have to be analysed and taken into account (Storme, 2014; Storme et al., 2017).

The key question here is, what really holds researchers and the university back from flying less? The life-threatening impact of climate change is well reported and still the air travel miles of the research community rise (Hopkins et al., 2016). In other words, there exists a gap between on the one hand the change that many researchers advocate for based on their knowledge of climate change and on the other hand their travel behaviour (Schrems & Upham, 2020). This gap is also referred to as the value-action gap, the difference in what the academics do and what they say as their actions and concerns are not aligned (Nursey-Bray et al., 2019).

Let us initially consider this value-action gap purely from the individual point of view. Why do researchers need to travel so much? Researchers on business travel argued that even though there are various possibilities offered by the world of ICT, corporal mobility in the knowledge-sector is irreplaceable (Storme, 2014). Because the informal and tacit nature of the knowledge production, proximity with fellow researchers in the same field is essential. The belief that knowledge diffusion needs proximity is further intensified by the internationalisation discourse. the input from local peers does not suffice, research needs to be created in a one globalized research field (Ackers, 2008).

Louise Ackers showed in her 2008 article that this corporeal mobility appeared in the academic culture as well as in policy documents is a logical indisputable outcome for the internationalisation trend. Many academics feel however that the face-to-face meetings are, even if it would not be a part of policy documents, a vital element of knowledge diffusion and research progression.

Geographer Tom Storme, James Faulconbridge, Ben Derrudder, Jonathan Beaverstock and Frank Witlox conducted in-depth interviews with researchers in both 2012 and 2017. The surveyed researchers were affiliated with Ghent University for the first study, and both Ghent University as well as Aalborg University for the second one. In these surveys, it was not only the obligations laid down by the university that motivated researchers to travel far distances. In contrast, those interviews revealed that apart from the functional work-related reason, many researchers valued the social gatherings on the conferences, project meetings,... very highly as well. Those moments allowed talking about research informally. It allows seeing the person behind the article and to talk in more depth about the research. Articles have to uphold the demands and norms of a journal, whereas a conversation does not. A journal article is a one-direction passive way of conversing, contrary to a face-to-face meeting where active involvement and direct feedback is possible.

Apart from that, going to conferences, symposia, workshops and other kinds of meetings, having informal conversations about research,… gives the possibility to obtain new ideas. Some academics mentioned a surprise effect in the meetings, you meet people that you normally would not, come into contact with ideas that you otherwise were not planning on looking into. Another important element is the concept of "being visible". Some researchers noted that they did not attend for the formal parts of the conference, but the informal part: when they presented their research to peers, it was a way of being strategically visible. This is especially important for young researchers, being visible at conferences might increase their publication opportunities. Lastly, another important element for the researchers in the survey was the building up and maintaining a professional network. For young researchers, it is hard to build out a personal network, face-to-face meetings feel like a vital element. In contrast, senior researchers felt responsible for the personal network that they constructed and attended to invest in the personal relationships that were made throughout the years and to care for the projects that they started.

All these informal elements are captured by John Urry's "meetingness" (Urry, 2003; Büscher & Urry, 2009). This concept introduced by the sociologist in 2003 refers to the trend of meetings, not limiting themselves to their functional form, but defined by a broader sense which allows the informal practices around friendships and other kinds of relations. According to Urry, the proliferation of communication devices, which in some ways substitute for physical travel, was accompanied with an increase of social networks, and more importantly the increase of the corporal travel that those networks demand. The academic networks build-up are part of a social structure, of social life.

Travel is therefore not only functional, but is simultaneously a way of fulfilling the need for the proximity that these networks expect. Meetingness is an ongoing process, which is an important element for the academic air travel discussion. It is not about one single trip, but it is about the series of trips that establishes and cements (weak) ties of the network (Faulconbridge et al., 2009). It is therefore hard to determine the added value of one trip, to weigh the (academic or personal) return of that trip compared to its ecological cost. All the trips together, however, allows the researchers to build up network capital.

However, it is not only the individual researchers who want to build up this network capital. In the same research by Storme et al., many researchers attested that this network is demanded of them by their institution. It is expected that senior researchers engage in these international networks. If they want to keep the prestigious positions that they are in, they are obliged to be present, even if they have to fly arrive and depart on the same day (Storme et al., 2017). For young researchers, there is great pressure from their promoter to create a personal network and be visible, even if this comes at the cost of their personal and family life. The female participants in the study noted that because of their family obligations, they could not always live up to the expectations.

Career progression or the fear of not being able to promote is, apart from the research itself, a great motivator for travelling and thus puts an additional constraint on those who are not able to travel frequently, or those who are trying to limit their travel for ethical concerns. In their study *Fear of Not Flying*, Australian researchers of the University of Adelaide conducted in-depth interviews and a survey among Australian academics about their flying habits (Nursey-Bray et al., 2019). The results can be compared to the results of the studies of Storme et al.: 29 of the 32 respondents of the in-depth interview believed that travelling was essential to promotion. Most participants of that study were convinced that the policy framework of their university rewarded staff who were able to build up international networks and reputations. This corresponds to earlier research like the study of Dickmann and Harris in which they argue that there is a relation between business-related travel and career progression. Storme states that this link between travel and career progression is intensified by the trend of changing labour conditions of the last years (Storme et al., 2017).

Research groups have partly become firm-like entities. They are highly organized and hierarchically structured and most importantly, competing against each other for resources. In this competing context, it is common for research groups to employ their young researchers on project-based finances. This results in even more flexible careers as well as less job security. Researchers need to be constantly looking for extra finances to keep their position, or to look for better and more permanent job opportunities elsewhere.

According to Storme, this creates careers in which employees have less loyalty to their institution and this trend favours academics with a higher network capital. If you are able to build a broad personal network, you have more options for finding a permanent position. Therefore, building up and taking care of this network is not always necessary for knowledge-producing purposes, but can be partly needed for securing one's career and being able to continue researching within the academic world.

Public opinion perceives academics as employees that have great individual control over their transport and travel decisions (Hopkins et al., 2016). In reality, however, those decisions are heavily influenced by the institutional demands and conditions, although there is still an individual element at play. In the earlier mentioned *Fear of Not Flying*, correspondents noted the main barrier to fly less is an institutional one, and that institutions did not provide any incentive to stop flying (Nursey-Bray et al., 2019). On the contrary, those who travelled a lot were rewarded. The same findings were reported on as well in the interviews of Storme et al. (Storme, 2014; Storme et al., 2017). The authors of the *Fear of Not Flying* therefore argue that although individual decisions play a role in travel behaviour, that behaviour needs to be placed into the institutional context of the university. Individuals do have decision power, but there is also a need to shift the emphasis of individual blaming and responsibility to a responsibility that includes the institution those individuals operate in.

The same argument is made by Glover in his analyses on the air policies in Australian universities (Glover et al., 2016, 2017, 2018, 2019). International collaborations are not merely a reflection of the desires of the academics themselves and not even of the expectations within the research field. The broader internationalisation agenda of universities puts pressure on academics, especially with the growing emphasis on attracting external funds. The earlier mentioned survey of the Tyndall institute suggests personal factors in the decision-making process do exist, but these might operate in parallel next to structural factors like cost and expediency.

The question therefore is, are universities providing this structural context for researchers to be able to decline a faraway travel trip? Although there is an upcoming movement of academics and universities that try to change institutional flying policies, authors have argued that a gap still exists between the sustainable ambitions of the university and real commitments (*Flying Less*, n.d.; Glover et al., 2017, 2018; Hopkins et al., 2016). The problem lies within the internationalisation ambitions of the universities. Glover et al. investigated the policy documents on sustainability as well as internationalisation efforts of Australian universities and found that there is a mismatch both types of policies (Glover et al., 2016).

The sustainability documents provided no explicit targets, while all other policy documents prioritise internationalisation, therein assuming that travelling is an inherent part of internationalisation. The unspoken acceptance of air travel as an essential part of internationalisation was also present in the research of Hopkins et al. where they analyse the policy documents of institutions in New-Zealand. They describe this assumption about the necessity of travel as “Unspoken Words” (Hopkins et al., 2016). It is often not explained or investigated in policy documents why travel needs to be such a vital element for research. This research has noted the same results as the study on the Australian universities: internationalisation policies override sustainability objectives through the appointing and promoting of staff members, conference leaves, research and study leave policies. Policies on academic promotion demand evidence of international standing and collaboration. The conclusion of both of these researches is that if universities want to reduce their aviation emissions, their sustainability policies need to be integrated with other university policies and documents.

The need for internationalisation is however not only situated at the university level, but is present at every layer of the research community and (inter)national provided funding. The ‘European Charter for Researchers’ and the ‘Code of Conduct for the Recruitment of Researchers’ (the Charter and Code), a charter and code put forward to create a European Research Area, state that employers and/or funders must recognise the value of geographical mobility enhancing scientific knowledge and professional development (Ackers, 2008). Ackers states that European policy tends to define mobility as a proxy for internationalisation. This major emphasis on mobility as a crucial element of internationalisation and internationalisation as a vital element for excellent research is even present in variables used for international university rankings (Ackers, 2008; Glover et al., 2017; Jöns & Hoyler, 2013).

This system of layers and constraints makes the flying-dilemma a coordinated collective action problem (J. Higham & Font, 2020). Actions from only one party within this dilemma will not suffice, a collective commitment is needed. Although universities do have to operate within a very competitive market, they are a spill figure in changing this academic culture of highly emitters, not only by their policies but by advocating this new narrative and responsibility towards their international institutional partners, disciplinary associations, and public research funding agencies.

The aforementioned assumption that travelling, internationalization and excellent research are all and the same, doesn’t have to be the case. In their research of 2019*,* Wynes et al. showed that having more international collaborations and attending more conferences does not necessarily lead to more excellent research (Wynes et al., 2019).

They calculated the potential relation between emissions on the one hand and metrics of academic productivity, including the hIa-index, on the other hand, and found that there is no statistical link between the emissions and academic productivity. This suggests that the contradiction between excellent research and sustainability does not need to be irreconcilable.

2.3. Reducing aviation emissions in the academic community

There are numerous ways in which the academic flying problem can be handled. As stated in the previous section, there are after all multiple viewpoints from which to analyse this wicked problem of academic flying.[3] The data used in this thesis gives a few starting points to reinforce or nuance existing flying policies at the University of Ghent. Therefore, this thesis places a strong emphasis on measures that the university, or researchers within a university, can take. However, there are other solutions put forward in literature to reduce the overall academic flying emissions. Consequently, this section will give an overview of the main solutions put forward in the literature.

The most common solution provided by research on academic flying can be found in the research on the impact of scientific meetings. Even in the first critical articles on academic flying, the importance of how scientific organization and institutions organise their meetings was included. This comes as no surprise, given the enormous pollution impact of a meeting, whose emissions are primarily produced by air travel (Desiere, 2016; Hischier & Hilty, 2002; Janisch & Hilty, 2017). The American Geophysical Union fall meeting produced 11.000 metric tons (Lester, 2007). The RGS-IBG Annual Conference causes an environmental impact of 772,5 metric ton CO_2 (Hall, 2007).

There are multiple solutions proposed in the literature. One of the first is just simply having fewer conferences, instead of an annual conference (Desiere, 2016; Hall, 2007). A second more prominent proposed way is optimising the location of the conferences. Locating conferences in hard-to-reach locations, or locations without established research communities, results in more emissions. For example, Glover notices that while most Australian universities are located at the East Coast of Australia, conferences are often held in the fairly inaccessible centre of Australia (Glover et al., 2019). Optimisation of the location can lead to great reductions. To illustrate the effect that meeting site selection can have, Stroud and Feeley estimated the greenhouse gas emissions of four conferences of the International Biogeography Society (Stroud & Feeley, 2015).

[3] (Academic) air mobility and the associated sustainability problems are in literature described as a wicked problem (Hopkins et al., 2016; Ramani & Zietsman, 2016; Reardon & Marsden, 2016; Xue et al., 2014). A wicked problem describes a complex problem that is difficult solve and wherefore multiple perspectives and agents are needed because of a complex (social) system interdependencies. It is a problem that cannot be solved by just solving one aspect.

This resulted in an average of 324,1 tonnes CO_2 per meeting. If meetings had been held at their optimal location, this could reduce down to an average of only 162,3 ton per meeting, a reduction of 49,1%. Similar results were found in the research of engineer Francesco Orsi (Orsi, 2012).

Orsi suggests that instead of holding a meeting in a more central location, multiple meetings could be held on multiple continents, thereby decreasing the focus on so-called mega-meetings. In his model and with the case study of a small conference in Wageningen, savings could be up to one-third of the original emission amount. Orsi projects that with larger meetings, decentralizing the meetings would have even greater reductions. A second measure to reduce the impact of academic air travel is the implementation of ICT within the academic research field. There is a growing consensus in research that ICT can make an essential contribution towards the reduction of greenhouse gas emissions, not only by increasing the efficiency but through a shift in consumption paradigm as well (Coroama et al., 2012). Teleconferencing can, for example, be used as a substitution of physical mobility. Wynes and Donner note that improving ICT access within the university is vital to changing air travel behaviour (Wynes & Donner, 2018). In their earlier mentioned survey on air travel behaviour of researchers of UBC, the most common response to the question, “How could UBC support you to reduce your need to fly?” was to improve teleconferencing on campus (46%).

Similar results were found in a survey on teleconferencing within the Artificial Life (ALIFE) community (Fellermann et al., 2019). Inclusion of video presentations to reduce air travel was the preferred sustainable measure according to the participants. The vast majority would ‘strongly welcome’ the inclusion of virtual remote talks and poster presentations.

Therefore, the Tyndall Institute proposed several practical ways of implementing teleconferencing in their roadmap (Le Quéré et al., 2015). The conference can be webcast and therefore reach a larger public, speakers can give an online presentation instead of flying over, conferences could be held simultaneously in multiple locations, facilitated with high-bandwidth web links between auditoria, etc. In an article by the University of Zurich, the precise effect of using teleconferencing was calculated. Coroama, Hilty and Birtel organised a conference on research management on two continents simultaneously. They compared the emissions produced by mobility and the extra ICT equipment on the one hand, and on the other hand the hypothetical emissions produced by mobility as if it were just one conference without teleconferencing (conducted by survey). Compared to the one-site alternative, the two-site conference with teleconferencing reduced the travel-related greenhouse emissions by 37% and 50% (Coroama et al., 2012).

Other researchers are however critical in accepting the strengthening of telecommunication as the ultimate solution. Storme points out that these researchers often use telecommunication as a complementary good, not as a substitute good. Telecommunication is not used to replace meetings, but rather to strengthen international relations and it encourages further globalization of the research field (Storme et al., 2017). In his in-depth interviews, researchers indicated that telecommunication was only used when the agenda planning made it impossible to travel to that specific meeting/conference. Participants thought that the telecommunication had great potential for substituting the formal elements of the meeting, but could not replace the informal ones. Furthermore, Hopkins et al. argue that using telecommunication as a mean of reducing academic air travel is unproductive if there are no targets of quotas set (Hopkins et al., 2016). The implementation of telecommunication would therefore not suffice as a stand-alone solution.

Lastly, a solution for the academic flying that is more fundamental and radical than the previous ones, a shift towards slow science. Today's research culture is characterized by a “Publish or perish” culture (Frith, 2020). The focus is on producing an ever-growing amount of articles without taking the time to research and analyse research topics in-depth. Academics split up their research into different articles to uphold the publication standards. A basic assumption in slow science is the plea to look differently at timescales and to consider the bigger aims of science. This eternal pressure to perform is also visible in the academic meeting culture. In numerous surveys or interviews, academics thought this switch in culture to be essential for changing our travel behaviour (Fellermann et al., 2019; Le Quéré et al., 2015; Nursey-Bray et al., 2019; Storme, 2014; Storme et al., 2017). Those participants point out that the drastic change in air travel behaviour will not take place until the full agenda of the researchers is considered not as a symbol of academic success and in depth-research becomes the full focus of the academic world again. Many researchers did not feel the need to constantly travel, nor were they able to, but they felt pressured to make connections and be visible rather than focus on their research. This is not only problematic from a sustainability point of view, but it harms the gender equality of the research field.

One of the researchers that made a strong argument for a change in research culture to tackle the mobility problem, is the aforementioned Anne Passek. Drawing on the theory of feminist social technoscience, Pasek pleads for alternative modes for collective research-creation and collaboration. Incremental and institutional change will be needed if the research community wants to fundamentally change its emissions. Travel is not only an enrichment to the academic their research and personal life, but it can also be a real geographic burden.

Meetings often take place in Europa or America, disadvantaging groups of other continents, and certain researchers, e.g. female academics, are not able to combine family care and long travel hours. The recognition of this structural exclusion is a first step in the remaking of the carbon-intensive academic world. Changing the multiple trips per year to only one trip a year could already fundamentally change not only the research hierarchy, but also its content. Northern researchers would be less able to research southern areas and would be incentivised to cite local southern researchers, therefore changing the hierarchy. Another voice that pleads for changing our research-creation culture is biochemist Hervé Philippe (Philippe, 2008). Phillipe makes the connection with the economic degrowth movement, a global movement that emphasizes the need to reduce global consumption and production and put GPD into question as a suitable indicator. The ever-rising pressure to produce academic output has a strong connection to the degrowth idea. Hervé proposes to replace a large number of short meetings with longer annual meetings, allowing more time for the research itself, disincentivizing researchers splitting up their research.

From the overview given in this Chapter, it should be clear that the problem of academic aviation emissions is a multi-faceted problem that will require multiple actors enacting policies on different levels, from the micro-level at the individual departments to the European framework and a widescale change in mindset and culture. This work is located at the meso-level, i.e. at the university and faculty-level, exploring the possibilities for data-driven policy measures based on the travel data of Ghent University employees obtained in the first 1,5 years of the sustainable flying policy at the university.

Chapter 3

Data generating process

The goal of this thesis is presenting data-driven policy recommendations related to academic air travel at Ghent University. To successfully arrive at this goal, a suitable dataset that is also informative for policy-purposes has to be constructed. The added value of this research is the in-depth analysis of the links between travel behaviour and properties relevant to Ghent University staff members. This chapter therefore describes the steps that were necessary to obtain such a dataset, starting from the two data sources that form the basis of this research: the travel-related data collected by Uniglobe Smart Travel, which has to be combined with relevant personnel-related data from Ghent University.

Special attention is given to the current unsuitability of the initial dataset obtained from Uniglobe Smart Travel for the analyses in the following chapters, and the steps that were necessary to transition from an unsuitable dataset to a suitable dataset. The individual flights belonging to the same trip, such as the outbound and the inbound flight of the same journey, are not yet linked together. Therefore this initial dataset is also called the unlinked dataset in this work. As such, the entries belonging to the same journey have to be linked together, finally leading to the so-called *linked-flight dataset*.

The insights obtained in this chapter on data generation and modification is subsequently translated to policy recommendations in Chapter 7. As the collection, monitoring and analysis of travel data are cornerstones of the current sustainable travel policy at Ghent University, the unsuitability of the current data reporting is problematic as it hinders staff members tasked with performing in-depth analyses. For brevity, the discussion in the body of this thesis is limited to the cause of this incompatibility of the datasets, i.e. the naming convention, while the steps to address this discrepancy are included in Appendix I.

For the data acquisition process, it is important to note that travel information linked to individual staff members is considered personal information, and thus falls under the *Generic Code for the processing of personal and confidential information* of Ghent University. As such, the processing and preparation of the final dataset used in this work had to be performed by a staff member of the Environmental Department. However, the algorithms and code used to perform the collecting, cleaning and linking of the various data sources were constructed as part of this research. All variables that can be used to identify individual staff members were removed in the final considered dataset of individual trips.

3.1. Structure of Ghent University

Before delving into the two data sources provided by both Uniglobe Smart Travel and Ghent University itself, it is necessary to give the necessary organisational context of Ghent University. Two personnel-related parameters are relevant for this research: the employee job category and the (sub)organisation within the university the staff member is affiliated with.

Ghent University is a large university, with over 15.000 staff members. The university is organised in 11 faculties, that are supported by 9 administrative departments. These administrative departments are grouped under the term "Management", and abbreviated by "ca". The list of the 11 faculties is given in Table 1 below, where the official abbreviation of each faculty that is used both by Ghent University and throughout this work is also listed together with the research discipline each faculty is active in.

Each faculty is subsequently divided into its own departments, but the number of departments at a faculty can differ. For example, the Faculty of Pharmaceutical Sciences only has three departments, while the Faculty of Engineering and Architecture has ten. These departments are assigned a two-number code as an identifier, which uniquely defines them together with the abbreviation of the faculty.

Table 1: List of the faculties at Ghent University, with their abbreviation and research discipline.

FACULTY	ABBREVIATION	RESEARCH DISCIPLINE
FACULTY OF ARTS AND PHILOSOPHY	LW	α
FACULTY OF LAW AND CRIMINOLOGY	RE	α
FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION	EB	α
FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES	PP	α
FACULTY OF POLITICAL AND SOCIAL SCIENCES	PS	α
FACULTY OF ENGINEERING AND ARCHITECTURE	TW	β
FACULTY OF BIOSCIENCE ENGINEERING	LA	β
FACULTY OF SCIENCES	WE	β
FACULTY OF MEDICINE AND HEALTH SCIENCES	GE	γ
FACULTY OF PHARMACEUTICAL SCIENCES	FW	γ
FACULTY OF VETERINARY MEDICINE	DI	γ

Table 2: Employee job classification at Ghent University.

EMPLOYEE CATEGORY	EMPLOYEE SUBCATEGORY
PROFESSORIAL STAFF	Full professor
GUEST PROFESSOR	Guest professor
ACADEMIC ASSISTING STAFF (AAP)	Predoctoral fellows (PhD student, Teaching Assistant,…)
	Postdoctoral fellows
	Scientific research staff
ADMINISTRATIVE AND TECHNICAL STAFF (ATP)	Administrative and technical staff members

Furthermore, the employee job classification of Ghent University is used throughout this work, as summarised in Table 2. Within the group of the Academic Assisting Staff, the subcategories of predoctoral fellows, postdoctoral fellows and scientific research staff are taken into account. There are smaller groups present in the university (volunteering staff, prospective employees, etc.), but due to their limited size and diversity they are not of interest for this work.

3.2. Data acquisition and linking process

The following section gives an overview of the variables and cleaning steps involved for the various datasets. Dataset cleaning and linking describe the steps necessary to make the two major datasets compatible with one another: (i) the dataset provided by Uniglobe Smart Travel, the travel agency responsible for the monitoring of and reporting on the travel data of Ghent University employees, and (ii) data obtained via the Department of Personnel and Organisation with employee information.

3.2.1. Uniglobe Smart Travel

Ghent University has been using a framework contract for its academic and policy-oriented trips since May 2017. With the approval of the sustainable travel policy in the executive council in May 2018, this framework contract subsequently became mandatory.

Ghent University concluded this framework contract with the travel agency Uniglobe Smart Travel. Consequently, this travel agency has collected travel data since 2017, and thus provided the necessary data for this research. Previous travel analyses by the Environmental Department were also based on data provided by Uniglobe Smart Travel.

Employees of Ghent University still have the option to book tickets outside the mandatory contract. If they do, they have to pay an additional €50 per booked ticket outside the contract. This payment is subsequently used as CO_2 compensation. Between 2018-2019, these extra payments for bookings outside the contract yielded over €51.000 according to the Financial Department. However, they were unable to give more detailed data on these bookings.

By their estimation, 1.020 flights were booked outside of the contract over the course of 8 months, averaging to approximately 125 flights per month. However, it is difficult to make a thorough evaluation of the success of the travel policy framework without having exact and complete data, especially on the evolution of tickets booked outside of this framework (and thus outside of the considered dataset).

The initial dataset obtained via Uniglobe Smart Travel contains the following fourteen parameters, while two additional parameters, marked with *, were constructed from this dataset for the purpose of this work. These are listed in Table 3 below.

Flight records for July 2018 until December 2019 are considered in the final dataset. While limited data is available for the period 2017 – 2018, July 2018 was chosen as the starting point as the framework contract for ticket booking became mandatory at this time. However, not all entries included a known routing. As such, these entries were excluded for the purpose of this research.

Table 3: Variables included in the dataset provided by Uniglobe Smart Travel.

Booking number	Destination city	Distance (km)	Routing
Traveller name	Airline	CO_2 emissions (ton)	Area
Ticket price	Type of cabin	Departure	Frequent flyer*
Destination country	Advance purchase days	Arrival	Compensation(s)*

3.2.2. Department of Personnel and Organisation

The Department of Personnel and Organisation (DPO) of Ghent University provided a list of employees active during the considered period, including their employee (sub)category, affiliation, and gender. Therefore, the initial dataset of individual flights is further enriched with additional information from Ghent University itself: Based on the traveller name in the flight information, the relevant employee's information can be extracted from the dataset provided by Ghent University.

However, two major complications arose during the extraction of employee information based on the traveller name. First, not all travellers who booked via Uniglobe Smart Travel are on the payroll at Ghent University, and therefore not included in the received database of the Department of Personnel and Organisation. Groups of students travelling abroad for a study trip, professors at other universities being flown to Ghent for a variety of reasons (guest lecturers, jury members for PhD defences, international members of Boards involved in internationalization efforts of Ghent University,…) do regularly show up in the dataset of flights, but cannot be linked to a staff member. Approximately 20% of all flights (2.114 of the 10.255 entries) could not be linked to a staff member.

Second, the major identifier to combine the two datasets is this name, i.e. the name that is given to Uniglobe Smart Travel when booking a ticket. However, there is no guarantee this is identical to the way staff members choose to be listed in the Ghent University internal database.

3.2.3. Construction of a linked-flight dataset

One of the main disadvantages of the format Uniglobe Smart Travel currently presents the data in is that one entry or one booking number does not unambiguously correspond to one individual trip. The full dataset contains single entries that can correspond to (i) an inbound and outbound flight, (ii) a single flight, (iii) a single intermediate flight, etc.

As such, it is difficult to obtain accurate distributions for the emissions per business trip or the average amount of kilometres flown for one trip from the initial dataset with unlinked individual flights. Therefore, the first major hurdle in this research is the construction of a dataset where one entry corresponds to one full trip, meaning an inbound and outbound flight. For example, the initial dataset can contain four different individual entries:

1) Brussels – London;
2) London – Sydney;
3) Sydney – London;
4) London – Brussels;

It should be clear that it is necessary to combine these four individual flights in one trip to obtain a correct view of the duration and emissions belonging to this one journey of one individual. It is also necessary to group these flights together when considering concepts such as frequent flyers, as this would otherwise lead to a gross overestimation of the average number of flights per staff member.

To achieve this, entries belonging to the same trip have to be identified and linked to each other, from which a new entry can be formed that combines the routings, changes the arrival and departure date and sums the contributions for the distance, emissions, and ticket price. The full methodology to arrive at this final linked-flight dataset from the initial unlinked-flight dataset can be found in Appendix I. Table 4 on the following page gives a summarising table on the different datasets, their nomenclature and the number of entries they contain.

Table 4: Summary of the number of datasets with the corresponding amount of remaining entries.

DATASET	NUMBER OF ENTRIES
Initial unlinked-flight dataset	10.255
Initial unlinked-flight dataset with known routings	9.793
Final linked-flight dataset	7.721

To conclude this chapter, Table 5 gives an overview of the included variables in the final linked-flight dataset, where the variables in the third column were constructed based on the information from the flights themselves.

Table 5: Included variables in the final linked-flight dataset.

FLIGHT VARIABLES	ADDED STAFF-RELATED VARIABLES	CONSTRUCTED VARIABLES
Booking number	Faculty or management	Frequent flyer information
Traveller name	Department	Countries
Routing (airports)	Job category	Continents
Ticket price	Job subcategory	Duration of the stay
Advance purchase days	Gender	Kind of trip (round trip, etc.)
Departure date		
Arrival data		
Airline		
Distance (km)		
CO_2 emission (ton)		
Seat class		

Chapter 4

Characterising Ghent University flights

4.1. Flown kilometres and emissions

This section of the empirical analyses will statistically analyse every variable individually, and most importantly assess what their emission impact is at the university.

4.1.1. General description

In 2019 alone, air travel at Ghent University was responsible for at least 9.003 ton CO_2.[4] Analogously, Ghent University produced at least 5.006 ton CO_2 from July 2018 until December 2018. This corresponds with respectively a total of over 38 million kilometres flown in 2019, and over 21 million kilometres for 2018. For the complete period, this gives an average of 0,566 ton CO_2 emitted and 2.406 kilometres flown per employee of Ghent University.

The emissions corresponding to the flights are calculated via CO2logic, the tool developed by Greentripper. As observed in Figure 1 on the following page, the number of flown kilometres the major determinant in the calculation of the emissions. In this plot, the only additional difference between data points is the seat class, which is analysed in-depth in Section 4.1.1.4. The correlation between kilometres and emissions is 0,941.

As a result of this high correlation, the histograms for the kilometres and the emissions per trip presented in Figure 2 on the following page largely follow the same pattern. For the correct analyses of the flown distances the linked-flight dataset as described in Section 3.2.3 has to be used, i.e. the dataset where individual flights are grouped together into their corresponding full business trip.

First, there is a very high peak in the number of flights, which subsequently declines more slowly around the 2000 kilometres break. This gives away one of the first major findings on the air travel data: Ghent University employees mostly fly to close by destinations, i.e. their trips are local. This extremely steep climb and slower decline is not a normal distribution.

[4] This number is calculated from the provided dataset. There are still multiple employees who travel outside the framework contract, and are therefore not taken into account in the calculations of this work.

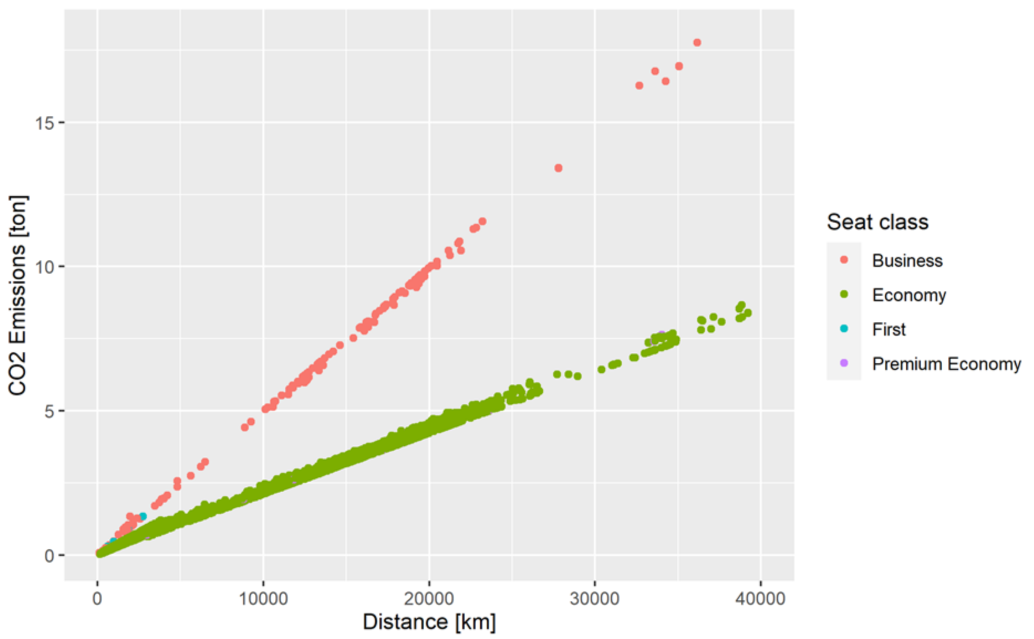

Figure 1: Influence of seat class on the relation between distance (in kilometres) and the emissions (in ton CO_2).

This is confirmed by the results of the Shapiro-Wilk test for normality, displayed on the following page. The H_0 or null hypothesis represents the first peek of the sample having a normal distribution.[5] The fact that the p-value is lower than 0.05 means that there is evidence that the sample is not normally distributed. Appendix II studies the distribution of this first peak, which was found to follow a gamma distribution.

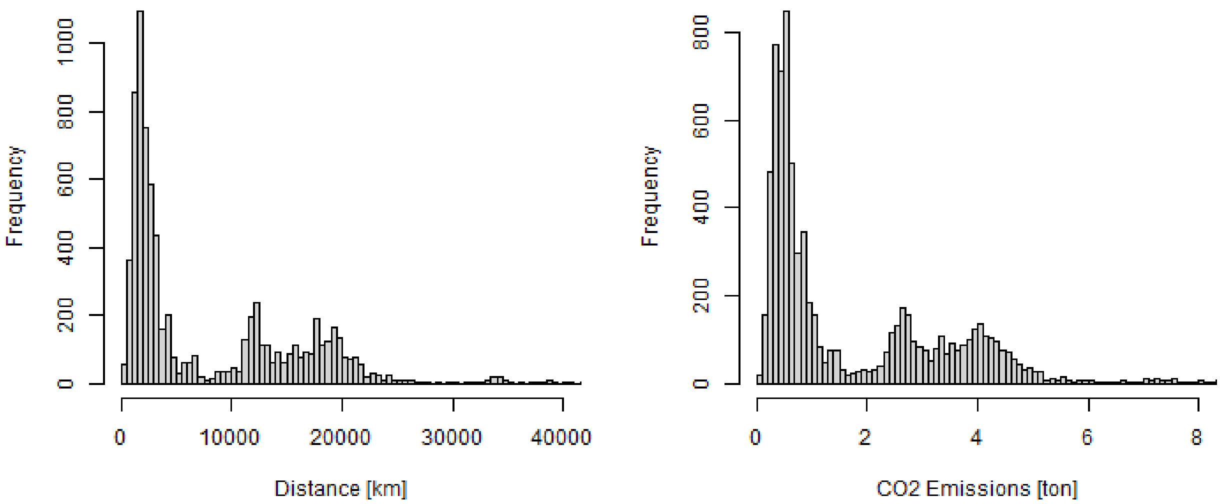

Figure 2: Histograms of the distance (in kilometres) and the emissions (in ton CO_2) of individual trips.

[5] The sample was limited to distances < 7.500 km, allowing for a study of a unimodal distribution.

```
                Shapiro-Wilk normality test

data:  data$Kilometers
W = 0.94148, p-value < 2.2e-16

                Shapiro-Wilk normality test

data:  data$Emissions
W = 0.79015, p-value < 2.2e-16
```

This non-normality of the distribution has vital implications for the remainder of this work, as normality is one of the conditions for common statistical tests like the t-test. Therefore, alternative tests applicable to non-normal distributions will be used.

The global maximum at 2.000 km is followed by a decline, which reverses and leads to two smaller local maxima between 10.000 and 20.000 kilometres. These could be attributed to the presence of an ocean between Ghent and popular destinations such as the United States of America. The histogram ends with a very long tail.

The presence of this steep peak at the beginning of the histogram immediately raises the following question: are we able to reduce the total institutional emissions by targeting these short flights? Table 6 gives the emissions that could have been avoided (both in absolute and relative terms) if employees were forbidden to fly distances below a certain threshold.

Before interpreting these results, two side-notes have to be kept in mind. First, the distance represents the total distance of the outbound and inbound trip, so a trip of 500 kilometres means a 250 km outbound and a 250 km return flight. Secondly, with the introduction of the green and yellow city lists, the majority of these flights should already be prohibited. Therefore, small reductions for prohibiting flights < 500 km or 750 km come as no surprise.

The results from these simulations show that reductions can be achieved by limiting business trips via air travel under a distance threshold.

Table 6: Avoided emissions (in ton and %) if flights below a threshold were forbidden.

Distance threshold [km]	500	750	1000	1500	2000	3000
Emissions avoided (ton)	5,95	27,34	88,63	382,74	891,52	1725,81
% emissions avoided	0,04	0,19	0,63	2,73	6,35	12,30

However, Ghent University is not one homogeneous group. First of all, departments might have different ways of funding or a different research culture. An example of this can be found in a study on the complete carbon footprint of the Norwegian University of Technology and Science (NTNU). The carbon footprint of faculties such as Social Science and Humanities had a significantly lower carbon footprint compared to Natural Science, Engineering, and, in particular, the Faculty of Medicine (Larsen et al., 2013). According to the authors of that study, a lot of the pollution differences are inherent to the field of study and research focus. Within the total emission output of the faculties of NTNU, air travel played a significant role in creating the differences.

Secondly, as mentioned in Section 2.2, surveys and interviews showed that there are differences within the job categories at a university. On the one hand, existing air travel data showed an unequal distribution of travel emissions: a small group of people is responsible for the larger part of the emissions. Especially professors seem to travel more extensively (Ciers et al., 2019; Le Quéré et al., 2015; Wynes et al., 2019).

On the other hand, young academics or academic assisting staff note a pressure to be active in the international field, thus feeling an externally imposed need for travel (Storme et al., 2017). Lastly, research shows that the possibilities for travelling are not equally divided among men and women and therefore create different travel behaviour (Gustafson, 2006; Jöns, 2011).

This heterogeneity among the research community at Ghent University means that a study that only considers the emission of the university as one entity would yield an incomplete picture. Consequently, the following subsection analyses the emissions based on these three different factors: the faculty and research departments, job category, and gender.

4.1.2. Differences between faculties

Table 7 displays the absolute frequency of flights for each faculty, while the relative frequency proportional to the total number of employees at that faculty is given as well. [6] The management (CA) is given as well. This table shows how frequently an employee flies, disregarding the flown distance or the seat class.

[6] In order to obtain the relative frequency, the number of employees in that faculty has to be extracted from the dataset provided by DPO. This is number is given in the third column of Table 7. As the dataset of flights encompasses a period between July 2018 and December 2019, the number of employees in a faculty is also the total number of contracts that were active in that faculty during this period. Consequently, this number is higher than a number that gives a snapshot of the staff numbers at a certain faculty at one single point in time.

Table 7: Absolute and relative frequencies of business trips for the different faculties.

ORGANISATION	ABSOLUTE FREQUENCY	STAFF MEMBERS	RELATIVE FREQUENCY [%]
CA	291	2.034	14,3
DI	286	899	31,8
EB	317	1.096	28,9
FW	113	380	29,7
GE	595	4.648	12,8
LA	867	1.825	47,5
LW	540	1.794	30,1
PP	367	919	39,9
PS	241	587	41,0
RE	181	685	26,4
TW	1.376	3.113	44,2
WE	887	2.608	34,0

Certain faculties fly more than others, even in relative numbers accounting for the size of the faculty, especially the faculties of the exact sciences, the beta-faculties, fly very frequently. If each flight could be allocated to one employee, almost half of the employees of the Faculty of Engineering and Architecture and the Faculty of Bioscience Engineering would have flown. Faculties like the Economy and Business Administration and the Faculty of Law and Criminology have a lower relative frequency.

The Faculty of Medicine and Health Sciences has a very low relative frequency. However, this can be attributed to the inclusion of the University Hospital in this faculty, which distorts the total number of employees linked to this faculty. The relative frequency of this faculty therefore does not give an accurate view of the academic flying culture in that faculty. Relatively speaking, the employees belonging to the administrative departments do not travel much compared to their peers affiliated with a faculty.

Table 8 on the following page gives more insight into the total picture by listing the absolute emissions and kilometres for the individual faculties. In absolute terms, the Faculty of Engineering and Architecture, as well as the Faculty of Bioscience Engineering, again dominate the total numbers. With its 511 ton CO_2, the management is responsible for a large fraction of emissions, even compared to the other faculties.

Table 8: Total emissions and kilometres for the different faculties.

ORGANISATION	EMISSIONS (TON CO_2)	KILOMETRES (KM)
CA	511,41	2.175.270
DI	448,53	1.895.300
EB	587,50	2.322.442
FW	150,25	653.151
GE	1.058,20	4.274.222
LA	1.971,66	7.766.034
LW	838,32	3.644.484
PP	557,94	2.474.983
PS	357,25	1.530.608
RE	312,41	1.239.874
TW	2.434,92	10.564.027
WE	1.565,99	6.813.079

Table 9 on the following page gives the mean, median and standard deviation of the flown kilometres of every faculty. In other words, this table represents not how much, but how far the employees of certain faculties fly. The huge differences in the mean and median show again that most flights are short, but long-haul flights happen as well. The Beta-faculties have a higher mean compared to the others. The gamma-faculties are more divided, with the Faculty of Veterinary Medicine and the Faculty of Pharmaceutical Sciences having a lower mean compared to the Faculty of Medicine and Health Sciences. Within the alfa-faculties, only the Faculty of Economics and Business Administration has a higher mean.

The question now arises whether these differences are significant? A Kruskal-Wallis test followed by a pairwise Wilcoxon-test makes it possible to examine differences between medians, and therefore does not need the traditional normality-condition (Gujarati, 2009). The Kruskal-Wallis rank sum test below only considers the differences between the faculties. The null hypothesis is that there is no difference between all the faculties. However, the P-value is very low, so the null hypothesis cannot be accepted at the 5%-significance level: there are differences between the faculties.

```
        Kruskal-Wallis rank sum test

data:  Kilometers by Faculty
Kruskal-Wallis chi-squared = 55.815, df = 10, p-value = 2.224e-08
```

Table 9: Mean, median and standard deviation of the flown kilometres per faculty.

ORGANISATION	MEAN KM	MEDIAN KM	STANDARD DEVIATION KM
CA	7.475	2.606	8119
DI	6.627	2.947	6.913
EB	7.326	2.532	9.063
FW	5.780	2.214	6.222
GE	7.184	2.856	7.291
LA	8.957	4.265	8.338
LW	6.749	2.951	7.123
PP	6.743	2.632	7.335
PS	6.351	2.575	6.890
RE	6.850	2.609	7.810
TW	7.677	2.947	7.915
WE	7.681	2.822	8.249

The pairwise Wilcoxon-test displayed below looks at where the cause for this difference is situated. The Faculty of Bioscience Engineering, which had high mean and median value, has a median that differs from almost every other faculty except for the Faculty of Engineering and Architecture and the Faculty of Law and Criminology.

It is therefore correct to state that the Faculty of Bioscience Engineering flies further than the other faculties. The median of the Faculty of Engineering and Architecture is significantly different from the Faculties of Pharmaceutical Sciences and Political and Social Sciences. Other differences are not significant with a significance level of 5 %.

```
        Pairwise comparisons using Wilcoxon rank sum test

data:  df2_fac$Kilometers and df2_fac$Faculty

   di      eb      fw      ge      la      lw      pp      ps      re      tw
eb 1.00000 -       -       -       -       -       -       -       -       -
fw 1.00000 1.00000 -       -       -       -       -       -       -       -
ge 1.00000 1.00000 1.00000 -       -       -       -       -       -       -
la 0.03847 0.00162 0.00309 0.01493 -       -       -       -       -       -
lw 1.00000 1.00000 0.34578 1.00000 0.05325 -       -       -       -       -
pp 1.00000 1.00000 1.00000 1.00000 0.00199 1.00000 -       -       -       -
ps 1.00000 1.00000 1.00000 1.00000 0.00027 0.86368 1.00000 -       -       -
re 1.00000 1.00000 1.00000 1.00000 0.37505 1.00000 1.00000 1.00000 -       -
tw 1.00000 0.07401 0.03607 1.00000 0.64101 1.00000 0.31380 0.02297 1.00000 -
we 1.00000 1.00000 1.00000 1.00000 0.00319 1.00000 1.00000 1.00000 1.00000 0.65080

P value adjustment method: bonferroni
```

The difference between faculties and management is also tested but is not significant as can be seen from the following test:

```
        Kruskal-Wallis rank sum test

data:  Kilometers by Sector
Kruskal-Wallis chi-squared = 0.8044, df = 1, p-value = 0.3698
```

Are these differences also visible in the distributions of the individual faculties? Figure 3 displays the violin plots of all the faculties and their corresponding kilometres, with the mean and median values visible as markers as well.[7] Both the mean and median values of the beta-faculties lie above those of the other faculties, which could be attributed to the denser probability region near 20.000 km in this case.

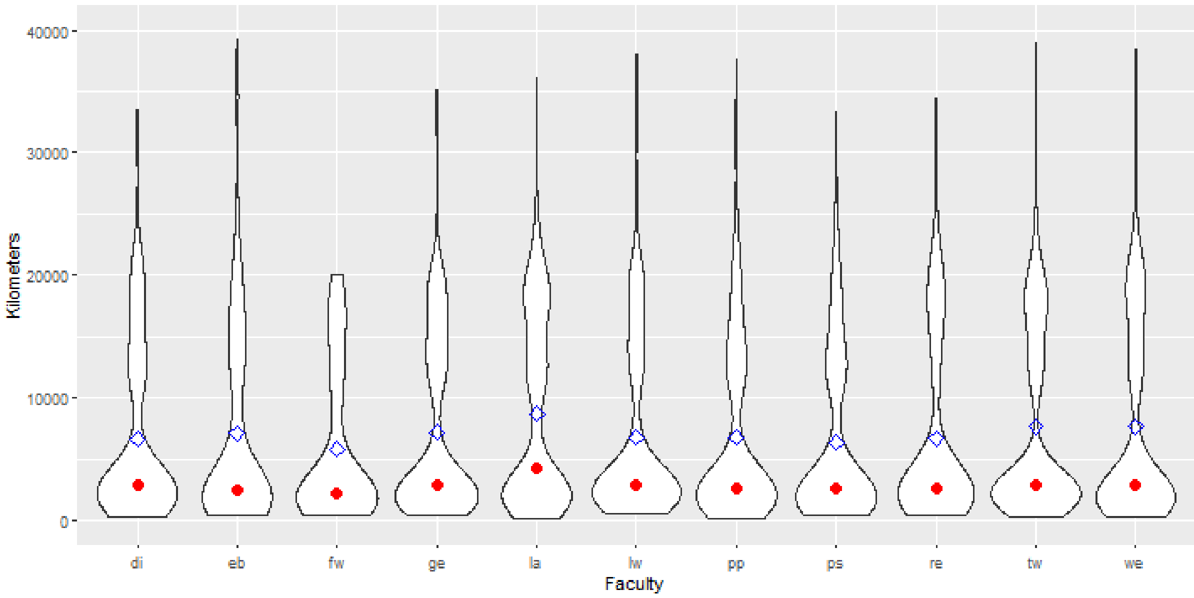

Figure 3: Violin plots of the distributions of the kilometres, median and mean value marked by red and blue respectively.

Figure 4 shows the density plots of the faculty-specific distributions. In general, the kilometres per faculty seem to follow the same distribution with a high, steep peak in the beginning, slowly decreases one or two local maxima between 10.000 and 20.000, followed by a long tail. Some elements are more outspoken in certain faculties. Interestingly, the local maxima close to 20.000 km is only larger than the one close to 10.000 for the density plots of the three beta faculties. In contrast, most of the alfa faculties only exhibit a single peak between 10.000 and 20.000 km.

[7] While boxplots are a more common visualisation tool, violin plots were the preferred method tool in this case given the non-unimodal distribution. A boxplot would not give an accurate representation of the distribution, hence a visualisation method that shows the probability density was chosen.

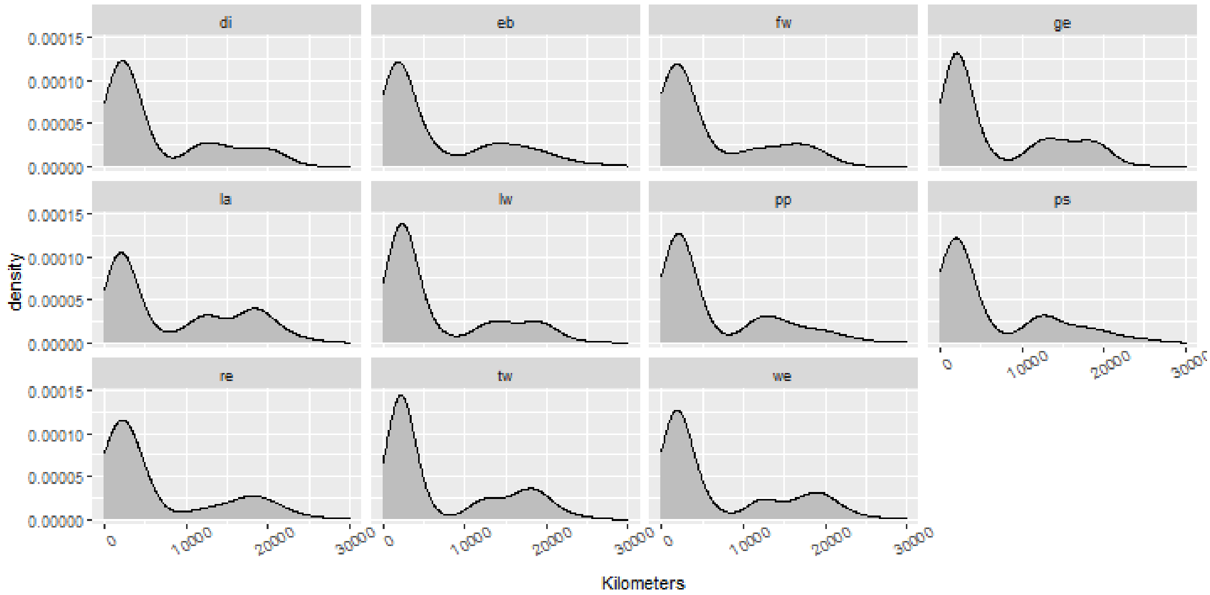

Figure 4: Density plots of the flown kilometres per trip, by faculty.

However, as mentioned in Section 3.1, faculties are not homogeneous entities but comprise several departments. Faculties do not necessarily have the same number of departments and each department can be of a different size. This limits the ease by which they can be compared, as some of the departments have a low number of flights as well as a low number of employees.

An illustrative example of the internal differences between the departments of the same faculty is given in Figures 5 and 6. Figure 5 represents the violin plots of the departments affiliated with the faculty of Political and Social Sciences. The number of observations in each violin plot is added above the plot itself.

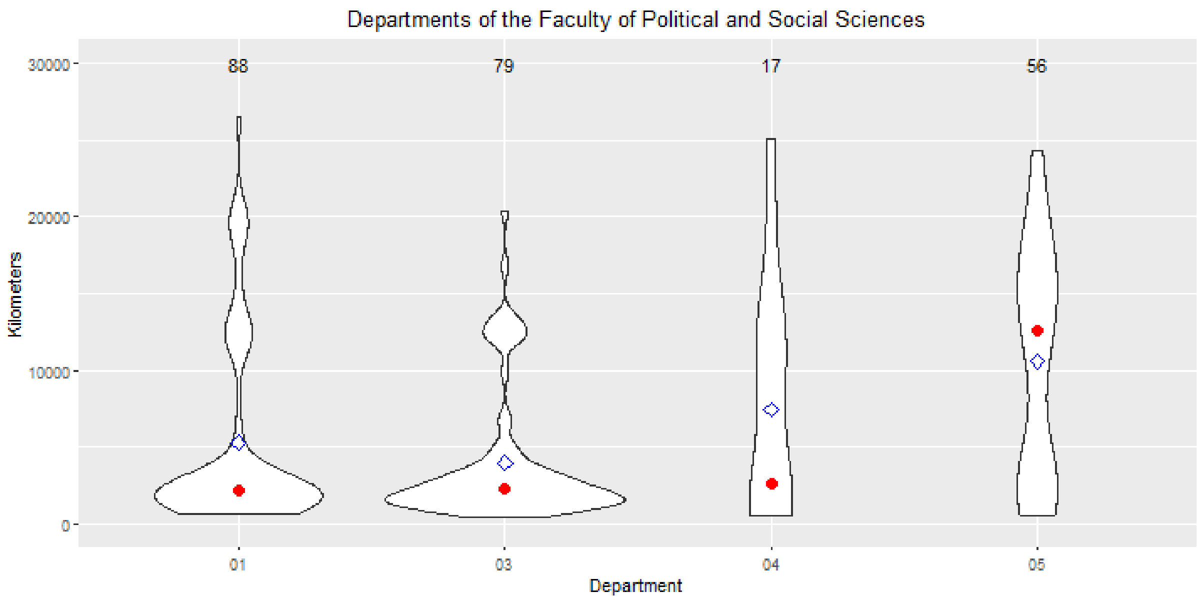

Figure 5: Violin plots of the flown kilometres of the departments of the Faculty of Political and Social Sciences.

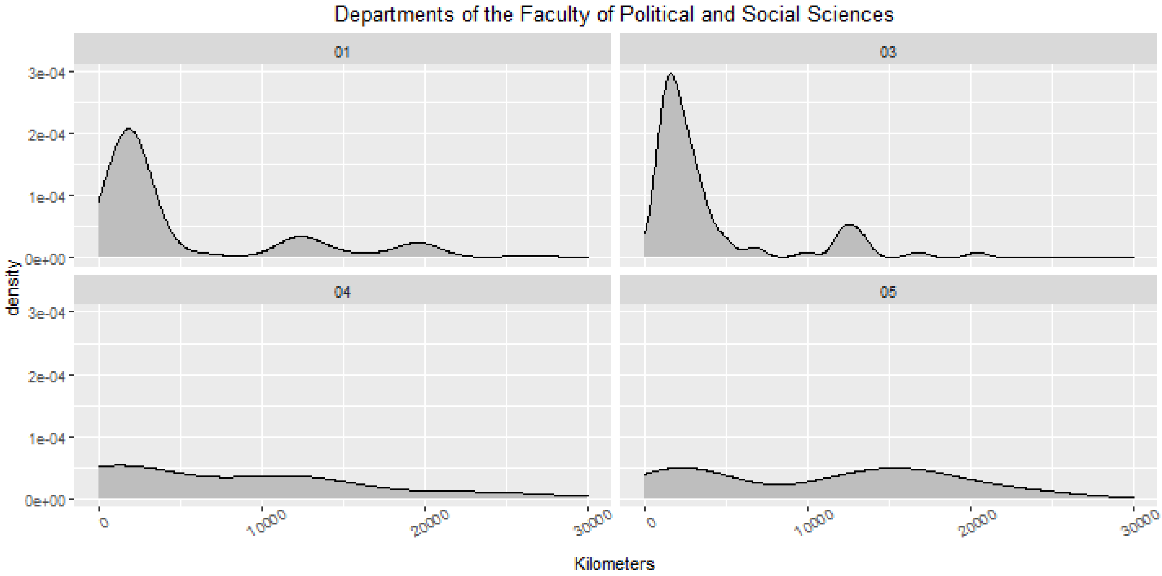

Figure 6: Density plots of the kilometres per trip in the departments of the Faculty of Political and Social Sciences.

The department of Sociology (PS04), and the department of Conflict and Development (PS05) do not follow the same distribution as the other departments and faculties. Both departments exhibit an abnormally high mean value in their distributions, and the long tail in the distribution is not present. While the discrepancy for PS04 could be attributed to the low number of observations in the violin plot, the 56 observations in the violin plot of PS05 show that it is significantly different from the distributions described before. This is further illustrated in the density plots shown in Figure 6. The plots for the departments of the Faculty of Bioscience Engineering are given in Figure 7, showing this is not an isolated phenomenon. For completeness, the distributions of the departments of the other faculties are given in Appendix III.

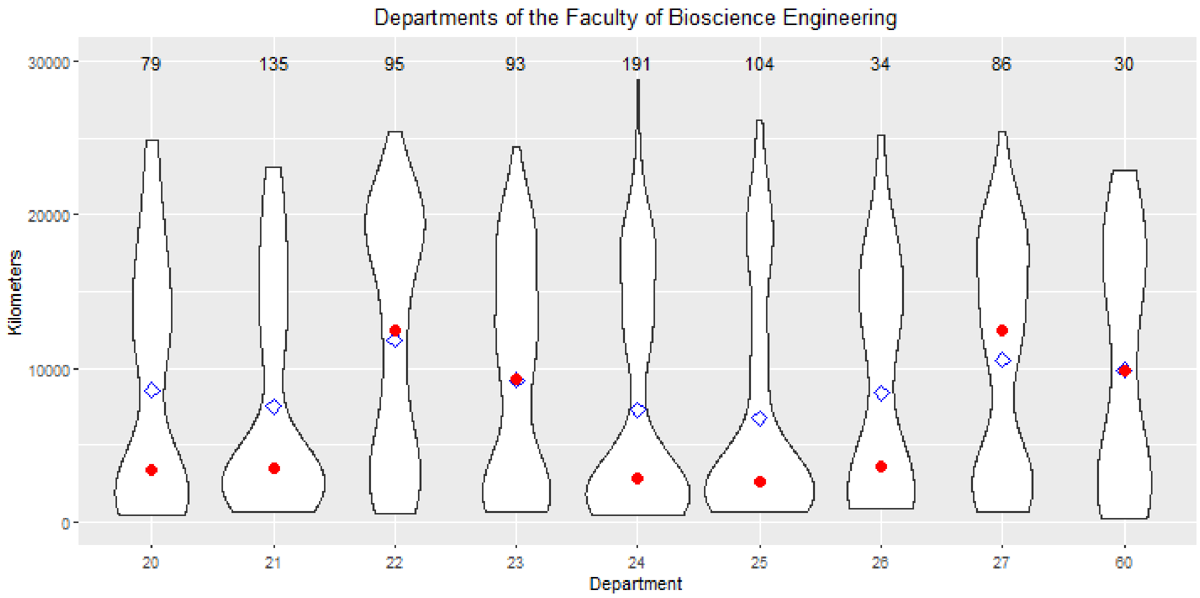

Figure 7: Violin plots of the flown kilometres of the departments of the Faculty of Bioscience Engineering.

This subsection can be summarized by stating that there are differences between the faculties as well as within them. At the faculty-level, both the Faculty of Bioscience Engineering and the faculty of Engineering and Architecture in particular seem to have a different flying culture compared to the other faculties.

Therefore, this thesis notes that on the one hand, policies that keep in mind those differences or policies that act on the faculty or even departmental level might be interesting to consider. The different research cultures of a faculty or department could be taken into account with faculty or departmental based policies, and specific issues and excesses could be targeted more easily.

On the other hand, most of the departments and the faculties do follow the same pattern as the whole university. Therefore, it could also be argued that implementing university-wide policies is indeed feasible and that the differences between departments and faculties are not significant enough to be used as a valid counter-argument, and that these outliers are more a sign of excessive travel behaviour.

4.1.3. Job categories

This subsection studies the relation between job (sub)categories and the flight behaviour of employees. The total amount of business trips for each type of job function at Ghent University is given in Table 10, the emissions and kilometres in Table 11.

Table 10 shows although the professorial staff is not the biggest group of employees at the university, they are the group that fly the most relative to their size. With a relative frequency of 94,92%, they leave the other groups of employees far behind. This is in line with the earlier mentioned pattern in other universities where academic professional staff often fly the most and are the biggest polluters.

Table 10: Absolute and relative frequencies for the business trips for the job categories.

JOB CATEGORY	FREQUENCY	STAFF MEMBERS	NORMALISED FREQUENCY [%]
AAP	3.488	11.122	31,35
Predoctoral	2.464	6.487	37,98
Research staff	834	3.506	17,63
Postdoctoral	161	913	23,78
Professorial staff	1.904	2.006	94,92
Guest professors	61	831	7,34
ATP	533	2543	20,96

Table 11: Total emissions and kilometres for the different job categories.

JOB CATEGORY	EMISSIONS [TON CO_2]	TOTAL DISTANCE [KM]
AAP	5.778	25.607.747
PREDOCTORAL	4.124	18.334.198
RESEARCH STAFF	1.303	5.701.552
POSTDOCTORAL	303	1.359.119
PROFESSORIAL STAFF	3.900	15.208.423
GUEST PROFESSORS	142	447.937
ATP	847	3.598.007

However, unlike in other studies where the professorial staff is often responsible for the largest share of the emissions, this is not the case at Ghent University. Academic Assistant Staff (AAP) is responsible for the largest amount of emissions, which is unsurprising given that they are the largest group of employees at the university. This can be seen in Table 11: the professorial staff is responsible for 3.900 tons of emissions, while the assisting academic staff emitted 5.778 tons.

These two tables show a large difference between predoctoral and postdoctoral fellows. Predoctoral staff members have a higher relative and absolute frequency and produce a larger amount of emissions than their postdoctoral colleagues. This might indicate differences in career progression.

Table 12 gives more insight into this behaviour by giving the mean, median and standard deviation for the kilometres per trip for the individual job categories, thus explaining how far each employee group typically travels. In this table, postdoctoral fellows appear to have the largest mean, despite their lower frequency. Their standard deviation is the second largest, implying great differences within the group itself.

Table 12: Mean, median and standard deviation of the flown kilometres per job category.

JOB CATEGORY	MEAN	MEDIAN	STANDARD DEVIATION
AAP	7.297	2.885	7.688
PREDOCTORAL	7.402	2.947	7.619
RESEARCH STAFF	6.771	2.575	7.525
POSTDOCTORAL	8.441	2.947	9.289
PROFESSORIAL STAFF	7.988	3.293	8.063
GUEST PROFESSORS	7.343	2.318	8.875
ATP	6.750	2.606	7.842

The professorial staff has the third-largest mean and second-largest median, suggesting that they not only fly more often, but also further. The group of Administrative and Technical Staff (ATP) has a lower mean and median value compared to the other categories.

The question then arises whether or not these differences between employee (sub)categories are significant? The Kruskal-Wallis test followed again by the Pairwise Wilcoxon-test show that there are not many significant differences among the groups of employees, at least not in the median values.

```
        Kruskal-Wallis rank sum test

data:  Kilometers by Job.Subcategory
Kruskal-Wallis chi-squared = 20.045, df = 8, p-value = 0.01017
```

As seen in the results displayed below, only the research staff (WP), a small fraction of the Academic Assisting Staff (AAP), and the predoctoral fellows show a significant difference with the professorial staff members.

```
        Pairwise comparisons using Wilcoxon rank sum test with continuity correction

data:  df3$Kilometers and df3$Job.Subcategory

          ATP    GuestProf Postdoc Predoc WP
GuestProf 1.0000 -         -       -      -
Postdoc   1.0000 1.0000    -       -      -
Predoc    0.2942 1.0000    1.0000  -      -
WP        1.0000 1.0000    1.0000  0.0437 -
ZAP       0.1132 1.0000    1.0000  1.0000 0.0085

P value adjustment method: bonferroni
```

To conclude this subsection of the empirical analyses, the distributions of each subcategory of employees are displayed in Figure 8. The probability density function of each category appears to follow the previously described pattern characterised by a steep initial peak, followed by a decline and one or two local maxima between 10.000 and 20.000 km, followed by a long tail.

The main takeaway from this subsection is that the major difference between the employee categories does not seem to be the distance they fly, but rather how frequent they fly. As this is interesting from a policy point-of-view, this is further explored in the section dedicated to frequent flyers.

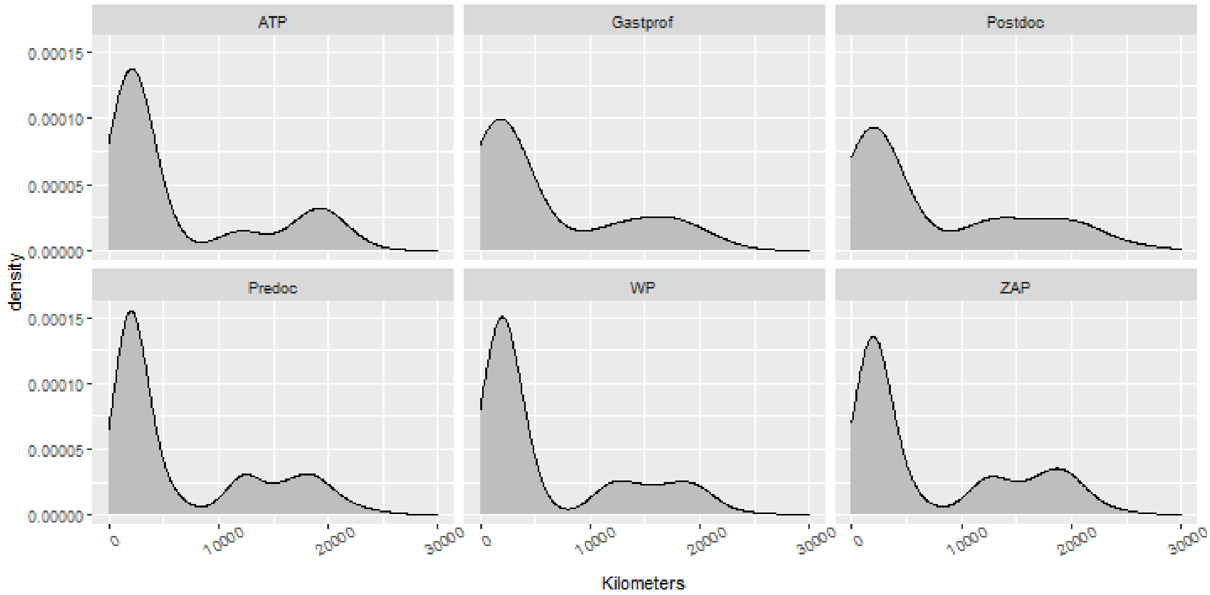

Figure 8: Density plots of the flown kilometres per trip, by job subcategory.

4.1.4. Gender

The previous analyses explored the differences in flown kilometres between faculties, departments and different kinds of jobs. This subsection will look into the difference between female and male employees. The gender of the employee is based on the information provided by the Department of Personnel and Organisation (DPO). The university does recognize transgender and binary identities, but is bound by the Flemish regulations, which impose a strict framework concerning gender identities (Ghent University, 2019c). Official documents state that Ghent University is looking into the recognition of binary identities in its database. However, identity X was not found in the provided dataset. This thesis is unfortunately limited by the provided information. Consequently, the exclusion of non-binary identities in this research is not based on moral grounds but needs to be attributed to the lack of proper information on gender identification.

Table 13 displays the considered properties per gender, both at the aggregated and averaged level. Listed are the total number of contracts for male and female employees at Ghent University for the period July 2018 – December 2019, the total number of flights by a male or female employee, the corresponding total amount of emissions and kilometres per gender, and lastly two kinds of averages. The first average describes the average if the total amount of emissions is divided by the total amount flights performed by a (fe)male employee (the number in the first column) and the second one if the total amount of emissions is divided by the total amount of (fe)male employees at Ghent University (the number in the second column). A similar analysis has been performed for the total and averaged kilometres.

Table 13: Aggregated and averaged flight properties on gender-level.

	MALE	FEMALE
NUMBER OF CONTRACTS	13.014	11.784
TOTAL NUMBER OF FLIGHTS	3.720	2.354
TOTAL CO2 EMISSIONS [TON]	7.046,60	3.763,06
CO2 EMISSIONS PER FLIGHT	1,89	1,60
CO2 EMISSIONS PER EMPLOYEE	0,54	0,32
MEDIAN CO2 EMISSIONS	0,80	0,68
STANDARD DEVIATION CO2 EMISSIONS	2,05	1,75
TOTAL KILOMETRES	29.163.599	16.258.432
KILOMETRES PER FLIGHT	7.840	6.907
KILOMETRES PER EMPLOYEE	2.241	1.378
MEDIAN KILOMETRES	3.191	2.632
STANDARD DEVIATION KILOMETRES	7.998	7.581

There is a clear difference between male and female employees: female employees fly less than their male colleagues and they make shorter flights. Before performing any parametric tests, the distribution of the flown kilometres needs to be validated. Therefore, Table 12 additionally includes the median and standard deviation of the flown kilometres and emissions, while Figure 9 shows the distribution of the flown kilometres in a histogram. The mean value for each gender is highlighted by the vertical line.

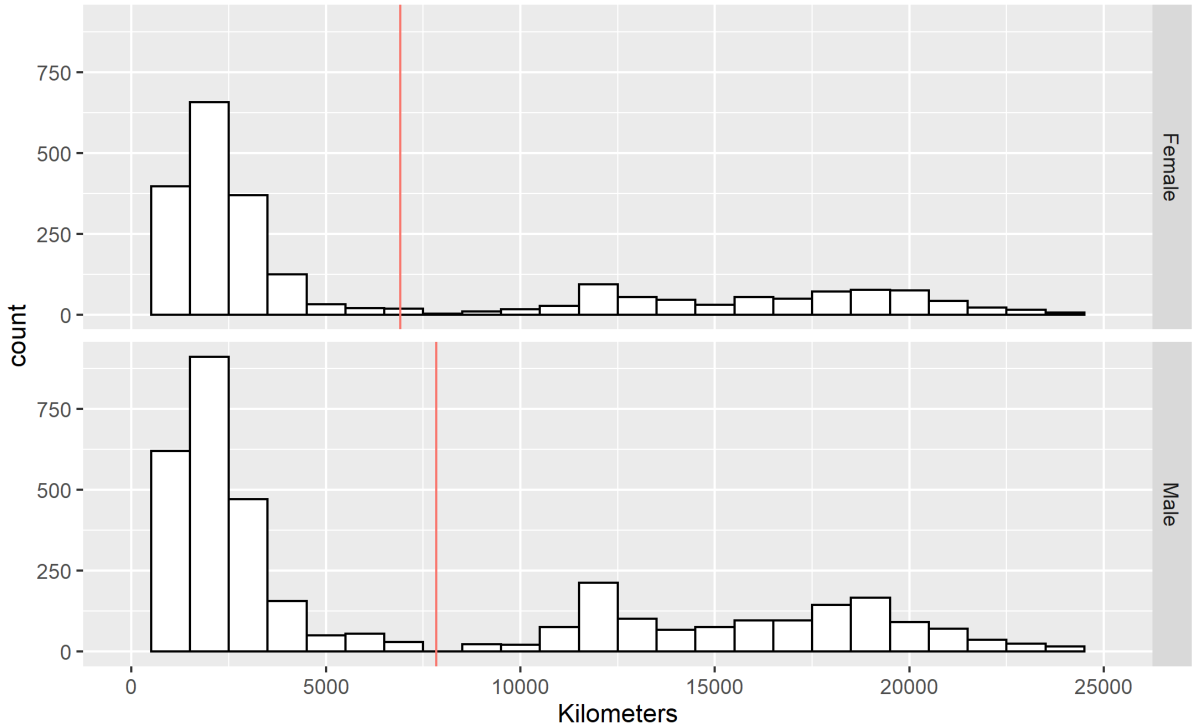

Figure 9: Histogram of the flown kilometres per trip, separated by gender.

The distribution in the histograms again follows the same trend as earlier discussed, a majority of very short flights in the beginning, followed by a small uprising in the number of flights between 10.000 and 20.000 km. The genders do not significantly differ in general shape, although both the median and mean are lower for female employees. There is also a small difference in the standard deviation and variance. Analogously, more outliers for very far flights are present in the histogram of the male employees. This is again a non-normal distribution, thus the Kruskal-Wallis test is applied.

```
        Kruskal-Wallis rank-sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 68.827, df = 2, p-value = 1.133e-15

        Kruskal-Wallis rank-sum test

data:  Kilometers by Gender
Kruskal-Wallis chi-squared = 66.879, df = 2, p-value = 3.002e-15
```

For emissions as well as kilometres, the difference between gender is found to be significant, as the P-value is lower than 0.05. The question therefore arises whether this difference is persistent at every job level and over different faculties? Following Tables represent the observed differences in the mean, and whether or not this difference is significant according to the Kruskal-Wallis test between the different faculties (Table 14), the research disciplines (Table 15), the faculties and management (Table 16), and different job categories (Table 17). The exact results of the Kruskal-Wallis tests are given in Appendix IV-a.

Table 14: Mean values for the kilometres per flight per faculty, separated by gender.

	DISCIPLINE	MALE	FEMALE	SIGNIFICANT DIFFERENCE
ADMIN.	-	7.625	7.326	No
RE	α	8.152	5.378	No
PP	α	8.594	5.421	Yes
PS	α	7.600	4.618	Yes
EB	α	6.933	7.998	Yes
LW	α	6.240	7.235	Yes
EA	β	7.714	7.550	No
WE	β	7.664	7.714	No
LA	β	9.754	7.240	Yes
GE	γ	7.485	6.937	No
DI	γ	7.098	6.028	No
FW	γ	5.505	6.114	No

Table 15: Mean values for the kilometres per flight per research discipline, separated by gender.

RESEARCH DISCIPLINE	MALE	FEMALE	SIGNIFICANT DIFFERENCE
α	7.263	6.326	No
β	8.239	7.508	Yes
γ	7.107	6.627	No

The results presented in these tables give additional insight into the travel behaviour on a more granular level, allowing for an in-depth analysis. For instance, it is not correct to make the statement that women on average fly less and they fly shorter trips than their male counterparts in *all* faculties. As seen in Table 14, the Faculty of Economics and Business Administration can be taken as an example, where the Kruskal-Wallis rank-sum test finds a significant difference between the two genders, with female employees travelling further on average. Furthermore, while the mean value of male employees is often higher than those of their female colleagues (or vice versa), this difference can only be considered statistically significant in five of the eleven faculties.

Furthermore, it is interesting to note that these significant differences are not persistent at a more aggregated level. For example, Table 15 gives the mean values of the kilometres per flight for each research discipline, where each research discipline comprises several faculties. To further illustrate this, the five α-faculties can be considered. For this cluster of faculties, four of the five each exhibit a significant difference between genders. However, the significant difference between genders disappears when considering these α-faculties as one entity.

Aggregating the three research disciplines one step further to obtain the difference between the administration and the mean value, separated on gender for all faculties, is done in Table 16. There, a significant difference between male and female colleagues once more appears for personnel linked to a faculty, while only one research discipline (the β-faculties) and five individual faculties showed a significant difference at the more granular level.

Table 16: Mean value of the kilometres per flight, separated by gender at the organisation level.

	MALE	FEMALE	SIGNIFICANT DIFFERENCE
FACULTY	7.853	6.874	Yes
ADMINISTRATION	7.675	7.326	No

The aforementioned tables classified personnel based on their workplace, e.g. whether they work in a specific faculty or the central administration, and subsequently aggregated this to higher levels such as the research discipline. In contrast, it is also possible to use a classification based on the job function, as it is known from the literature that different jobs can lead to different travel behaviour. As such, it is interesting to consider the different job categories from Ghent University and separate these on gender, to reveal significant differences in travel behaviour for different jobs. The results from this analysis are given in Table 17 on the following page.

Table 17: Mean value for the kilometres per flight per job function, separated by gender.

JOB CATEGORY	MALE	FEMALE	SIGNIFICANT DIFFERENCE
AAP	7.707	6.799	Yes
Research staff	7.325	6.071	Yes
Predoc	7.787	6.943	No
Postdoc	8.488	8.377	No
ATP	6.330	7.130	No
Professorial staff (ZAP)	8.231	7.180	Yes
Guest professor	6.827	8.399	No

The main analysis shows that even though the university level the distributions of the kilometres per trip exhibit the same type of distribution for both genders, their mean values are significantly different. These results are consistent with the findings in the literature on gender mobility.

As Storme in his research on academic flying already noted, the heavy mobility responsibilities in the academic world result in fewer opportunities to achieve academically for women (Storme, 2014; Storme et al., 2017). Earlier surveys showed that regardless of family situation, men travel more than women. If there are family obligations, they mostly have an impact on women (Gustafson, 2006; Jöns, 2011). Young children reduce the travel activity of women, whereas no consistent effect is found among their male colleagues. When looking at their personal relationships, female academics partners are far less likely to migrate together with their spouse compared to male academics, and female academics note a lack of emotional support from their partners (Vohlídalová, 2014).

This results not only in flying less, but flying less far. With family and social obligations at home, it is not always feasible to stay away from home for longer periods, as long travel hours immediately result in longer trips. By flying less, taking fewer longer trips as well as being less able to sustain important informal academic relations, the internationalisation possibilities of female academics slink. However, as discussed in the literature section, this internationalisation aspect is key for career progression and thus the current travel culture plays an immense role in the existing gender inequalities. Krüger and Lévy stress the crucial role that institutions have in shifting traditional gender orders (Krüger & Levy, 2001). However, shifting the gender roles and solving the existing gender inequalities in academic career progression cannot be disconnected from the geographic toll travelling has on women.

Consequently, this thesis argues that gender and diversity policies need to include analyses and rethinking of the travel policies and obligations of the university. Furthermore, the empirical findings presented in this subsection highlight the need to take existing faculty-level differences into account when shaping policy.

4.1.5. Two-way ANOVA to test for interactions

This last section of 4.1. will use a two-way ANOVA to analyse the categorical variables (gender, faculties and job categories) and the flown distance in kilometres. A two-way ANOVA is used to analyse if two or more factors affect a response variable, and whether or not there is an interaction effect between the two or more factors on the response variable. The two-way ANOVA has few assumptions. The assumption of normal distribution and the assumption of a constant variance are analysed in Appendix IV-b. However, these conditions are not met. The discussion of the results should therefore be taken with some caution. The two-way ANOVA is performed twice: First with an effect on gender and faculties, and second between gender and job category.[8] Due to the unbalanced nature of the datasets, a Type III ANOVA test is used, as implemented in R.

```
Anova Table (Type III tests)

Response: Kilometers
                            Sum Sq   Df  F value    Pr(>F)    
(Intercept)             8.8077e+09    1 145.3959 < 2.2e-16 ***
Gender                  1.6075e+06    1   0.0265 0.8706037    
Facultymanagement       1.7980e+09   12   2.4735 0.0031710 ** 
Gender:Facultymanagement 2.1963e+09   12   3.0213 0.0003037 ***
Residuals               3.5686e+11 5891                       
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Anova Table (Type III tests)

Response: Kilometers
                       Sum Sq   Df   F value    Pr(>F)    
(Intercept)        7.2728e+10    1 1191.1538 < 2.2e-16 ***
Job.Category       6.5104e+07    2    0.5331 0.5867852    
Gender             7.1113e+08    1   11.6470 0.0006474 ***
Job.Category:Gender 3.7079e+08    2    3.0364 0.0480812 *  
Residuals          3.6091e+11 5911                        
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The two-way ANOVA analyses shows that there is a significant interaction-effect between job categories and gender, and as well as between faculties and gender. This could be expected seeing as the more statistically appropriate Kruskal-Wallis test showed differences for gender within the job-categories as well as within the faculties.

[8] The interaction effect between job-category and faculty/management was not performed because of the non-compatibility of the two categories and the presence of aliased coefficients when attempting to run a Type III ANOVA for unbalanced datasets. This error could possibly be attributed to perfect multicollinearity between variables, which might be caused by the absence of some combinations of the factors. For example, management, which is part of the categorical variable faculty/management, does not include ZAP or AAP. The interaction between faculties and their staff compensation and the effect on travel behavior could therefore be interesting for future research.

4.2. Seat class

The CO_2 emissions of aviation travel are determined by several factors: the flight distance, the flight profile, the aircraft model, its weight, the cargo loading on passenger aircraft, the occupancy rate and last but not least, the seat class (Govaert, 2019). Not all of these factors are taken into account in Greentripper, the emission calculator by CO2logic and calculation method used by Uniglobe Smart Travel. The exact occupancy rate is not taken into account, nor are the size and model of the plane. In contrast, the calculator uses average values provided by Bilan Carbon of the French Agency for the Environment and Energy Management (ADEME). However, the specific seat class is still included in the Greentripper calculation. Greentripper differentiates between short- and long-haul flights. For short-haul flights, the calculator distinguishes between economy, business and unknown class seats, while long-haul flights are differentiated between economy, business, first and unknown class seats.

Cabins have a major influence on emitted emissions. A non-economy class seat takes up more space due to heavier seats and entertainment devices. The average area of an economy seat expressed as a percentage is 100%. For Premium economy, this becomes 131% on average, while a business seat rises to 180%, and finally for first-class seats can reach over 300%. In his research on methods to calculate greenhouse gas emissions, Arul calculated an emitting difference of factor 2 (Arul, 2014). The British Department for Business, Energy and Industrial Strategy assigns an even higher difference of factor 4 between economy and non-economy seats (Govaert, 2019). Previous studies on the estimation of the impact academic flying have similarly considered a factor 2 to 4 (Ciers et al., 2019; Wynes & Donner, 2018).

As these differences in seat class are included in the Greentripper calculations, these two groups of flyers, economy and non-economy, are visible in the data. Figure 1 already showed the relation between the emissions and kilometres, while the difference between economy and non-economy is visible. The unlinked dataset was used to construct this figure, as it is possible to have different types of seats during a full trip with multiple individual flights. The figure shows a clear difference between economy and non-economy seats, a difference that increases with increasing kilometres.

In studies and roadmaps on reducing the carbon emissions of institutions, eliminating non-economy flights has been put forward as a major step forward towards carbon reduction (Ciers et al., 2019; Le Quéré et al., 2015; Wynes & Donner, 2018). In EPFL replacing all non-economy classes by economy, flights could lead to a 17% reduction in their air travel GHG emissions, amounting to 840 ton CO_2 per year. For the University of British Columbia, obligating economy tickets led to a CO_2 reduction of 1.723 ton, corresponding to 7,8% of the total emissions of the whole campus.

However, those numbers are not consistent with the findings for Ghent University. At Ghent University only 174 of the 9.793 flights from July 2018 until December 2019 were non-economy class, which corresponds to only 1,7% of the total amount of flights and 1.303 ton CO_2, corresponding to 5,98% of the total emissions.

Tables 18-20 give additional insight into the profile of Ghent University employees that fly non-economy. It appears that these employees are most often male, members of the professorial staff and from a β-faculty. The group of young academics, predoctoral and postdoctoral fellows, appear to fly the least in non-economic seats. Unsurprising, as some sources of academic mobility funding intended for young academics impose economy class (Ghent University, 2018d-e).

One could argue that imposing economy class in future policy decisions is important because it emphasises individual impact and responsibility. For the individual employee, flying in a non-economy class still has a much larger impact and allowing employees to fly non-economy with university finances might raise ethical questions. However, if the university aims to significantly reduce emissions, prohibiting non-economy flights might not be sufficient and has more symbolical value than an actual impact.

Table 18: Distribution of non-economy class seats by job groups of Ghent University employees.

Postdoc	Predoc	ATP	Professorial staff	Guest professor	Research staff	Rest Group
1	3	14	155	9	10	3

Table 19: Distribution of non-economy class seats by gender of Ghent University employees.

Male	Female
171	24

Table 20: Distribution of non-economy class seats by the employee affiliation.

FW	LW	PS	DI	PP	RE	WE	EB	EA	GE	LA	CA
3	3	3	6	4	7	14	20	26	30	74	5

4.3. Destinations

4.3.1. The geographical spread of destinations

Extracting the individual countries in each trip now allows for a visualisation of the travel behaviour of Ghent University. This is done in Figure 10 and 11, each visualising a choropleth map where individual countries are shaded according to the number of occurrences they have in the linked-flight dataset, explicitly taking intermediate stops into account. The problems as mentioned in Appendix I do not allow for a comprehensive and correct analysis of these destinations from the unlinked-flight dataset. For example, an inbound flight from Seoul has Brussels as final destination in the original dataset obtained via Uniglobe. Consequently, an analysis based solely on the final destinations was not feasible. Furthermore, as Belgium is often the first or last stop of a trip, Belgium is excluded from this map to avoid distortion of the scale.

In Figure 10, the initial focus is on the EU area, given the high density of destinations located there. This is unsurprising, as flights to other continents often have London, Paris, Frankfurt or Schiphol as their initial destination to catch a connecting flight. The high number of occurrences of The Netherlands in the dataset can be attributed to employees taking Schiphol Airport as their initial airport instead of Brussels Airport.

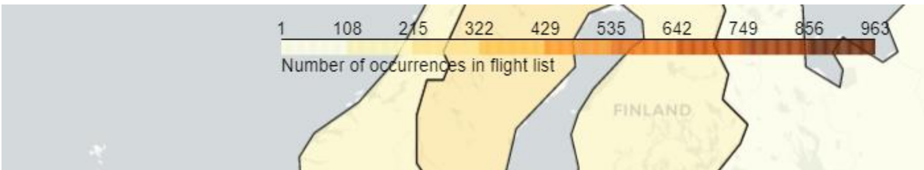

Figure 10: Choropleth map of the occurrences of EU-destinations in the dataset.

Figure 11 expands this map by considering non-EU destinations. It is immediately clear there are three major regions of travel: North America, with the United States of America, prominently featured on the map, China and Ethiopia.

The United States of America is featured nearly as much as Germany in the dataset. However, a single trip to a non-coastal region of the US can take up to four connecting flights to reach. Consequently, these numbers are slightly inflated. Furthermore, the noticeable presence of Ethiopia on this map could be attributed to the participation of Ghent University in the VLIR-UOS Interuniversity Collaboration program NASCERE, a long-term collaboration aimed towards providing PhD scholarships to Ethiopian academic staff at Flemish universities (Ghent University, n.d.-g).

4.3.2. Ghent University Global Campus

One of the cornerstones of the internationalisation strategy of Ghent University is Ghent University Global Campus (GUGC), a campus affiliated with Ghent University in South Korea (Ghent University, n.d.-h). GUGC opened its doors in September 2014 and has known a steady growth since then, currently offering three bachelor programs affiliated with the Faculty of Bioscience Engineering. Given the importance of GUGC in the internationalisation policy of the university, any research on the travel behaviour of Ghent University staff members that fails to include an analysis of the influence of the Global Campus would be remiss.

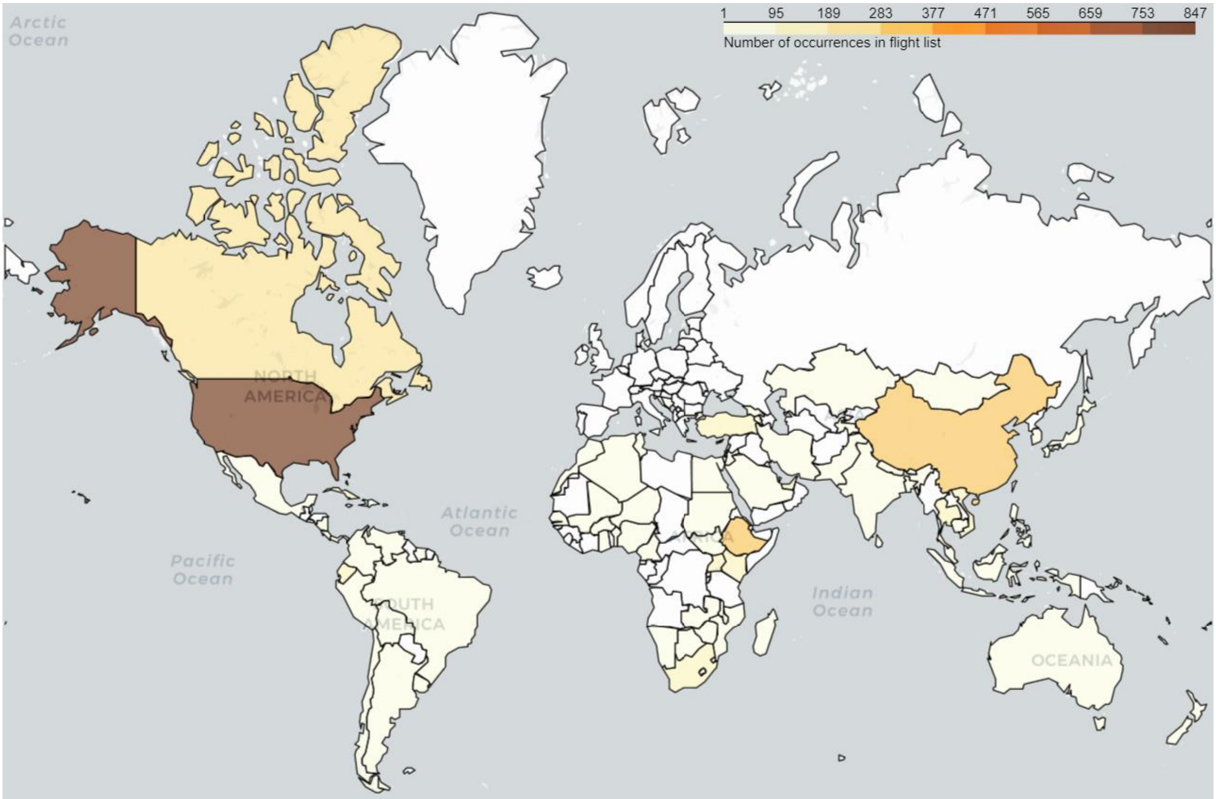

Figure 11: Choropleth map of all non-EU destinations in the dataset.

Nowadays the campus is primarily staffed by a group of employees that permanently reside in South Korea, while a small number of employees linked to either the Faculty of Bioscience Engineering or the central administration make shorter business trips for the organisational aspect of the Campus.

From July 2018 to December 2019, a total of 81 trips to South Korea were made, corresponding to 1,05% of the trips present in the linked dataset. Unsurprisingly given the distance of the Global Campus from Belgium, this 1% of trips is responsible for 2,87% of the total CO_2 emissions, i.e. 403 ton CO_2. It would however be incorrect to attribute all these emissions to the presence of the Global Campus in South Korea, as not all flights to South Korea necessarily have a visit to the Global Campus as a goal. For example, Ghent University currently has 7 bilateral agreements for both student and staff mobility with South Korean institutions. Therefore, flights to South Korea can also occur as part of these agreements, or for regular international scientific conferences (Ghent University, n.d.-g-i).

To verify this, it is necessary to consider both the affiliations and employee (sub)groups of staff members travelling to South Korea. This is done in Tables 1 and 2 for the affiliation and the job functions respectively. As seen in Table 21, slightly more than half of the trips to South Korea can be attributed to employees of the Faculty of Bioscience Engineering, the faculty responsible for the bachelor programs in GUGC, or the central administration.

Table 21: Staff affiliations of employees travelling to South Korea.

LA	TW	WE	CA	LW	GE	DI	RE
34	15	11	8	3	3	3	3

The employee (sub)groups displayed in Table 22 shed more light on this question, as it can be seen that approximately half of the trips were made by the professorial staff.

Table 22: Employee (sub)groups for travellers to South Korea.

Employee category	Employee subcategory	Amount of trips
Assisting Academic Staff		24
	Predoctoral fellows	21
	Postdoctoral fellows	0
	Research staff	3
Professorial staff		40
Administrative and technical staff		12

Given the location of the Global Campus and its role in the internationalisation policy of Ghent University, one might have expected a higher CO_2 contribution from travels to this destination. However, the overview presented in this subsection yields a more nuanced view.

4.3.3. Green and yellow cities

One of the most significant policy measures introduced as part of the sustainable travel policy of Ghent University is the creation of the lists of so-called green and yellow cities (Ghent University, 2018c). This list of green cities consists of cities that are prohibited to travel to by plane ever since this framework entered into force. These locations are less than 6 hours away by train, and therefore other modes of transport are designated. However, there are exceptions to this rule, as this obligation expires if the train ticket costs €100 more than the corresponding flight ticket, or if there are three transfers. In contrast, yellow cities are those that lie less than 8 hours away by train. When employees want to book a trip to these cities, a trip with the bus or train is proposed by Uniglobe Smart Travel as the preferred option but they can still choose to fly by plane.

The publication of a list of cities where it's either prohibited or discouraged to travel by plane is not a unique policy measure, not even within the regional context of Flemish universities. The University of Leuven uses a 'white' and 'grey' list (University of Leuven, 2020). Cities are on the white list when the flight plus three hours takes about the same time as the train ride from Leuven, therefore employees can only take the train. The grey list is similar to Ghent University's yellow cities, i.e. cities with a maximum of 7 hour travel time by train, and the employee can choose the mode of transportation.

Did the introduction of this green and yellow city list affect the travel behaviour of the academic employees? The variable *Destinations* give the possibility to look at how many times employees still flew to one of those cities. Table 23 represents how many times employees flew to the cities on the green or yellow list. The datasets with the unlinked and linked data are compared.

The table shows that despite the destination-restrictions, there are still employees that travel by plane to nearby cities. The difference between unlinked and linked datasets once more highlights the importance of linking intermediate stops, inbound and outbound journey. Nearby cities such as Amsterdam or Lille are often just a first stopover in the whole travel route.

Table 23: Comparison of flights to green and yellow cities between the datasets.

	UNLINKED DATASET	LINKED DATASET	% OF TOTAL LINKED FLIGHTS
GREEN CITIES	134	104	1,33
YELLOW CITIES	398	336	4,32

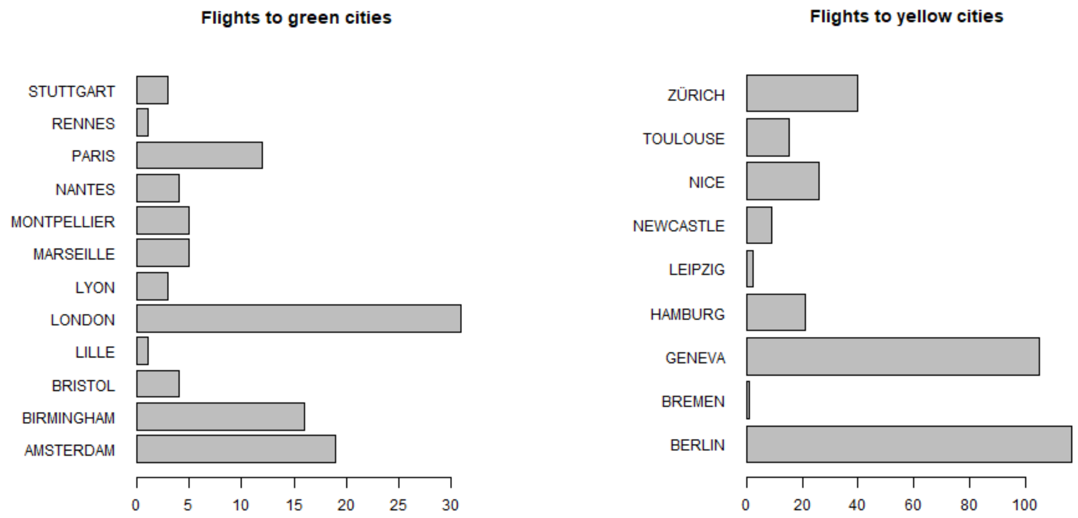

Figure 12: Bar plots displaying the number of flights to individual green (left) and yellow (right) cities.

The reason for the flights to green cities is unknown. This could be due to incorrectness in the final data, although it is also a possibility that employees made use of the exception-rules, e.g. their train ticket might have been €100 more expensive than the plane ticket. Figure 12 shows which individual green cities employees frequent most often. The presence of cities such as London or Amsterdam could be attributed due to incorrect data, even in the linked dataset. However, it is unlikely that a city such as Bristol or Nantes is a stop-over for a connecting flight. Finally, the orange cities Ghent University employees travel to consist of only 9 individual cities, with Zürich, Berlin, and Geneva as the main attractions. It is important to note that over 2% of the trips made by Ghent University employees were headed to Berlin or Geneva, two 'yellow' cities.

4.4. Timing

The duration of the trip does not influence the emitted emissions, but it can be important to take into consideration from a moral point of view. Flying a long distance for a short visit abroad, which surveys and interviews indicate does happen in the academic field, raises ethical questions. In Storme's in-depth interviews, participants noted that they are expected to "be there", even if it comprises a short meeting and a transatlantic flight. Multiple obligations and meetings lead to overflowing agendas and very short stays. Therefore, the short duration of trips might be part of the earlier described *meetingness* of Urry.

Figure 13 displays the distribution of the observed durations for individual trips in the linked-flights dataset.

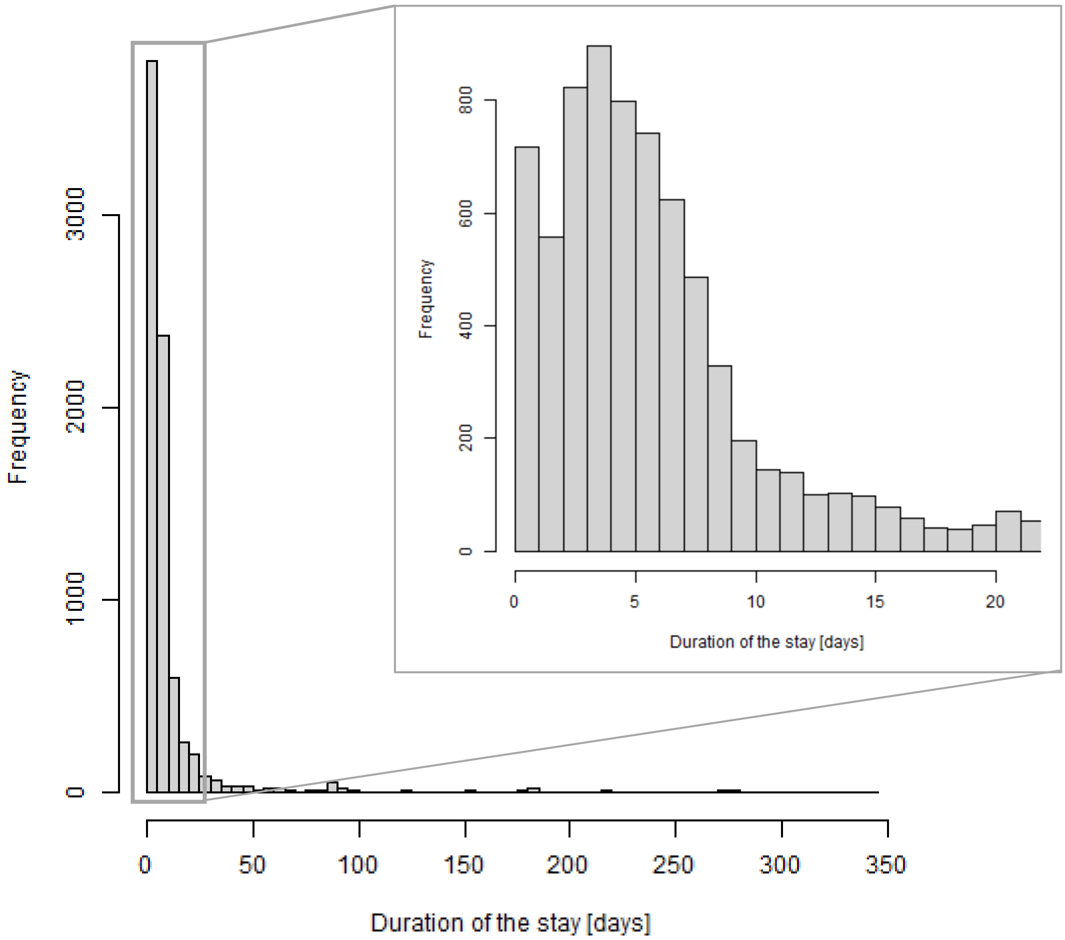

Figure 13: Histogram of the duration of the stay in days.

As expected, short trips dominate the histogram, with several very long stays as outliers. This is unsurprising, as research staff often go abroad for a semester or a full year on sabbatical. In addition to this, a complementary histogram focused on stays shorter than 3 weeks is plotted inline. The median trip is five nights long, with approximately 4% of trips having a duration of more than 40 nights. Furthermore, it is noteworthy that there are still very short duration flights, lasting less than 1 day. These statistics are remarkably similar to the findings reported for the University of British Columbia (Wynes & Donner, 2018).

To verify whether the duration of the trip is related to its distance, both variables are plotted in Figure 14. From this figure, the distance and thus also the emissions can be considered nearly independent from the duration of the stay. A Pearson correlation coefficient of 0.25 is obtained between the two variables.

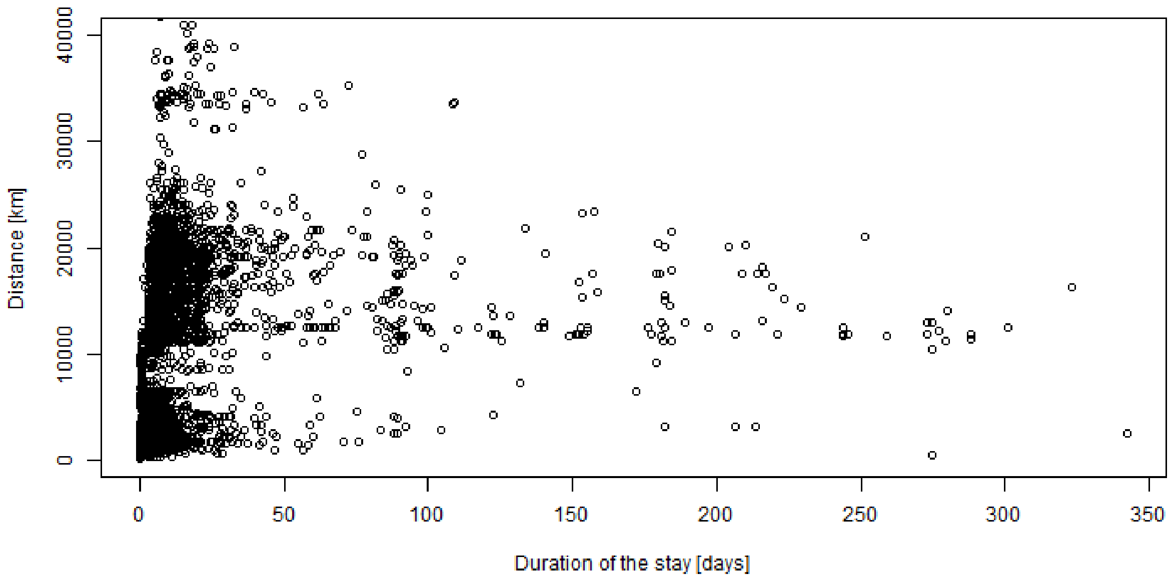

Figure 14: Duration of the stay plotted versus the distance in km of the trip.

The final timing-related question that arises is when staff members perform international trips. This is visualised for 2018 and 2019 in Figure 15, where the number of trips is binned for every week of the year, allowing for a visualisation that can be related to the university's academic calendar. As the dataset starts from July 2018, half of the data points of 2018 is missing. As such, it would be speculation to attempt to draw a comparison between 2018 and 2019 based on the limited data, as some periods for 2018 and 2019 follow the same trend (e.g. from week 27-32, week 41-52), while other regions deviate (e.g. week 33-40). Consequently, data from a longer time period is necessary to draw more general conclusions for the timing throughout the year.

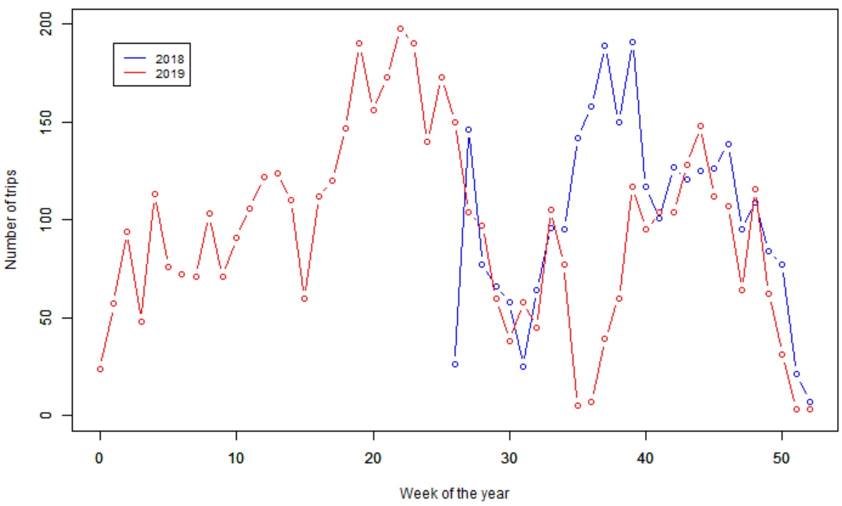

Figure 15: Number of trips for each of week of the year, separated for 2018 and 2019.

4.5. The effect of stopovers

This section discusses the effect of indirect flights. Booking direct rather than indirect flight routings are promoted as a way to reduce travel emissions (Wynes & Donner, 2018). Take-off and landing take up a tremendous amount of emissions and stopovers often result in a far longer route (Ritchie et al., 2020). Ciers et al. calculated that changing to more direct flight a potential 9% reduction in EPFL's air travel GHG emissions, corresponding to 440 ton CO_2 (equivalent) per year. The vast majority of indirect flights (98,3%) has much higher emissions than their corresponding direct flight (Ciers et al., 2019).

However, other research and CO_2 calculators suggest that indirect flights might not always be the most CO_2 intensive one. A flight without stopovers needs more fuel to fly the long distance and therefore has a higher weight (Govaert, 2019). Govaert analysed and evaluated several existing CO_2 calculators, including Greentripper. For example, the calculation methods of Treelogical and Myclimate assigned a lower amount of emissions to an indirect flight to Sydney compared to its equivalent direct flight because of the additional weight.

However, the study of Ciers et al. does address the issue of this increased weight leading to higher energy expenditure and take this into account for their calculation (Ciers et al., 2019). Only 1,7% of the total amount of flights of EPFL would have had lower emissions when flying indirect. They state that the extra weight of fuel only affects the emissions of the direct flight and indirect flight if the difference between direct and indirect flight is low. However, the vast majority of the trips add a large number of kilometres on their travel distance when adding a stopover.

It is not the goal of this work to re-evaluate the calculation method.[9] For the purpose of this research, it is sufficient to argue that indirect flights can influence the total emissions of a business trip. Consequently, from a policy perspective, it is interesting to consider the presence of stopovers in the present dataset. When considering stopovers, it is vital to use the linked-flight dataset. Counting the number of stopovers with the unlinked-flight data would lead to inaccurate results, which is again a plea to use linked-flight datasets when analysing travel behaviour.

Table 24: Absolute and relative frequency of the number of flights per trip.

# OF INDIVIDUAL FLIGHTS	1	2	3	4	5	6	7	8
FREQUENCY	398	4167	420	2258	186	198	10	5
PERCENTAGE	5,2	54,0	5,4	29,2	2,4	2,6	0,1	0,1

[9] As this has already been done by Govaert.

Table 25: Mean, median and standard deviation of the number of flights per business trip.

	MEAN VALUE	MEDIAN VALUE	STANDARD DEVIATION
ALL TRIPS	2,784	2	1,17
ONLY OUTBOUND AND RETURN FLIGHTS	2,847	2	1,125

The vast majority of the academics have flown via a direct flight. This is also visible in Table 25 which gives the mean, median and standard deviation of the number of flights per trip. However, there are still a lot of flights with a large number of stopovers: four flights per trip, i.e. two intermediate stops during the whole trip, is the second most frequent in Table 24.

The correlation between the flown kilometres and the flights per trip is 0,671. Analogously, the correlation between the CO_2 emissions and the flights per trip is 0,638. This is further explored in Figure 16, which plots the relation between kilometres and stopovers. These results suggest that longer distances often have more stopovers. This is unsurprising, as planes often need extra fuel for long distances. However, Figure 16 also reveals that there are short flights that have multiple stopovers.

As a conclusion, in terms of direct and indirect flights, this thesis states that there might be possible efficiency gains. While this work did not set out to calculate the effect of taking an alternative direct route compared to the indirect flights, one can assume that choosing more direct routes could lead to a reduction of the overall emissions.

Two comments must be made about this possible efficiency gain. First, as stated before, the effect of stopover is still open for debate and it might be useful to use other calculators then Greentripper to be sure about the emission-effect. Secondly, changing to more direct routes might not always be possible (Ciers et al., 2019; Wynes & Donner, 2018). The destination might not be available by a direct flight or not be available at the right time.

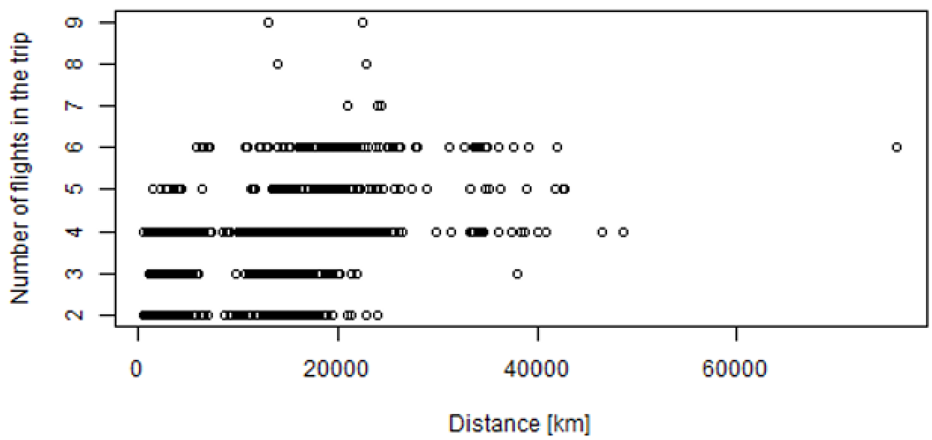

Figure 16: Relation between the flown distance and the number of flights in the trip.

4.6. Airlines

The provided dataset by Uniglobe included the airline for every individual flight. The specific model of the plane is not included in the Greentripper CO_2-calculation which makes use of averages (Govaert, 2019). Although this thesis does not intend to deviate from the emissions calculated by Uniglobe through Greentripper, the inclusion of airlines in the dataset presents a unique opportunity to concisely analyse the use of specific airlines booked by Uniglobe for the employees of Ghent University, as differences among airline pollution can be substantial. Some carriers perform better than others as they invest more heavily in fuel efficiency. A 7-year study by the University of Warrick of the 20 largest airlines found significant differences among the international carriers. Finnair had the lowest carbon footprint, due to the age and type of its planes, while US Airways and American Airlines emerged as the highest polluters (Warrick Business School, 2016).

The Airline Index of Atmosfair is a more comprehensive study on the carbon footprint of airlines. Atmosfair is an independent German non-profit organization which on the one hand offers offsets for greenhouse gases, and on the other hand, does calculations of greenhouse gas emissions of air travel (Atmosfair, n.d.). One of its major projects is the Airline Index, an index that compares and ranks the carbon efficiency of the 200 largest airlines (Atmosfair, 2018). The Airline Index compares the aircraft type, engines, winglets, seating and freight capacity as well as load factors for both passengers and co-loaded freight, using detailed sources from authorities and official statistics. Atmosfair states that the CO_2 emissions of an airline can be calculated with an error margin of less than 2%. By informing passengers on the pollution intensity of airlines, Atmosfair aims to make climate efficiency a factor of competition among major airlines. Atmosfair gives an extensive overview of the used formula, calculations and numbers, and therefore has won numerous awards for their transparency.

Although the objective of Atmosfair's Airline Index is to inform individual passengers and the broader public, it can also be used to evaluate a complete dataset of flights, as performed in this research. The data in the variable *Airlines* was combined with the Airline Index. This index introduces 7 efficiency classes (A, B, C, D, E, F, G) among the airlines. No airline reaches the highest class A, further emphasising the needed efficiency improvements. Furthermore, the Airline Index ranks all airlines in their total index, and uses this rank as well as efficiency points as parameters in the index. An illustrative example of the ranking is included in Figure 17, where these three parameters (rank, efficiency points, efficiency class) are included. The complete Atmosfair Airline Index can be found in Appendix V-a. Hence, this section uses those three parameters to analyse the carbon efficiency of the airlines present in the considered dataset. However, not every airline included in our dataset was considered in the Airline Index. This thesis, therefore, divided the airlines into three groups.

Overall ranking							
Rank	Airline	Country	EP* '18	EP* '17	EK*	Type*	Pax (in Mio.)*
1	TUI Airways	UK	79,3	78,9	B	Charter	10,9
2	LATAM Airlines Brasil[1]	Brasilien	78,8	72,3	B	Net Carrier	33,8
3	China West Air	China	77,8	78,6	C	Regional	7,2
84	Brussels Airlines	Belgium	50,5	49,0	E	Net Carrier	7,7

Figure 17: Illustrative example of the Atmosfair Airline index ranking, with 'EP' short for 'Efficiency Points' and 'EK' for 'Efficiency Class', figure adapted from Atmosfair Airline Index 2018.

First, there are airlines that are matched with the normal Airline Index. Those are assigned a rank, class and efficiency point. Second, there are low-cost carriers or so-called budget airlines like Ryanair, Wizz Air, Aer Lingus etc. Those budget airlines are purposely removed from the regular Airline Index because of methodological issues in total CO_2 calculation and representation. Those methodological issues include the subsidies those airlines receive. Those subsidies result in extremely low ticket prices, which encourages passengers to fly more than they normally would. As not flying is still the most sustainable way of travelling and technological efficiency gains cannot compete with the growing body of air travel passengers, this needs to be taken into account when assigning a climate impact to those airlines. Other airlines may also receive subsidies but do not use them for low-price policy. As such, low-cost airlines don’t have a ranking number or efficiency point assigned to them but are classified into the different classes (A-G). Therefore, this research follows the reasoning of Atmosfair and discusses the low-cost carriers separately, as the number of flights with these low-budget airlines is important when discussing the overall climate impact of the Ghent University’s used carriers. The list of low-cost carriers and their efficiency class can be found in Appendix V-b. Lastly, although the Airline Index is very comprehensive, not every airline around the globe is included. As such, these missing airlines comprise the third category. These airlines are often very specific regional or national airlines, for example Air Namibia. Other airlines like IndiGo Air bankrupted before the Airline Index of 2018 was published. The missing airlines have of course no efficiency point, rank or class.

Table 26 displays the frequencies of the specific categories. The unlinked dataset was used for these variables, as each flight within one trip can have a different airline. Of the 10.225 flights, 8 flights didn’t have an airline specified. Although there are far less low-cost carriers in the total amount of airlines mentioned in the Index Airline rapport, 40 to 125, the low-cost carriers in the considered dataset take up a significant amount of airlines. This might be due to the high use of low budget airlines such as Ryanair, which is the second most frequent airline in the dataset.

Table 26: Frequency of categories of airline carriers in the unlinked-flight dataset.

	AMOUNT OF UNIQUE AIRLINES	AMOUNT FLIGHTS
NORMAL AIRLINES	129	7.824
LOW-COST AIRLINES	71	998
MISSING AIRLINES	15	769

Figure 18 represents the distribution of the rank, as well as the efficiency points of the regular airlines. A higher rank corresponds to higher efficiency, and the higher the efficiency point, the more efficient the airline is. The histogram of ranks exhibits high peaks in the second half of the histogram, indicating that the dataset includes lower-ranked airlines. The efficiency points yield the same kind of conclusion with its peak between 50 and 60 efficiency points. For comparison, the highest-ranked airline TUI Airways has an efficiency point of 79,2. On average the efficiency point is 55,15 and the average ranking is 67,61.

The frequency of efficiency classes in Figure 19 confirms these findings by showing that the lower classes D and E are the most common ones for the regular airlines. This is also influenced by the extensive use of certain low-ranked airlines. With a total of 2.016 flights, Brussels Airlines is the most popular airline for Ghent University employees, while only having an efficiency of 50,5 points and rank 84 in the index ranking.

The low-cost airlines do provide somewhat better results, with more carriers in classes B and C. However, it is important to remember that the result for these low-cost airlines was not meant to be compared to the normal Airline Index.

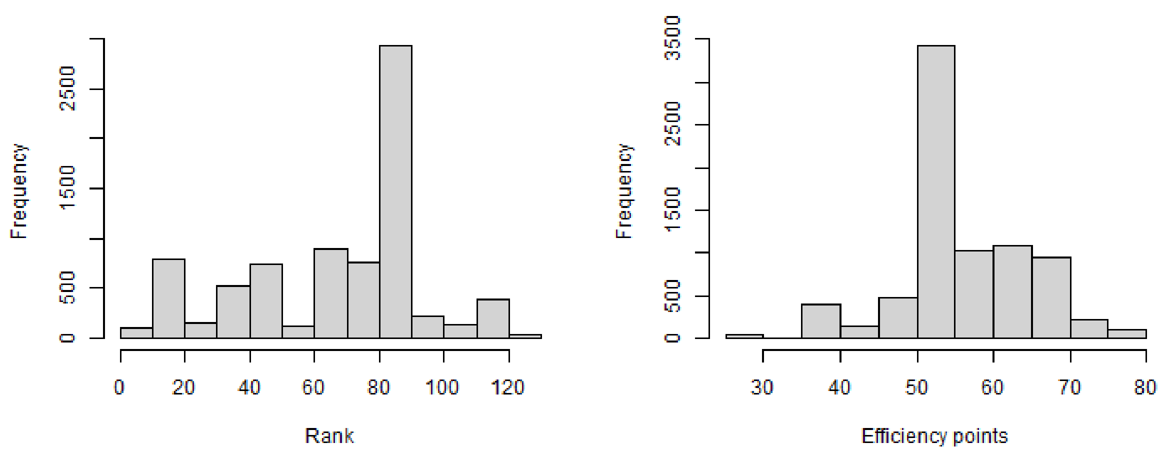

Figure 18: Distribution of the ranks (left) and efficiency points (right) of the airlines taken by Ghent University employees.

Consequently, these results do not shed a positive light on the overall carbon efficiency of the airlines used by Ghent University between July 2018 and December 2019. It is, however, necessary to be realistic as it might not always be possible to take an alternative airline. Brussels Airport, the most used departure point in our dataset, would need to have a different airline available. This might not always be the case, as it is very well possible that more carbon-efficient airlines do not fly frequently enough from that airport to the desired destination. The literature section showed that academics agendas are often overcrowded with responsibilities and therefore strict demands on flights are imposed.

As the most popular carrier Brussels Airlines is the largest Belgian airline, one could suspect a wide set of destination options for this airline from Brussels Airport, while other options might be more limited or more expensive (Brussels Airlines, n.d.). However, especially the use of lower-cost carriers still raises some questions and it might interesting to investigate the possibility to more often promote airlines with a lower carbon footprint, to reduce the use of airlines with a high carbon footprint, or to reduce flights with low-cost carriers that enjoy ambiguous subsidy policies.

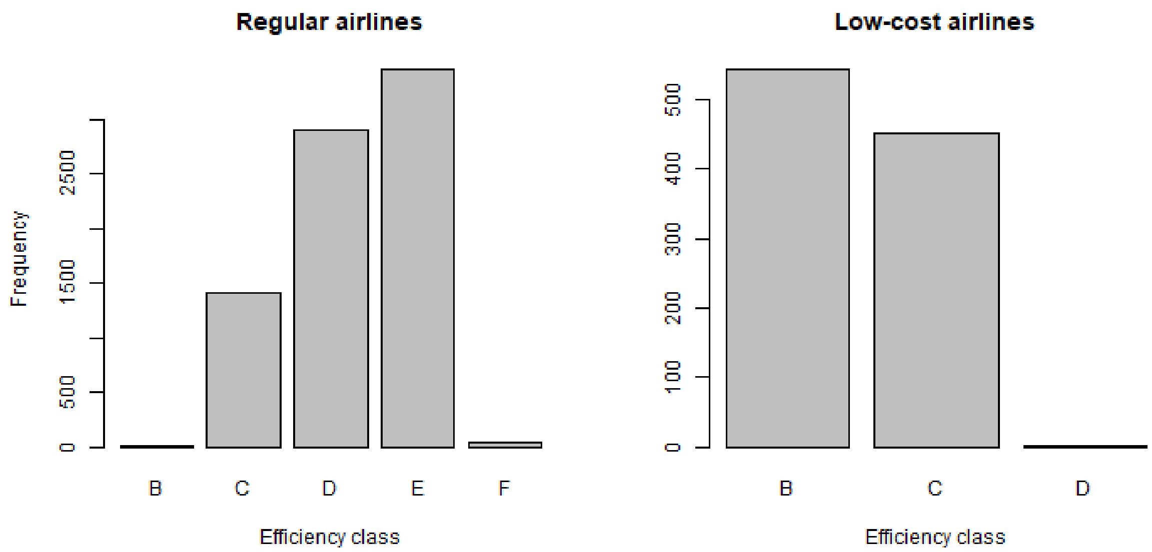

Figure 19: Distributions of the regular (left) and low-cost (right) airlines taken by Ghent University employees.

4.7. Frequent flyers

Ethical questions have been raised on frequent flying or ‘binge flying’, both in literature as well as in the broader public debate (Burns & Bibbings, 2009; Deane, 1988; J. E. S. Higham et al., 2014; Kugel, 2020; Urry et al., 2016; Walawalkar, 2019). At the individual level, air travel is one of the largest contributors to one’s carbon footprint. Avoiding a flight is therefore far more effective than the commonly promoted methods for reducing CO_2-emissions, such as recycling (Wynes & Nicholas, 2017). As one flight already has a significant effect on the overall impact of one person, special attention is given to individuals that fly multiple times per year.

Articles in public press and research claim that frequent flying is a privilege and that the norm for unlimited flying needs to be questioned as it is not maintainable. Consequently, analysing the amount and characteristics of frequent flyers at Ghent University, based on the provided air travel data, can be interesting both from an ethical and a policy point of view. After all, there already are a few precedents to discourage frequent flying at Ghent University, but there is no universal policy. For example, the Faculty of Engineering and Architecture recently implemented an additional rule for their mobility funds, where funding is limited to one conference per applicant every two years (Ghent University, 2019b).

An initial characterisation of these frequent flyers is given in Figure 20, where the histograms of the number of trips by job group are given, split by year (2018 and 2019). Separating by year allows us to verify that the shape of the distribution does not significantly change by the considered period, only the scale.

The different limits of the x-axes for the subplots displayed in Figure 20 show that the maximum values of the histograms are significantly different. The histogram of the trips belonging to members of the professorial staff exhibits a long tail, while both the predoctoral and postdoctoral fellows have some members that performed 3-4 trips. The majority of the frequent flyers limited themselves to two trips by plane during the considered period. In contrast, a non-negligible number of frequent flyers in the professorial staff fly up to 10 times per year.

To further illustrate this behaviour, a detail of the distributions of the professorial staff members in given in Figure 21. While the extreme values of 31 trips in 2019 and 16 trips in 2018 can be attributed to one individual and thus be considered outliers in the current histogram, the difference in behaviour between individuals of the professorial staff and other groups at Ghent University should be taken into account for future policy recommendations

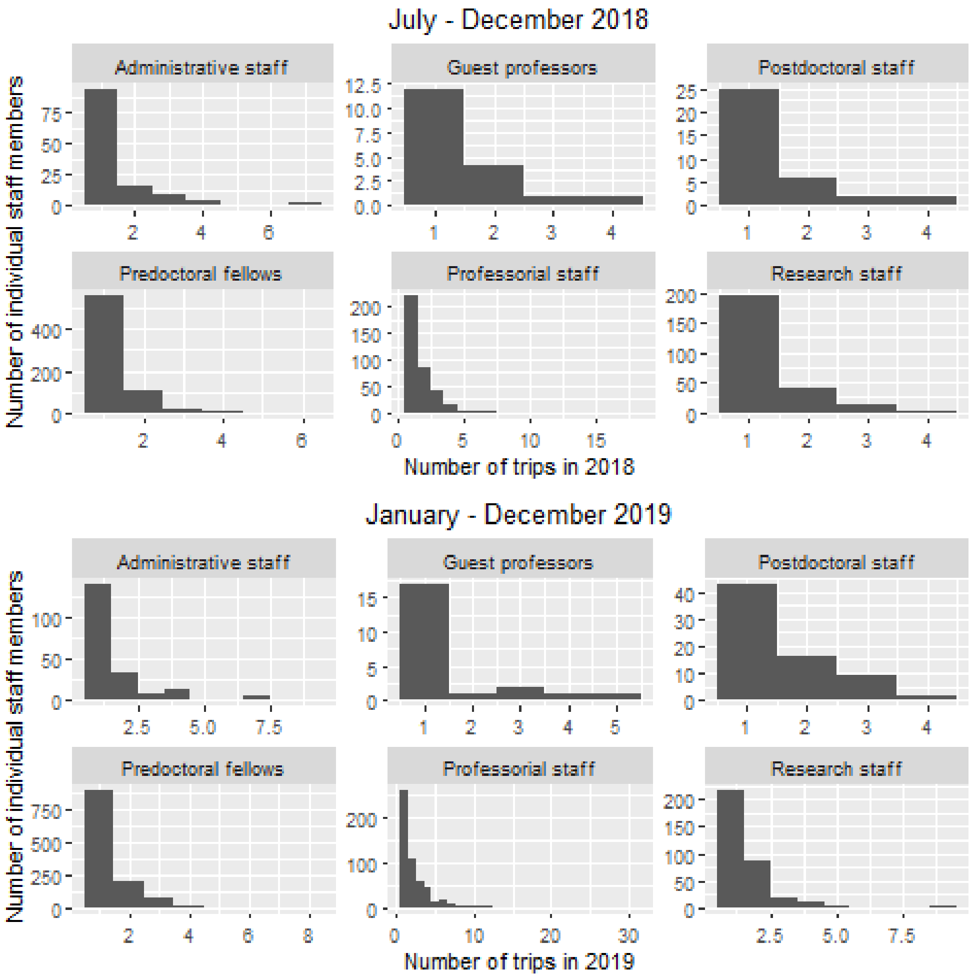

Figure 20: Histograms of the number of trips by staff members of different job categories, split by year (2018, 2019).

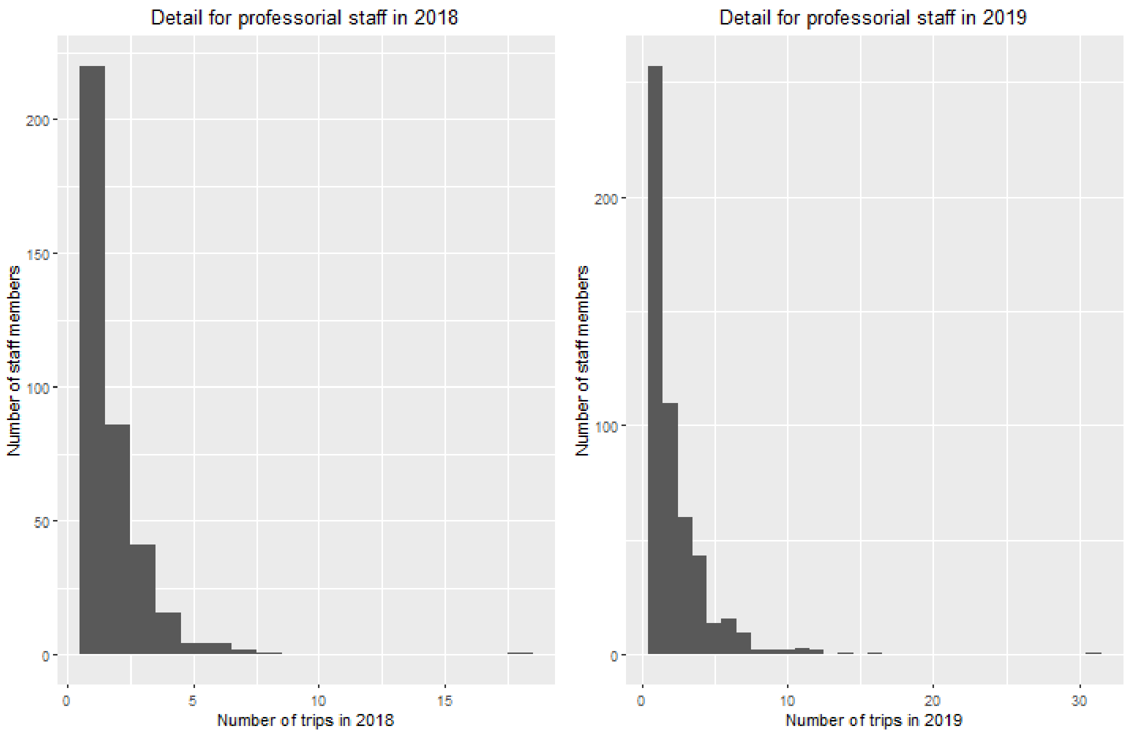

Figure 21: Histograms of the number of trips by individual members of the professorial staff, split by year (2018, 2019).

However, it is not sufficient to merely consider the job groups of the individuals that frequently fly, the affiliations of these staff members should also be taken into consideration to account for faculty-bound regulations or culture. The histograms for staff members of each faculty and the administration is given in Figure 22 on the next page.

From these histograms, it is clear that some faculties have a larger portion of the frequent flyers than others: the three beta faculties (Faculty of Engineering and Architecture, *tw*, the Faculty of Bioscience Engineering, *la*, and the Faculty of Sciences, *we*) all exhibit longer tails with a significant number of employees flying twice or more.

An additional question now arises: what fraction of CO_2 emissions and the flown kilometres from Ghent University can be attributed to these frequent flyers? For the rest of this subsection, 'Frequent flyers' are defined as individuals that perform at least 3 trips per year.

Table 27 answers these question and can be interpreted as follows: in 2019, 346 employees of Ghent University made more than two trips via plane. These 346 employees were responsible for approximately 30% of all flight-related CO_2 emissions, and approximately 28% of the flown kilometres. As 2.330 individuals have made one or more flights in 2019, these 346 employees represent 14,8% of the employees travelling via plane in 2019. In other words, a small fraction of the university employees is responsible for a rather large amount of the impact via 'binge flying'.

Table 27: Properties of the frequent flyers at Ghent University, split by year (2018, 2019).

	2018	2019
Total number of Frequent Flyers (FF)	136	346
% of travelling employees that are FF	9,06%	14,8%
% total emissions from FF	20,9%	30,2%
% total kilometres from FF	18,4%	28,4%

Policies that try to minimize frequent flying among the employees seem promising in terms of emission-reduction. Therefore this thesis argues that focussing on frequent flyers should be one of the main priorities in the following policy measures. Examples of policy measures are a frequent flyer tax, limiting the number of trips per year per employee or department, etc.

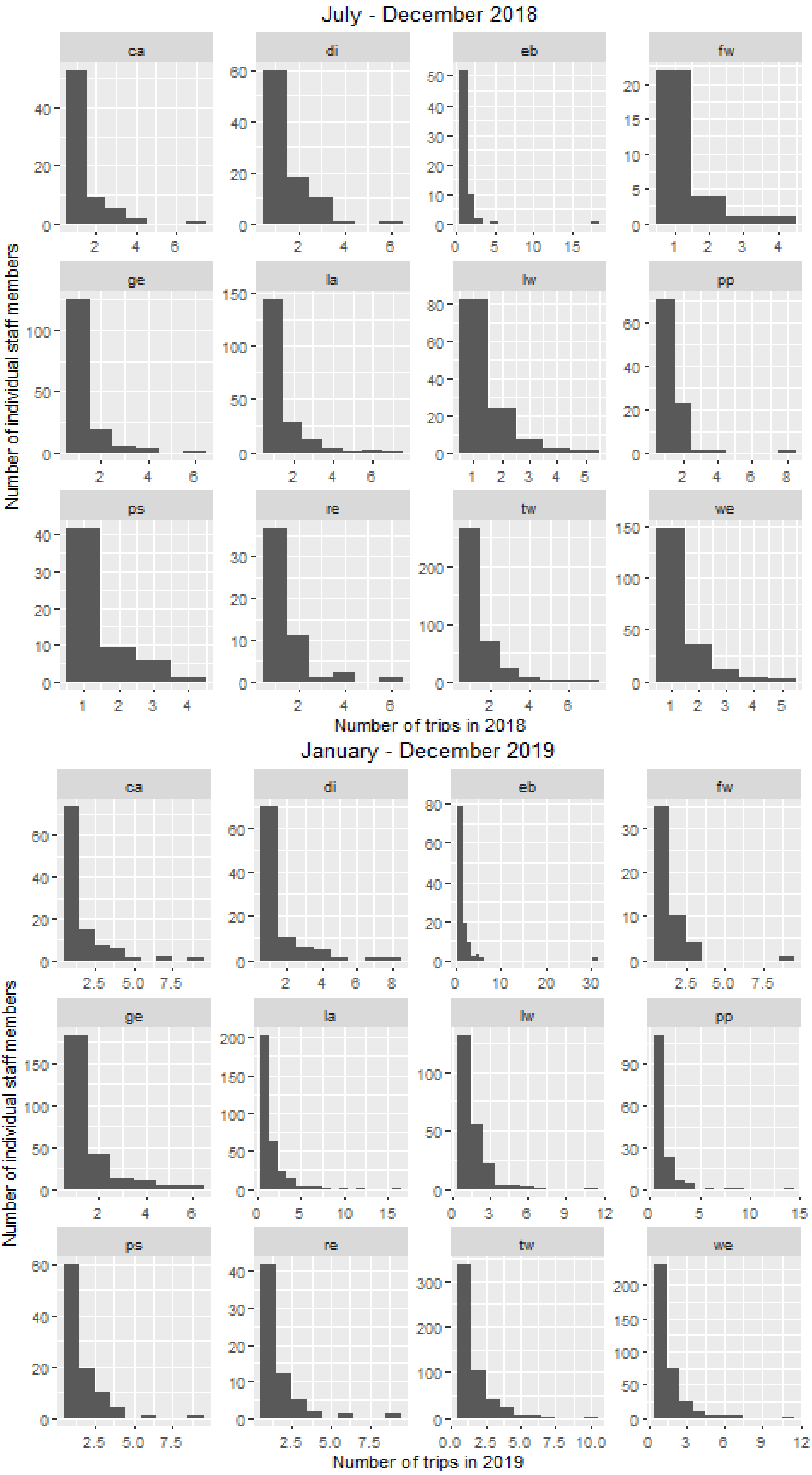

Figure 22: Histograms of the number of trips by staff members of faculties/administration, split by year (2018,2019).

Chapter 5

Financial compensation

The ticket price per individual flight is included in the dataset obtained via Uniglobe. This allows an analysis of the financial aspects of academic flying and more importantly an evaluation of the current CO_2 compensation.

5.1. Air travel funding at Ghent University

Employees at Ghent University have a wide variety of options to fund their international trips. This does not imply that every employee has access to finances for their trip, only that analysing the origin of these funds is difficult. After all, this origin is not included in the reporting. This complicates evaluating the regulations the trip falls under. A non-exhaustive list of finance options is given below (Ghent University, n.d. a-i).

First of all, a researcher can use the received funding for a certain scientific, e.g. European projects/funds, projects funded by industry, etc. Secondly, academics paid by other funds, such as the FWO, can apply there for refunding their trip. Those two funding options do not fall under in-house regulations. However, FWO has recently imposed a sustainable travel policy on his researchers as well (FWO, 2019). Thirdly, researchers can use the funding of the department. Lastly, Ghent University also provides resources for incoming and outgoing mobility. This funding is distributed among the faculties and they then create the faculty-specific regulation. An example is the faculty mobility and sabbatical fund. The fund aims to provide funding for the mobility of younger researchers, more specifically for conferences, on the one hand, and to provide travel costs for professorial staff that wants to engage in a sabbatical, on the other hand. The expectation of the regulations connected to the faculty mobility and sabbatical fund learns that few regulations are connected to sustainable travelling. However, almost every faculty demands active engagement, e.g. a presentation or moderator role during the conference, before allowing funding. Some faculties limit the number of times an employee can apply, e.g. the Faculty of Medicine and Health Sciences, and the Faculty of Engineering and Architecture. Other faculties limit their funding to economy class, for air travel as well as by train. Examples are the Faculty of Law and Criminology, and the Faculty of Medicine and Health Sciences.

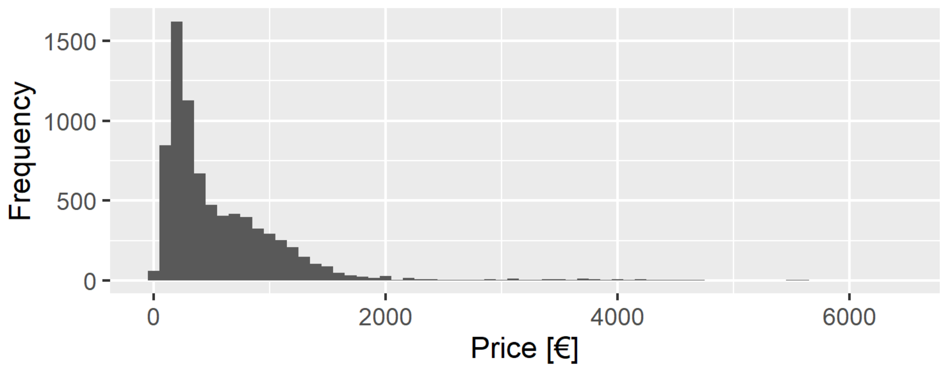

Figure 23: Distribution of the price per business trip.

In total, the university spent €4.594.706 on air travel. The real number might be higher considering that not every fund is controlled by the university. On average, an employee paid €573,18 for one trip, while the median is €379,61. However, there are large differences between the prices, given the standard deviation of 565,71, further confirmed by the long-tailed distribution displayed above. The highest price was €6.355,77 and 158 flights were over €2.000. In other words, the amount the university currently pays for its air travel might be considered rather large. Differences in the medium price per trip paid by the faculties and between employee categories can be observed, but they are limited to certain groups or faculties, as can be observed in the tables below, as well as via the Kruskal-Wallis test together with the Pairwise Wilcox Test.

Table 28: Mean, median and standard deviation of the price (€) per business trip, by faculty.

FACULTY/MANAGEMENT	MEAN	MEDIAN	STANDARD DEVIATION
CA	529	328	468
DI	491	288	450
EB	583	353	664
FW	436	295	356
GE	618	336	718
LA	721	505	777
LW	450	295	449
PP	478	315	433
PS	465	287	473
RE	622	334	889
TW	560	390	487
WE	534	357	498

```
        Kruskal-Wallis rank sum test

data:  df3$Price and df3$Facultymanagement
Kruskal-Wallis chi-squared = 170.06, df = 12, p-value < 2.2e-16


         Pairwise comparisons using Wilcoxon rank sum test

  data:  df4$Price and df4$Facultymanagement

     ca      di      eb      fw      ge      la      lw      pp      ps      re      tw
  di 1.00000 -       -       -       -       -       -       -       -       -       -
  eb 1.00000 1.00000 -       -       -       -       -       -       -       -       -
  fw 1.00000 1.00000 0.73948 -       -       -       -       -       -       -       -
  ge 1.00000 1.00000 1.00000 1.00000 -       -       -       -       -       -       -
  la 0.01596 1.5e-05 0.08285 0.00102 0.00674 -       -       -       -       -       -
  lw 0.16761 1.00000 0.00997 1.00000 0.00287 4.4e-14 -       -       -       -       -
  pp 1.00000 1.00000 0.75143 1.00000 0.81744 3.3e-07 1.00000 -       -       -       -
  ps 1.00000 1.00000 0.18292 1.00000 0.28866 5.7e-07 1.00000 1.00000 -       -       -
  re 1.00000 1.00000 1.00000 1.00000 1.00000 0.03999 1.00000 1.00000 1.00000 -       -
  tw 1.00000 0.03999 1.00000 0.10407 1.00000 0.02205 4.3e-08 0.00569 0.00181 1.00000 -
  we 1.00000 1.00000 1.00000 1.00000 1.00000 8.7e-05 0.00093 0.68366 0.17110 1.00000 1.00000
```

The Faculty of Bioscience Engineering has a significant difference in the median price with every other faculty at the 5% significance level. The Faculty of Engineering and Architecture has a significant difference with some of the other faculties. These two were also the faculties that showed a significant higher median for the flown distances in Section 4.1. and the faculties who more often flew non-economy. The Faculty of Arts and Philosophy has several significant differences with other faculties, although no reason for this deviation is proposed.

For the employee categories, there are less significant differences at the 5% significance level. Only the group of professorial staff had a significantly higher difference, despite the guest professors having a very high median and mean value for their ticket prices, as displayed in Table 29.

Table 29*:* Mean, median and standard deviation of the price (€) per business trip, by job category.

JOB CATEGORY	MEAN	MEDIAN	STANDARD DEVIATION
ASSISTING ACADEMIC STAFF	486	327	391
PROFESSORIAL STAFF	704	401	799
GUEST PROFESSOR	902	424	1.212
ADMINISTRATIVE AND TECHNICAL STAFF	512	331	497

```
        Kruskal-Wallis rank sum test

data:  df3$Price and df3$Job.Category
Kruskal-Wallis chi-squared = 128.69, df = 6, p-value < 2.2e-16


        Pairwise comparisons using Wilcoxon rank sum test with continuity correction

data:  df_rel$Price and df_rel$Job.Category

          AAP     ATP     GuestProf
ATP       1.00000 -       -
GuestProf 0.38831 0.43367 -
ZAP       1.8e-14 0.00029 1.00000

P value adjustment method: holm
```

5.2. Current CO_2 compensation mechanism

This is analysis without the newly introduced mandatory CO_2 compensation of €10 plus 21% VAT, making it €12,1 per ton emitted CO_2. A first evaluation of this compensation has already been made by Govaert. She argued higher compensation is more appropriate if the university wants to take its climate ambitions seriously. With her survey, Govaert showed that the majority of the employees even supports an increase. 86% of respondents were willing to pay more than the current amount.

Govaert noted that the reasoning behind the low price-setting is to lower the barrier for voluntary compensations. Seeing as the compensations at Ghent University are mandatory, this argument does not hold. The following discussion will introduce additional arguments as to why Ghent University should increase its compensation and could even benefit from it.

First of all, the compensation appears to only be a small fraction of the total sum paid by the employee for their trip. Even for longer trips, the compensation remains small compared to the full ticket price. This is shown in Table 30, which gives the average percentage the compensation represents within the whole ticket price, for short flights and long flights. The question arises whether an amount €7,69, which is the absolute mean for short flights, would encourage employees to fly less. In total, the employees of Ghent university paid €169.754 for their CO_2 compensation.

Table 30: Mean absolute and percentual compensation per flight.

	Mean abs. compensation [€]	Mean perc. compensation [%]
All flights	21,99	3,83
Flights < 10.000 km	7,69	3,13
Flights > 10.000 km	47,42	5,01

Secondly, by increasing the compensation, the university could increase the funding for CO_2 compensation projects or even consider using the finances for its own sustainability projects (Burrick, 2018; Govaert, 2019). Ghent University could additionally consider diversifying the compensation depending on distance or depending on the flight frequency (= a frequent flyer tax).

5.3. Simulations of different compensation schemes

As a first simulation, different fixed compensations than the current €12,1 per emitted ton CO2 were considered with the current dataset. Table 31 gives the results of these simulations. The fixed amounts were based on the different amounts Govaert questioned in her survey: €20, €66 and €150. Govaert herself based these numbers on scientific work on CO_2 compensations and existing examples of monetary equivalences of one ton emissions. All of these fixed amounts of compensation had a surprisingly large support base among the participants:

- 27% preferred €20;
- 39% preferred €66;
- 20% preferred €150.

These results show that a significant sum can be obtained by introducing a higher fixed compensation, which also corresponds to a higher fraction of the total amount paid per trip.

Table 31: Simulations of additional fixed compensations per ton emitted CO_2.

	€20 / ton CO_2	€66 / ton CO_2	€150 / ton CO_2
Total compensation	280.585	925.930	2.104.388
Abs. mean compensation	36,34	119,93	272,59
Perc. mean compensation	6,08	16,85	30,43
Perc. Mean compensation (<10.000 km)	7,97	14,29	27,04
Perc. mean compensation (>10.000 km)	9,36	21,30	38,66

The second type of compensation mechanism is one that grows after a certain threshold of emissions is reached. Table 32 represents compensations that grow exponentially after 1 ton CO_2 is reached, meaning that the original baseline compensation €12,1 increases. For example, the first ton CO_2 is compensated at €12,1. All emissions higher than 1 ton CO_2 are subsequently compensated at €12.1^{α}, with α the so-called growth factor. In other words, employees that fly further pay considerably more.

Table 32*:* Simulations of growing compensations per ton emitted CO_2.

GROWTH FACTOR (α)	1,1	1,2	1,5	2
TOTAL COMPENSATION	236.898	336.370	1.031.875	7.544.888
ABS. MEAN COMPENSATION	30,68	43,57	133,66	977,31
PERC. MEAN COMPENSATION	4,69	5,96	11,9	28,78
PERC. COMPENSATION (<10.000 KM)	3,3	3,5	4,48	7,65
PERC. COMPENSATION (>10.000 KM)	7,17	10,04	28,78	66,39

However, this compensation is not deemed the most relevant, as the majority of flights are short. They therefore keep paying a relatively low compensation.

Finally, Table 33 gives the effect the introduction of a frequent flyer tax has: each extra flight per year per employee is additionally taxed. As 20% of the individual flights could not be attributed to a staff member, this simulation is less complete. The analyses were split between 2018 and 2019. The compensation is constructed in the following way: If an employee flies more than once per year:

- Their compensation for the second trip is multiplied by 1,2
- Their compensation for the third trip is multiplied by 1,4
- Their compensation for the fourth trip is multiplied by 1.6
- Etc.

With a total of €1.293.822, this compensation yields more funding for compensation projects than increasing the fixed amount compensation to €66 per ton emissions. [10] On average, employees pay a lower amount of absolute and relative amount for their compensation, indicating the shift to the frequent flyers. Therefore, taxing frequent flyers might be an interesting tool for policymakers.

Table 33: Simulations of frequent flyer compensations.

	2018	2019
TOTAL COMPENSATION	153.266	1.140.556
ABSOLUTE MEAN COMPENSATION	56,1	229,03
PERCENTUAL COMPENSATION	4,55	6,33

[10] The large difference between 2018 and 2019 can partly be attributed to the fact that 2018 only contains data from July until December. Hence, a lower amount of frequent flyers will be present, which clearly leads to a lower total compensation.

Chapter 6

Regression model

To determine the effect of multiple explanatory variables on the overall travel emissions of Ghent University, the relation between the dependent variable *Emissions* and several independent parameters is estimated in an Ordinary Least-Squares (OLS) regression model. OLS determines the values of the impact of the independent parameters based on the least-squares principle, minimising the sum of the squares of the differences between the observed dependent variable in the air travel dataset and the predicted coefficients of the independent variables (Gujarati, 2009). Multiple models were analysed for this section but the three discussed models best represent the overall findings.

Determining a suitable set of explanatory variables for the regression model is not an easy task, as the dataset contains a wide variety of information, while other non-flight-related variables could simultaneously have an important influence as well. This section of the thesis, therefore, describes an alternative approach that will result in a regression model. Research traditionally starts with a research question, from which relevant variables and an associated model are selected, after which the researcher looks for a suitable dataset to construct the necessary variables. In contrast, as stated in the introduction, this research starts from a research question ("How can Ghent University reduce its emissions output from airplane travel?") combined with a provided dataset. Secondly, based on the research question and available data, a suitable model has to be extracted and the relevant variables for this model need to either be identified or constructed.

In this section, the variables to consider are primarily based on the univariate and bivariate analyses of various properties performed in the previous sections. Variables that seemed to influence the emissions of certain groups were included. Secondly, based on literature, additional variables were constructed with the intention to add them to the model. The research was therefore limited by the available data, both those included in the dataset and those available from public or policy documents from Ghent University. The OLS-regression was constructed at departmental level, which leads to a 1-level OLS. Constructing an OLS on the individual level of the employee would reveal the parameters that impact an individual's choice to fly, which is not the research goal.

In contrast, this research tries to understand what the university, the faculties and the departments can do to reduce their emissions. Subsequently, the Y-value in the regression models is, of course, CO_2 emissions, which is standardised by the size of the staff. Furthermore, only the departments affiliated to the faculties are considered, not the management.

The explanatory variables included in the model are as follows:

1) The median ticket price (*MedianTicketPrice*); This parameter serves as an addition of Chapter 5 on the influence of ticket pricing or more specifically adding extra compensation. The effect is not a priori presumed.
2) The percentage of the staff members in the department that can be considered frequent flyers (*Frequent Flyer Percentage, 'FFP')*. A frequent flyer is defined in this research as someone flying more than 3 trips over the considered period. This way, the effect of 'binge flying' within the department on the aggregated emissions of the department towards the rest of the parameters is taken into account. Trips are defined as complete inbound and return flights from the linked-flight dataset. The percentage amount of frequent flyers is expected to have a positive influence.
3) The ratio of Assisting Academic Staff in the number of Professorial Staff members (*AAPperZAP*). The staff composition is taken into account in the constructed models, given the observed differences among staff members of different job functions, not only in length and amount of the trips but also because of differences in-seat classes. This variable is added because of the perceived differences in the flying behaviour in Section 4.1.3.
4) Gender ratio of employees in the department (*PercWomen*); This parameter was added to control for the perceived differences in Section 4.1.4.
5) The percentage of guest professors is explicitly taken into account (*FractionGuest*). This is the ratio of guest professors on the total number of staff members. These are only those guest professors that are officially linked to a department. There may be other academic guest speakers, which could however not be detected from the data provided by DPO. As guest professors are a form of internationalisation and are part of the staff composition, they are interesting to include. Guest professors were briefly discussed in Section 4.1.3. and are expected to have a positive influence on the sum of emissions.

These parameters could all be extracted from the provided dataset(s), whereas the following three variables were additionally constructed from various sources at Ghent University.

1) *PercP* is an indicator for the so-called P-Points a department receives from the faculty, relative to the total staff size. P-Points are a measure for the financial means a department receives from the faculty and university to fund its staff members, and can, therefore, be considered a baseline. Therefore, a significant deviation from this baseline funding indicates the department uses other financial resources (such as project funds) to finance its staff hiring. The higher the amount of baseline funding, the smaller the contribution of competitive funding. This might indicate a less competitive department, possibly leading to a lower amount of emissions.
2) *PercInt* is an additional measure included based on the P-Points. In 2013 – 2014, several educational programs and research groups transferred from colleges to the universities. Over the past years, these research groups that originated from colleges have been integrated into existing research groups. However, it is possible that the research culture in these groups, such as the internationalisation context, differs from groups with a long-standing tradition in research. As such, the subset of the total P Points that is reserved for the integrated research groups is also taken as a relevant parameter to describe observed differences between departments. Integrated departments are expected
3) *AvgA1* is the final constructed variable that is included from an external data source. This gives the total amount of A1 publications divided by the number of academic staff members of that department, and can therefore be considered a proxy for the performance and research output. It's the average number of A1-publications per academic staff member per department. This variable, in other words, controls in the regression -model if there is a direct link between performance and academic flying, a heavenly debated topic in the literature.

Further explanation of the construction of these variables can be found in Appendix VI. Appendix VII provides for each used variable the inputs per department, in other words, the OLS-dataset.

For brevity, the discussion in this section is limited to the following three relevant regression models:

1) The first model includes all the described variables;
2) The second model only includes those variables that were significant in the first model;
3) The third model introduces dummy variables for each of the eleven faculties and uses the explanatory variables present in the second model.

6.1. Model 1

The initial model contains all the previously mentioned variables. Only three variables are significant with a significance level of 5 %, *median ticket price*, the *frequent flyers percentage* and the *fraction of guest professors*. Frequent Flyer Percentage and Fraction of Guest professors have the expected positive effect.

The Median Ticket price has a very small positive effect. Of the non-significant parameters, the percentage of women in the department has a positive effect on the emissions per staff member of the department. However, this is not consistent with previous findings from literature and the empirical findings presented in previous sections, which show that women on average fly shorter trips, which would correspond with lower emissions. The observed phenomenon at the individual level could differ from the effect at the aggregated level. More gender-equal departments could provide more equal internationalisation opportunities and equal academic mobility, which would lead to more academic mobility and therefore more emissions, as the result of this first model suggests.

The ratio AAP/ZAP has a very small negative effect, emphasizing the fact that professorial staff members on average fly longer distances and more frequent, but not enough for the staff composition to have a significant effect (at the 5 %-significance level) compared to the other included variables. Furthermore, none of the newly constructed parameters has a significant effect. The fact that some of these parameters are not significant, P-value being higher than 0.05, could have interesting consequences. For example, the regression model suggests that the research output of the department does not have a significant impact on its CO_2 emissions. Consequently, this raises the question of whether the research performance of a department would decline if it would be forced to lower its emissions. This suggests that the university could reduce the per employee emissions at the department without having a significant impact on its research output. The adjusted R^2 of this first model is 0.5276.

```
Call:
lm(formula = PercEmissions ~ MedianTicketPrice + FFP + PercWomen +
    AAPperZAP + FractionGuest + PercP +  AvgAl + PercInt, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.69565 -0.19554 -0.01742  0.13694  1.63715

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)      -0.2198205  0.2476216  -0.888  0.37756
MedianTicketPrice  0.0006337  0.0002169   2.921  0.00463 **
FFP              30.1157057  3.6373865   8.279 3.83e-12 ***
PercWomen         0.3525195  0.2426663   1.453  0.15054
AAPperZAP        -0.0041817  0.0121360  -0.345  0.73139
FractionGuest     1.9795490  0.9429021   2.099  0.03919 *
PercP            -0.0500379  0.2658733  -0.188  0.85123
AvgAl            -0.0562228  0.0461496  -1.218  0.22699
PercInt           0.0933118  0.0717462   1.301  0.19744
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3085 on 74 degrees of freedom
Multiple R-squared:  0.5737,    Adjusted R-squared:  0.5276
F-statistic: 12.45 on 8 and 74 DF,  p-value: 3.938e-11
```

6.2. Model 2

The next regression model only considers the significant parameters from the first model. While the effect of *MedianTicketPrice* might be significant, it is also extremely small with a coefficient of 0.0006. This means that an additional price increase of 1 euro to the median ticket price, will lead to an increase of 0,0006 tons normalized total amount of emissions of the departments. The percentage amount of guest professors, however, has a larger effect, highlighting that this kind of internationalisation does play a role in the emissions per staff member. An increase of 1 percentage point of the fraction guest professors, will lead to an increase of 0,02 tons emissions. Finally, the percentage of frequent flyers within a department has a large significant effect of 29,414. If the frequent flyers percentage increases with 1 percentage point, this will lead to an increase of 0,29 tons emissions. This suggests again that having a policy on frequent flyers might be interesting to consider. While the effect of an increase in percentage points for an additional guest professor or a frequent flyer might seem small, it is necessary to bear in mind following two remarks. First, the size of a department is often limited: 30% of the departments have a staff size smaller than 100, 70% smaller than 200. As such, the addition of one guest professor or frequent flyer immediately has an influence. Secondly, the variable to be modelled is the total emissions per staff member. As such, one has to multiply by the staff size when transforming this per capita emissions to the total emissions per department to obtain a reliable estimation.

These results are however in line with the results for the parameters in model 1. With a value of 0.5332, the adjusted R^2 is larger than the previous model. This means that this model is a slightly better fit than model 1 and that omitting the variables creates a more representative model.

```
Call:
lm(formula = PercEmissions ~ MedianTicketPrice + FractionGuest +
    FFP, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-0.6320 -0.1331 -0.0146  0.1159  1.7515

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)      -0.1164077  0.0905520  -1.286   0.2024
MedianTicketPrice  0.0005666  0.0001990   2.848   0.0056 **
FractionGuest      2.0286247  0.8668565   2.340   0.0218 *
FFP               29.4143855  3.5622550   8.257 2.75e-12 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3067 on 79 degrees of freedom
Multiple R-squared:  0.5503,	Adjusted R-squared:  0.5332
F-statistic: 32.22 on 3 and 79 DF,  p-value: 1.047e-13
```

6.3. Model 3

The final model now presents a regression model with the same parameters as the previous model, supplemented with 11 dummy variables, one for each of the 11 faculties. The empirical findings presented in previous sections show that while the faculties display similar distributions for their emissions, some of the faculties do exhibit lower air travel mobility. Additionally, this least-squares dummy variable model aims to capture the expected a priori similarity between departments of the same faculty, as these are bound by the same faculty-wide rules on funding e.g. conferences and sabbaticals.

The result of this third regression model illustrates that these differences only count for some of the faculties. Only the dummy variable corresponding to the Faculty of Economics and Business Administration has a significant effect at 5 %-significance level. Additionally, the dummy variables belonging to different faculties differ in sign, demonstrating the opposite effect they can have from a certain baseline emission per staff member.

```
Call:
lm(formula = PercEmissions ~ MedianTicketPrice + FractionGuest +
    FFP + Faculty, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.70302 -0.14720 -0.00241  0.09958  1.38705

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)       -0.0546973  0.1194732  -0.458  0.64852
MedianTicketPrice  0.0005363  0.0002091   2.566  0.01248 *
FractionGuest      0.5903473  1.0658610   0.554  0.58146
FFP               27.5909031  3.6374485   7.585 1.15e-10 ***
Facultyeb          0.5228246  0.1963939   2.662  0.00965 **
Facultyfw          0.0693680  0.1973581   0.351  0.72630
Facultyge         -0.0682375  0.1368357  -0.499  0.61959
Facultyla          0.1631113  0.1489127   1.095  0.27717
Facultylw         -0.0370015  0.1486661  -0.249  0.80419
Facultypp          0.0320273  0.1367590   0.234  0.81553
Facultyps          0.1409580  0.1952512   0.722  0.47278
Facultyre         -0.0428720  0.1947935  -0.220  0.82645
Facultytw         -0.0684743  0.1317100  -0.520  0.60481
Facultywe         -0.0364918  0.1249116  -0.292  0.77106
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.295 on 69 degrees of freedom
Multiple R-squared:  0.6365,    Adjusted R-squared:  0.5681
F-statistic: 9.295 on 13 and 69 DF,  p-value: 1.019e-10
```

The previously significant variable *Fraction Guest Professors* now becomes non-significant, which might mean that the number of guest professors is faculty-dependent and that the policy of the faculty has a more significant effect than the number of guest professors affiliated with a certain department. Because of the shift to non-significance of *Fraction Guest Professors*, two regression models with interaction effects between *Fraction Guest Professors* and the dummy variables for the faculties are analysed in Appendix VIII. The adjusted R^2 is again larger than the adjusted R^2 of the previous model indicating a better fit of the model.

However, the fact that nearly none of the faculties are significant at the 5-% significant level is not in line with the previous findings in Chapter 4. There, the Faculty of Engineering and Architecture and the Faculty of Bioscience Engineering showed a significant difference compared to the other faculties. The fact that all dummy-variable faculties but one appear to be non-significant, might be reason enough to choose model 2 as the better model. After all, the improvement of the adjusted R^2 is not large. Appendix IX subsequently investigates the Gauss-Markov assumptions for the chosen model, i.e. the second model.

Table 34: Summarising table of the discussed models, their variables and adjusted R^2 value.

	INCLUDED VARIABLES	ADJUSTED R^2 VALUE
MODEL 1	MedianTicketPrice, FFP, PercWomen, AAPperZAP, FractionGuest, AvgA1, PercP, PercInt	0,5276
MODEL 2	MedianTicketPrice, FractionGuest, FFP	0,5332
MODEL 3	MedianTicketPrice, FractionGuest, FFP, 11 dummy variables for the 11 faculties	0,5681

Chapter 7

Policy recommendations

This chapter translates the findings of the previous chapters into policy recommendations. Not all of the previous findings are relevant or unambiguous enough to create clear policies. These findings might, however, be useful for future research. This part is divided into three types of recommendations. First of all, this chapter will consider data management improvements. Secondly, based on the univariate and bivariate analyses as well as the regression model, this chapter will recommend policies or extensions of existing policies to reduce the overall flying emissions of Ghent University. The third part of this chapter will look into the factors that counterintuitively appear to have a small or non-significant effect on the overall emissions, which can be used to ease concerns that might arise from reduced air travel at Ghent University.

7.1. Data management

Travel data collection and monitoring is an essential part of the sustainable mobility policy at academic institutions. After all, it offers a first step in monitoring total CO_2 emissions, while also providing an evaluation framework for policy measures. Apart from the presented case-study of Ghent University, the universities of Gothenburg, TU Delft, Leiden, Brussels and Leuven have similarly switched to a mandatory framework contract, as well as to centralise and research their data.

In its roadmap for reducing air travel emissions for institutions, the Tyndall Institute even calls the data management a necessary precondition (Tyndall Center, 2015, p. 16). They state that reporting should be simple to reduce the administrative burden. The better the reporting, the better the monitoring. Good reporting also creates possibilities, e.g. providing a faculty, department or even an individual employee with their air travel carbon footprint to create awareness. Wynes and Donner state that providing university employees with detailed data on their air travel behaviour and the averages of their peers, can be an effective tool for behavioural change and therefore a useful policy instrument (Wynes & Donner, 2018).

After processing and analysing the data for this study, several problems emerged. The format in which the data is currently supplied makes it impossible to do "simple" or detailed data analysis and therefore complicates further data-driven policy recommendations.

The start of data management and collection were an essential part of the first policy measures at Ghent University. This thesis argues the further optimisation of data management should be a priority for future policy measures. To achieve this, this work sets out a threefold recommendation for the data management focused on (i) the link between personnel data and travel data, (ii) the linking of flights belonging to the same business trip, and (iii) motivations for flying.

First, this thesis recommends storing the personnel-related information during the booking itself, so there is an unambiguous link between one staff member and each booking. This can be done by e.g. the unique personnel number of the staff member performing the booking, or the unique CAS-name.

This leads to a twofold advantage. First, this avoids a pre-processing step during the analysis where the personnel information has to be added to the dataset based on the traveller name, which is not necessarily identical in both datasets. Second, around 20% of the traveller names did not appear on Ghent University payroll but were still booked via the Ghent University system. As such, assigning the staff member requesting the booking to that flight allows to still assign that flight to a department, leading to a better assessment of the emission impact.

Second, based on the data cleaning and linking performed in this work, as well as the differences in analyses on the unlinked-flight and the linked-flight datasets, this thesis urges to include a new variable in the data reporting: *TripID*. This parameter would be identical for all flights that are booked for the same business trip, which would allow researchers to easily link these flights together. This would still retain the information of the individual flights such as the seat class and the airline, both still relevant for policy purposes.

Finally, this work suggests adding the motivation for each business trip to the dataset of bookings. While this is currently optional to add when booking a flight via Apollo, the platform Ghent University uses to book flights, it is not included in the current data reporting. However, it is suggested to limit this motivation to several predefined options, such as “conference”, “project meeting”, “sabbatical”, etc. This allows future policy research to obtain insight into the motivations behind business trips, allowing policymakers to adjust policy where needed.

7.2. Data-driven policy recommendations

Based on the findings from previous chapters, seven different policy recommendations are proposed in this work. The first five recommendations are made with confidence based on the findings combined with literature. The final two recommendations are suggested with caution, as findings in the literature are ambiguous.

The first recommendation concerns the short-haul flights. This thesis showed that the overwhelming majority of flights are short-distance, and therefore argues that focusing on the first peak of the histograms presented in Section 4.1 is a promising avenue to reduce emissions. The analyses of the destinations showed that most flights are European, so alternatives by trains are available. Additionally, employees appear to still fly to the prohibited green cities and the discouraged yellow cities.

In her thesis on CO_2 calculations, Govaert argues that long-distance flights should be the main focus, as the distance is the parameter with the largest carbon-footprint effect. This thesis does not refute this claim, as the effect of distance on the emissions is self-evident. This is also evident from the figures presented in section 4.1, where the second group of flights was concentrated between 10.000 and 20.000 km. However, policies that would reduce, prohibit or minimise short flights, e.g. expanding the green cities list, would not just hold a symbolic value but could have real emission-reducing impact.

The second recommendation concerns the frequent flyers at Ghent University. This thesis finds evidence of their enormous impact in multiple ways. First, frequent flyers disproportionally contribute to institutional emissions: only 346 frequent flyers were responsible for more than 30% of the total emissions in 2019. Secondly, the constructed regression model, which examined the factors influencing departmental level emissions, presented a strong significant effect of the percentage of frequent flyers in that department. In other words, the presence of frequent flyers in a department significantly influences its emissions.

Therefore, this thesis suggests policies that could diminish or discourage frequent flying. Examples are charging a higher CO_2 compensation fee per business trip, therefore giving a financial incentive for the department or the individual to minimise its flights. Another example is limiting funding to one conference per applicant over a certain time period. Some faculties already apply this for their Mobility Funds. However, this limitation is not universal at the university, and certainly not for every type of funding. As already noted in Chapter 5, there is a wide variety of financial funding and the analyses of frequent flyers showed that every faculty has frequent flyers. Even the Faculty of Engineering and Architecture, which already applies an analogous rule in their Faculty Mobility Funding, has numerous frequent flyers.

Consequently, this thesis rather pleads for a university-wide rule on limiting flights, if such a rule would be implemented. A third example of limiting frequent flyers is the carbon budgeting approach. Carbon budgeting limits the number of emissions over a certain time period for an individual or a certain group, e.g. a department, which could be used to reduce frequent flying (Bows-Larkin, 2015; J. Higham et al., 2016; Whitmarsh et al., 2011).

A third recommendation concerns the gender and diversity policies at Ghent University. Chapter 4.1 showed that there are differences between the travel behaviour of male and female employees. While these differences are not omnipresent in every faculty, nor does it appear at the 5%-level significance level in the regression model, they are still analogous to previous findings in studies on gender academic mobility. Furthermore, according to the Kruskal-Wallis test, the difference is significant at the overall university level. Rather than suggesting the university should ensure equal mobility among gender and therefore create policies that encourage woman to travel more, this thesis argues the opposite. Instead of making women fly more, the university could create an environment where there is a smaller (international) mobility toll on its employees. Academic air travel might be a topic where gender policies and sustainability policies are not only aligned, but could actively enrich each other. Consequently, this thesis pleads for a lower emphasis on both internationalisation and academic mobility during the career of young academics, which could lead to a more gender-equal academic work environment.

The fourth recommendation is the replacement of high-pollution and low-budget airlines. Section 4.5 showed that the flights by Uniglobe Smart Travel are often booked with carbon-inefficient or low-budget airlines. The more carbon-efficient and less polluting airlines might not always be available for a certain location or date. However, the university could consider giving priority to the more carbon-efficient airlines when feasible.

Chapter 5 examined the financial opportunities for the university if it were to increase the CO_2 compensation, exploring distance-based and frequency-based compensations that could be used to nudge behaviour. Govaert already argued that the current compensation is too small, proposing compensation of at least €40 – 100. The fifth policy recommendation of this work adds additional arguments for increasing the current compensation of €12,1/ton CO_2 (Govaert, 2019).

Firstly, the data shows that in practice most employees pay a low compensation fee for their flight. This compensation corresponds to only 4% of the total price paid for the flight on average. Secondly, a higher compensation offers interesting possibilities for the institution itself. While the additional funds could be injected in the current projects supported by CO2logic, it could also be used to invest in the university's own sustainability projects, projects that might otherwise be left aside due to financial barriers.[11]

In contrast, the final two recommendations are less pronounced.

Section 4.5 revealed that a large number of business trips exhibited one or more stopovers, even for short flights. While there is no academic consensus yet on the emission difference between direct and indirect flights, this research suggests reducing the number of individual stopovers as its sixth recommendation, albeit with caution.

The seventh data-driven recommendation concerns policies that try to handle the diversity in each group within the university. Section 4.1 showed that there are distributional differences within and between faculties, as well as between employee categories. Not all the differences appear to be significant at a 5 %-significance level, and the general shape of the distribution seems to be consistent over faculties and job categories. However, examining the individual distributions of departments revealed that among the departments, some exhibited a completely different distribution.

Policies can either pursue a one-size-fits-all central policy approach or maintain a differentiated approach that takes the research culture of the department into account. The interpretation of these observations for this purpose is not self-evident. This work argues that both these approaches have merit. On the one hand, department-focused policies might help overcome the observed department-specific differences. On the other hand, the differences within the university itself are not large and the majority of departments follow similar distributions such that university-wide policies should not be withheld.

[11] A complete evaluation and exploration of possibilities for internal projects can also be found in the thesis of Govaert. She not only lists a set of options, but also gives the advantages and disadvantages of certain projects, as well the level of support for internal projects. Using the CO_2 compensation for internal projects is not a new proposal. The university of Gothenburg uses a climate fund. The climate fund is spent internally on different projects that are chosen each year by eight researchers from different disciplines. For example, efforts have already been made to use electric bicycles at the university. Another example can be found at the university of Leuven where academics can choose if they transfer the carbon-compensation to an internal or external carbon- reducing project.

7.3. Factors with limited influence on emissions

The chapter on policy recommendations concludes with three elements that one could intuitively expect to influence the emissions, but did not appear as significant in the various analyses presented throughout this work.

First, previous research proposes replacing all non-economy flights by economy class, which showed promising results for the reduction of institutional emissions (Ciers et al., 2019; Le Quéré et al., 2015; Wynes & Donner, 2018). Although flying non-economy has a huge influence on the total carbon footprint of an individual flight, the total emission impact of employees at Ghent University flying non-economy remains relatively low. At Ghent University only 174 of the 9.793 flights from July 2018 until December 2019 were non-economy class, which corresponds to only 1,7% of the total amount of flights and 1.303 ton CO_2, corresponding to 5,98% of the total emissions. This is far lower than the predicted 17% emissions reduction at EPFL. However, flying non-economy still has a significant impact on the carbon footprint of the individual. Therefore, obligating economy class seating cannot be set aside as non-useful. Implementing policies focused on class seating has merit as it emphasises the individual responsibility and impact of a single flight has, while also holding a symbolic value as the university chooses sustainability over comfort.

A second element that did not have the expected effect on the total sum of emissions is the fraction P-points, or baseline funding, of the department. A significant deviation from this baseline funding indicates the department uses other financial resources (such as project funds) to finance its staff hiring. The higher the amount of baseline funding, the smaller this contribution of competitive funding. In other words, P-points could be perceived as a proxy for the competitiveness of the department. The regression-model showed a non-significant positive effect at the 5%-level of the percentage of P-points. In other words, the funding a department receives is not relevant for the number of emissions, which might indicate that the competitiveness of a department is not influenced by the air travel behaviour. Therefore, policies reducing air travel emissions might not reduce the competitiveness of the department as perhaps feared, although more research here is needed.[12]

[12] This conclusion should be approached with the necessary caution. After all, other factors could be used as a proxy for competitiveness. P-points are definitely not a perfect variable, further research is preferred.

Lastly, the regression model presented a non-significant effect of the average A1-publications, or the average number of publications per academic employee at the department, at a 5%-significance level. In other words, the overall emissions of the department are not related to the scientific output of its employees. This finding is supported by similar results obtained by Wynes, Donner, Tannason and Nabors. In their study, they show that there is no statistical correlation between the H-index of their academic staff members and their produced air travel emissions. Therefore, this thesis argues that policies aimed at reducing air travel would not endanger the productivity of the individual departments.[13]

[13] Similar to percentage P-points, further research needs to shed more light on these statements. First of all, there could be other variables used to approximate the scientific output of a department. Secondly, every research field is different and has a different publication culture. This could influence the model. Thirdly, the regression model was constructed at the departmental level, but could also be constructed at the faculty, university, research group, or individual level. All of these could result in different findings.

Chapter 8

Conclusion

This thesis investigated how Ghent University can reduce its air travel emissions based on the analyses of air travel data of its employees. Collecting data is an essential element of the sustainable air travel policy at Ghent University and provides opportunities for evaluating, adjusting and optimising the current air travel policy. This data was collected by the travel agency Uniglobe Smart Travel and provides a research advantage over previous studies where researchers had to rely on surveys or data of the financial department.

The analyses on the air travel data were executed in the following ways. First, the literature review provided insights into previous data analyses of other universities or research communities and proposes insights into motivations and context behind academic flying. Secondly, the provided data by Uniglobe was assigned to individual staff members at Ghent University to add data personal data like gender, faculty, department etc. During this connecting process, several data issues occurred which resulted in recommendations concerning the data collection process, as summarised in Table 35. Fourth, every variable, provided by Uniglobe or constructed, was subsequently analysed by univariate and bivariate analyses. Those analyses indicate which variables would be interesting for the 1-level OLS-regression at the departmental level. Finally, three different models were analysed and the model with only the median ticket price, percentage guest professors and percentage of frequent flyers as explanatory variables was chosen as the most suitable model to explain the per employee emissions of the departments. All the relevant findings resulted in a set of policy recommendations, summarised in Table 35.

Table 35: Summary of the recommended policy changes.

POLICY RECOMMENDATION		BASED ON
FLIGHT-RELATED		
1.	Limit short-haul flights, e.g. by expanding the green cities list	Analysis of the destinations and the distributions of the flown kilometers
2.	Disincentivize frequent flying	Analysis of the impact of frequent flyers on the total emissions and the regression model
3.	Work towards a more gender-equal institution by placing a lower emphasis on international academic mobility	Literature and analysis by gender of the flown kilometers
4.	Actively promote more efficient airlines	Analysis of the used airlines and CO_2 calculators
5.	Increase the CO_2 compensation	Literature and simulations on the ticket price for different compensation schemes
6.	Promote flying with fewer stopovers	Analysis of stopovers, combined with literature and the current CO_2 calculator
7.	Both one-size-fits-all policies and policies that are faculty or department-specific have their own merits	Analyses of the distributions of the flown distances at the department-level
DATA-RELATED		
1.	Storing personnel-related information during the booking itself	20% of flights were not able to be connected to one staff member, and reduces complexity of data cleaning and linking
2.	Introduce a *TripID* variable to group all individual flights in the same business trip	Reduces complexity of data linking, allows for more straightforward comparisons
3.	Include motivations in the monitoring	Future research and policy adjustment possibilities

Although the institutional collection of air travel data provides unique opportunities and formed the basis of this thesis, there were several complications with the data that slowed down the research process, which creates barriers for future research. However, if Ghent University and Uniglobe Smart Travel collaborated to optimize the collection and reporting of the travel data, multiple opportunities arise for further research. A non-exhaustive list is presented below.

- First, the reason for travelling has not been analysed, as this information was not provided. Including this information allows analysing the motivations behind business trips, but simultaneously allows for an evaluation of the necessity of individual trips.
- Second, evaluating the effectiveness of the current policy measures was not possible because the current framework only became mandatory in 2018. Therefore, future research has the possibility of evaluating further policy measures by comparing the current data to future data.
- Future research could combine the current quantitative data with qualitative research, e.g. in-depth interviews for the departments with high or low emissions. Qualitative research could give a more nuanced view of the quantitative results, which is important for an organisation as diverse as a university.

- For this research, a simple 1-level OLS regression on the departments was constructed. The diversity within the department was therefore not taken into account in this work. Multilevel econometric models could provide further insights into the factors influencing the total amount of emissions.
- Future research could also expand on the implementation of certain policy measures e.g. carbon budgeting, expanding the green city list, frequent flyer taxation etc.

Next to the multiple policy recommendations based on the air travel data, this thesis provided insights into the opportunities managing and collecting data can hold. If the current problems with the data collection were to be tackled, future analyses of the air travel behaviour could lead to more specific and wider policy recommendations, even after new policies were to be introduced. Academic air travelling is clearly a wicked problem, a complex problem with multiple layers and interdependencies. The link between air travel and gender inequalities, where gender policies could be enriched by simultaneously taking air travel and internationalisation policies into account, is a prime example of the connection between multiple facets of a university.

However, this complexity does not mean that it is impossible to act. Multiple suggestions have been proposed in this thesis as well as in previous studies on Ghent University's air travel behaviour. With the implementation of its policy entitled *First steps into sustainable travel policy* in 2018, Ghent University started taking meaningful action and laid the foundation for further emissions reduction improvements. The first steps are taken, perhaps it is time for the next ones.

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Appendices

Appendix I
Data-related issues

The issues with the datasets can be divided in two categories: the ones related to the compatibility of data between the two datasets, and problems related to the interpretability and correctness of analyses on the resulting datasets.

a) Compatibility of datasets

The major identifier to combine the two datasets is the traveller name, i.e. the name that is given to Uniglobe Smart Travel when booking a ticket. However, there is no guarantee this is verbatim identical to the way staff members are listed in the Ghent University internal database, limiting the ease by which these databases can automatically be linked. Discrepancies in naming convention between the datasets can be traced back to four major categories of differences, each requiring a separate approach to solve the issue at hand:

i. Diacritical marks on letters

While the datasets containing all flight information does not contain any diacritical marks, the staff database of Ghent University does. This means that all names that include accented vowels, ç, ñ,… or those that are hyphenated will not immediately be recognised and thus need to be modified.

ii. Nicknames or different last names

Sometimes female employees are listed with their maiden name in one dataset, while the other lists them with a different surname. Similarly, the Department of Personnel and Organization allows employees to be listed by a call name instead of their given name, which can also lead to discrepancies between both datasets. In these cases, manual verification is necessary, as it is neigh impossible to automate this procedure.

iii. Presence of middle names

Similar to the previous category, it is possible that a different number of middle names is present in either datasets. In these cases, it is possible to check the first and last names to verify whether the entries in one dataset correspond to those in the other.

iv. <u>Uniqueness of the name</u>

A combination of a common given name and surname can correspond with different people, with different functions at the university. In these cases, a cascading principle is maintained, i.e. from literature it is clear that professorial staff if more likely to fly abroad than a postdoctoral fellow, who is again more likely to fly than a PhD student,…

b) <u>Unlinked-flight dataset</u>

The dataset from Uniglobe contains entries with both the individual flights and entries with a full business trip. As such, it is necessary to transform it, as much as possible, into a dataset with fully linked-flights. To do this, several steps are performed to identify different types of individual trips, using both the traveller name, booking number, departure and arrival date, as well as the routing. The analysis was performed by a staff member of Ghent University, based on the algorithm created for the purpose of this thesis.

In order to arrive at a linked-flight dataset, the unlinked-flight dataset is initially considered. Subsets of the unlinked-flight dataset are considered in each step, they are linked together where possible, and a new entry is added to the linked-flight dataset and the original entries are removed from the unlinked-flight dataset. In this way, no single entries are missed or not accounted for in the linked-flight dataset.

A new complication arises here: Uniglobe delivers their routings based on the airports frequented. However, several larger cities have multiple airports. This leads to further complications with automatic routings, as the linked of these flights has to manually performed and verified.

1) All flights get assigned a flight type according to their routing. To perform this analysis, all neighbouring cities and airports are assigned a ‘Home’ tag. Following six categories are subsequently considered:
    a. <u>Outbound and inbound flight</u>
       If the first and last destination of the trip is ‘Home’.
    b. <u>Outbound flight from Home</u>
       If the first destination is Home, but the last one is not.
    c. <u>Inbound flight to Home</u>
       If the last destination is Home, but the first one is not.
    d. <u>Special inbound and outbound flight</u>
       If the first and last destination are the same, and Home shows up twice in the routings

   e. Intermediate flight

      If the first and last destination are the same, and no Home is present in the routing

   f. Other

      None of the above

2) If the traveller name only shows up once in the full unlinked-flight dataset, it is impossible to link its entry to another flight. As such, those flights are removed from the unlinked-flight and immediately added to the linked-flight dataset.
3) The dataset is now filtered on each unique booking number. For each booking number, following conditions are checked:
   a. How many different travellers are booked under the same booking number? If there is only one traveller:
      i. Does the booking number contain entries that only correspond to an inbound and outbound flight? → If so, they are linked together.
      ii. Does the booking number contain two entries that correspond to a single outbound and a single inbound flight, both with/to the same destination? → If so, they are linked together in the order of their departure date.
      iii. Does the booking number contain two entries that correspond to an inbound and outbound flight, and an intermediate flight? Does the intermediate flight lie in the same timeframe as the inbound and outbound flight, and is its departure and arrival location consistent with the other flights? → If so, link.
   b. Else if there are two or more travellers under the same booking number:
      i. Are all routings the same for all members? Are all individual entries an inbound and outbound flight? → If so, consider each of these a different business trip.
      ii. Are there two entries per person? Do these two flight correspond to one inbound and one outbound flight? If so, link these together for every individual traveller.
4) Next, all unique intermediate flights are considered.
   a. For each intermediate flight, consider the other entries of the traveller in the datasets. Is it possible to match these flights based on their routings and departure/arrival dates to the same business trips? If so, link these together for each individual traveller where possible.
5) Next, the special flights are considered.
   a. Can these special flights be linked automatically to the same individual making other trips, based on the destinations and consistent with the timing of the individual flights? → If so, link together.

Finally, all flights that could not be linked together yet are now considered and linked manually. For this, the traveller name, destinations and timing are compared to manually determine whether or not the flights can be linked together. However, these often include destinations where the airports are different but located in the same region, e.g. the airports in New York City. If the destinations were to be given via cities instead of airports, this process could be simplified.

Appendix II
Further exploration of the distribution of emissions and kilometers

In Chapter 4, the general distribution of the emissions as well as the kilometers is shown to follow a non-normal distribution. But what distribution do the emissions and the kilometers follow? Different distributions were tested and it appears as that the only the fist peak can be described as following a specific type of distribution.

Up until the end of the first peak, between 5.000 – 6.000 kilometers, the emissions as well as the kilometers follow a gamma distribution. This can be seen in the following gamma distribution test, provided by R. The gamma distribution is defined as follows in the used package, defined by a scale and a shape parameter, where α is the scale parameter and λ is the shape parameter[1]:

$$f(x,\alpha,\lambda) = \frac{\lambda^{\alpha}}{\Gamma(\alpha)} x^{\alpha-1} e^{-\lambda x}, x \in \mathbb{R}^{+}$$

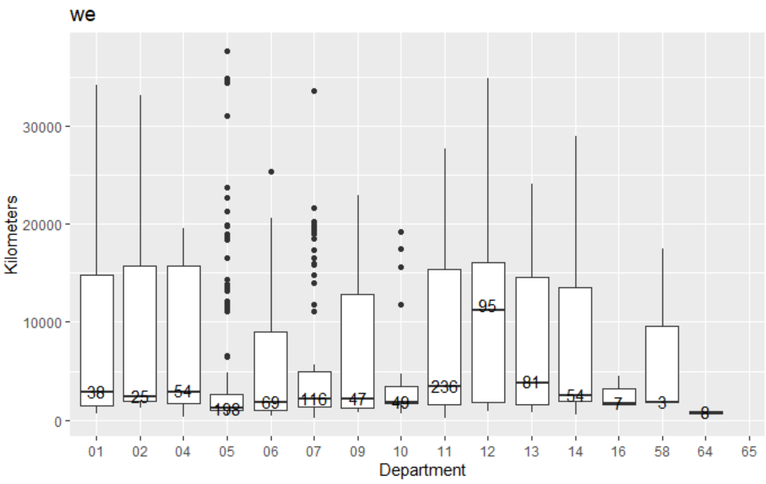
```
        Test of fit for the Gamma distribution

data:  r$Emissions
V = 4.6022, p-value = 0.001137

      Parameter estimates
shape           4.5805453
scale           0.1244796


        Test of fit for the Gamma distribution

data:  r$Kilometers
V = -2.481, p-value = 0.07938

      Parameter estimates
shape              4.4949
scale            478.4693
```

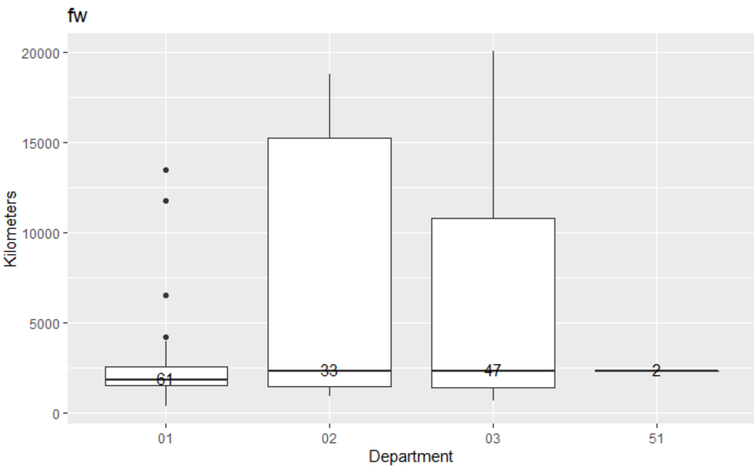
[1] Definition used by the goft library (goft: Tests of Fit for some Probability Distributions) used to perform the test procedure.

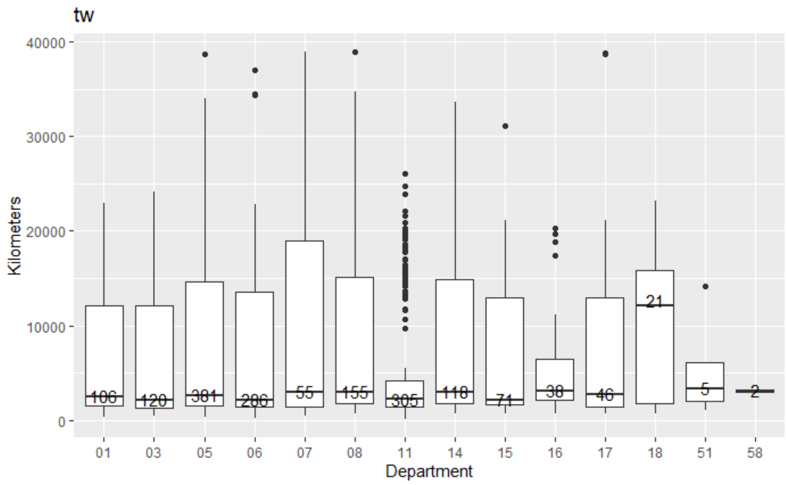
Appendix III

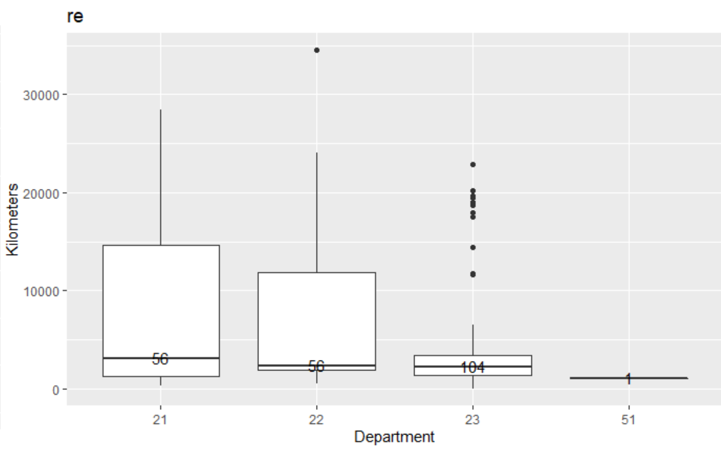
Distribution departments of the faculties

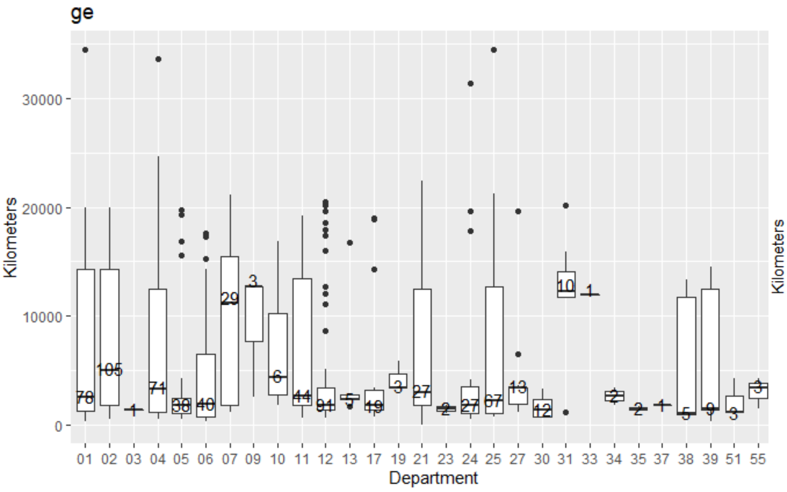
Unlike the figures in Chapter 4, there was chosen to represent the other departments in boxplots. Violin plots, as the figures used to represent the faculty of Political and Social Sciences as well as the Faculty of Bio-Engineering, are not suited for visualizing too many plots in one figure. Their characteristics, such as the width of the violins, disappears and the figure is too crowded.

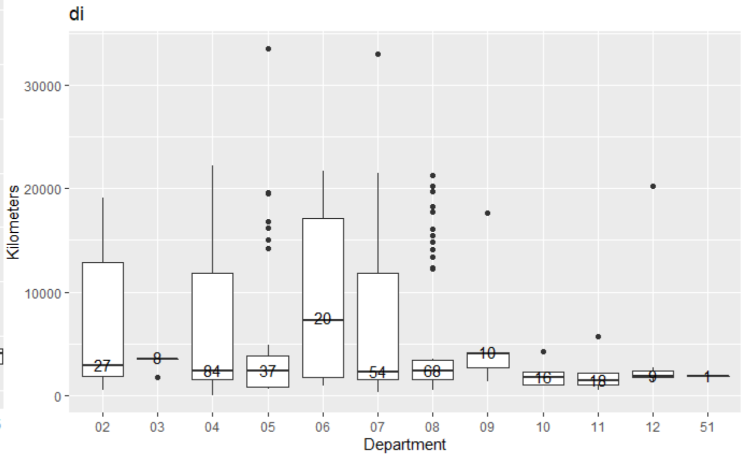


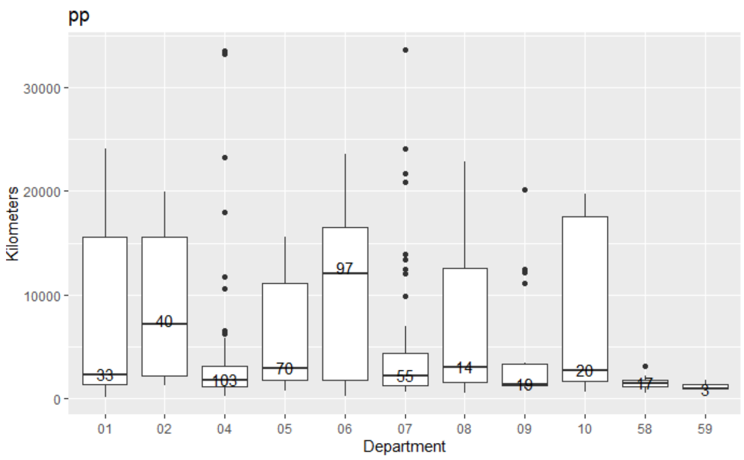


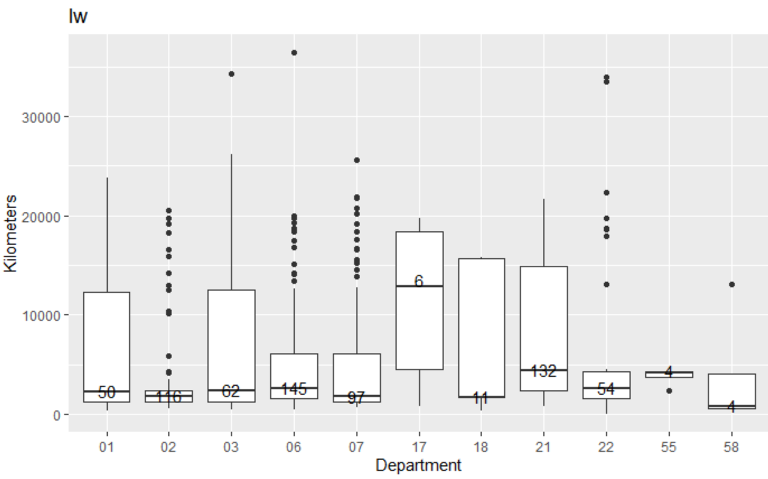


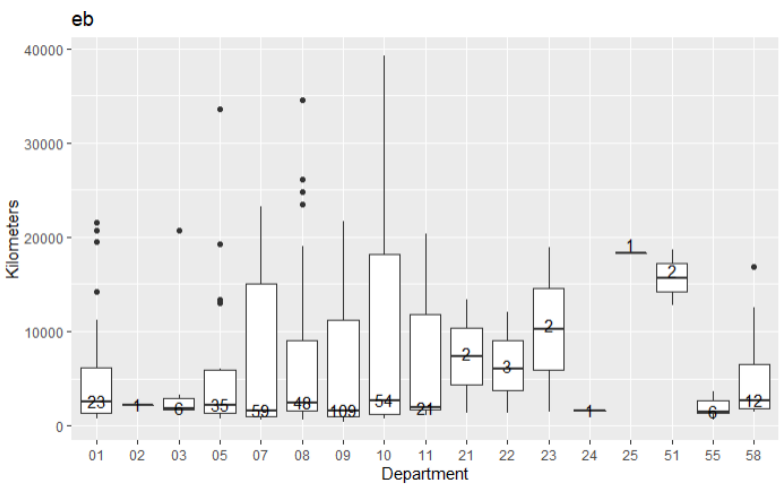



ge
Kilometers
Department


di
Kilometers
Department


pp
Kilometers
Department


lw
Kilometers
Department


eb
Kilometers
Department

Appendix IV
Analyses for the median flown kilometers

IV.a Kruskal-Wallis tests for the faculty, job category & gender

Faculty

Faculty of Veterinary medicine

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 3.1743, df = 1, p-value = 0.07481
```

Faculty of Economics and Business Administration

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 3.9843, df = 1, p-value = 0.04593
```

Faculty of Pharmaceutical Sciences

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 0.23226, df = 1, p-value = 0.6299
```

Faculty of Medicine and Health Sciences

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 1.2112, df = 1, p-value = 0.2711
```

Faculty of Arts and Philosophy

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 23.501, df = 1, p-value = 1.249e-06
```

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 4.6729, df = 1, p-value = 0.03064
```

Faculty of Psychology and Educational Sciences

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 15.095, df = 1, p-value = 0.0001022
```

Faculty of Political and Social Sciences

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 6.7933, df = 1, p-value = 0.00915
```

Faculty of Law and Criminology

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 1.9607, df = 1, p-value = 0.1614
```

Faculty of Engineering and Architecture

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 0.0029005, df = 1, p-value = 0.957
```

Faculty of Sciences

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 0.47576, df = 1, p-value = 0.4903
```

Type of Faculty

Alpha Faculties

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 1.144, df = 1, p-value = 0.2848
```

Beta Faculties

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 5.3211, df = 1, p-value = 0.02107
```

Gamma Faculties

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 3.1457, df = 1, p-value = 0.07613
```

Faculty/Management

Faculties

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 16.118, df = 1, p-value = 5.95e-05
```

Management

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 0.46119, df = 1, p-value = 0.4971
```

Job category

ZAP

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 6.3221, df = 1, p-value = 0.01192
```

AAP

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 5.8788, df = 1, p-value = 0.01532
```

Post-Doctoral Researchers

```
        Kruskal-Wallis rank sum test

data:  Kilometers by Gender
Kruskal-Wallis chi-squared = 0.56443, df = 1, p-value = 0.4525
```

Pre-Doctoral Researchers

```
        Kruskal-Wallis rank sum test

data:  Kilometers by Gender
Kruskal-Wallis chi-squared = 2.7176, df = 1, p-value = 0.09925
```

ATP

```
        Kruskal-Wallis rank sum test

data:  Emissions by Gender
Kruskal-Wallis chi-squared = 0.00132, df = 1, p-value = 0.971
```

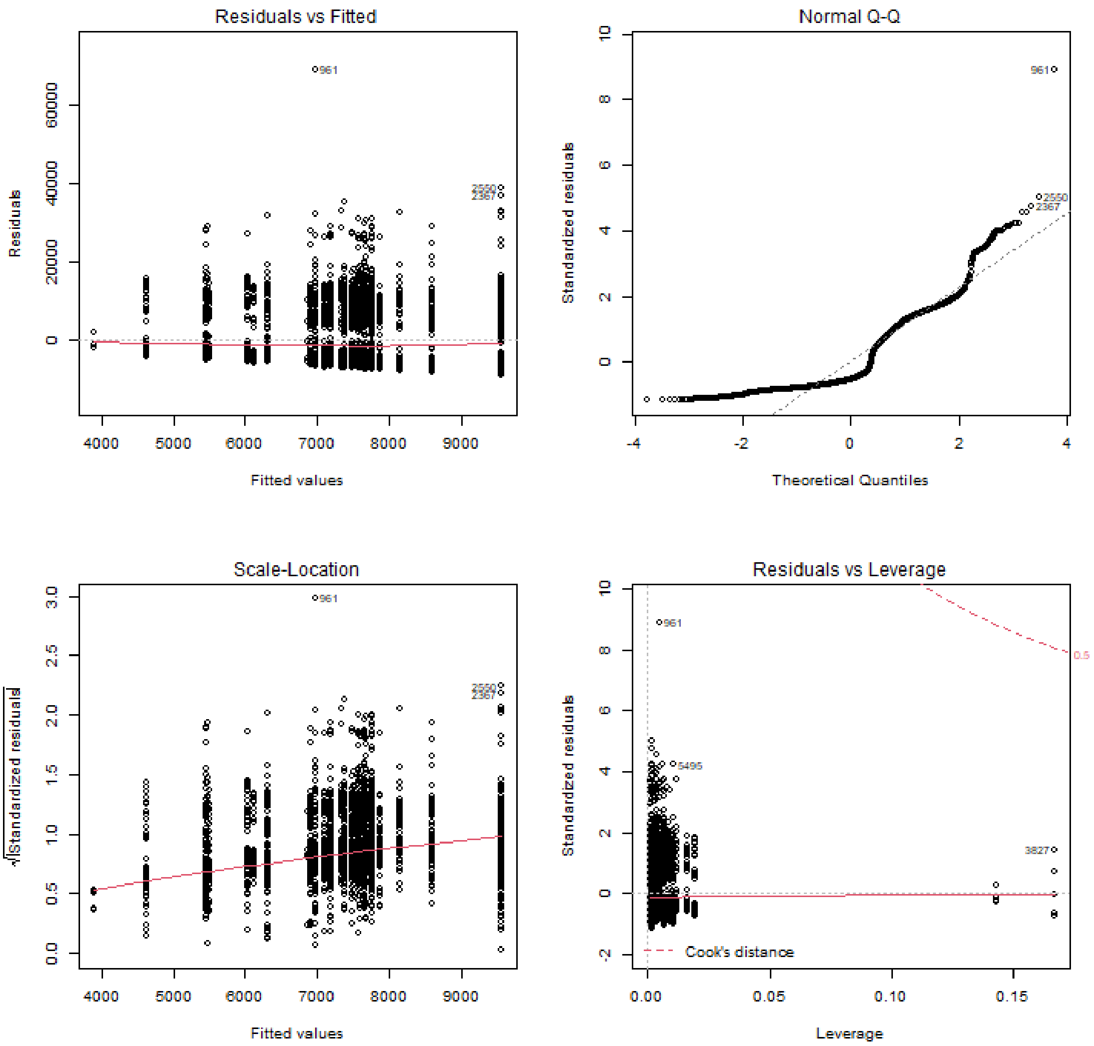
Guest Professors

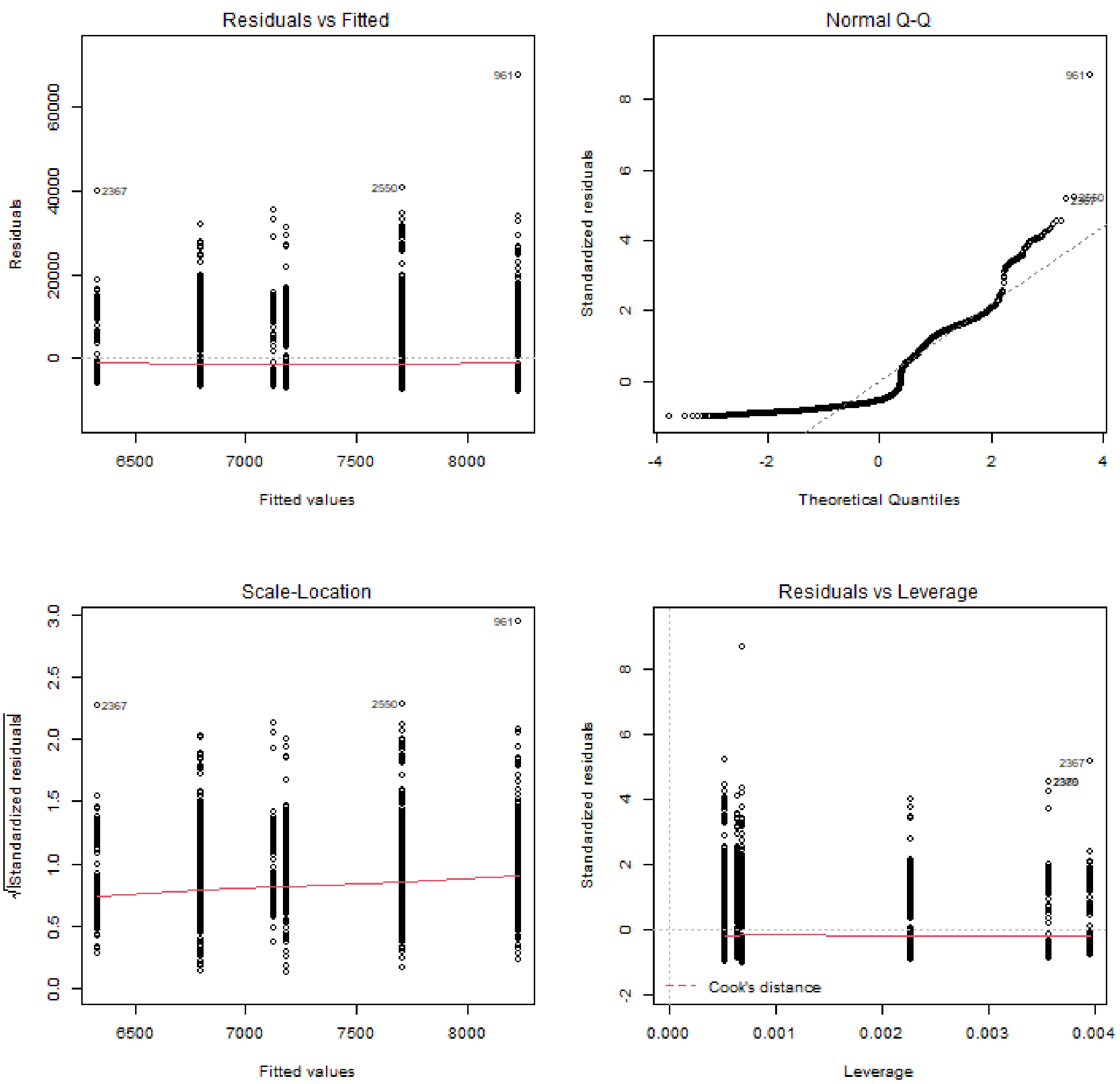
```
        Kruskal-Wallis rank sum test

data:  Kilometers by Gender
Kruskal-Wallis chi-squared = 0.89806, df = 1, p-value = 0.3433
```

IV.b Testing the assumptions of the 2-way ANOVA model

The first figure gives a summarization of the two-ANOVA-model with firstly an interaction effect between gender and faculties, secondly gender and job categories. The residuals vs. fitted-plot shows of the variance is constant. The data points should be equally distributed along the red line for constant variance, which should be horizontal and centred around zero. However, in both of the plots, the data points seem to be grouped in lines and a large number of outliers are present. The assumption of constant variance is violated.

The QQ-plots (quantile-plots) shows if the distribution is normally distributed. The quantiles of the distribution of the data are plotted against the theoretical quantiles. The data points of normal distribution would plot along the diagonal line of equality, the theoretical distribution. However, the data points show a very significant deviation. In other words, neither of the QQ-plots show a normal distribution. The assumption of normality is violated.




Residuals vs Fitted
Residuals
Fitted values
6500
7000
7500
8000
0
20000
40000
60000
961
2367
2550
Normal Q-Q
Standardized residuals
Theoretical Quantiles
-4
-2
0
2
4
6
8
Scale-Location
√|Standardized residuals|
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Residuals vs Leverage
Leverage
0.000
0.001
0.002
0.003
0.004
Cook's distance

Appendix V

a. Atmosfairs Airline Index 2018

Overall ranking								Distance-based ranking: <800 km			800-3800 km			>3800 km		
Rank	Airline	Country	EP* '18	EP* '17	EK*	Type*	Pax (in Mio.)*	EP*	EK*	Rank	EP*	EK*	Rank	EP*	EK*	Rank
1	TUI Airways	UK	79,3	78,9	B	Charter	10,9	69,1	C	17	79,4	B	2	79,2	B	1
2	LATAM Airlines Brasil[1]	Brasilien	78,8	72,3	B	Net Carrier	33,8	76,3	C	3	82,2	B	1	66,0	C	18
3	China West Air	China	77,8	78,6	C	Regional	7,2	76,7	C	2	77,9	C	4			
4	TUIfly	Deutschland	77,6	78,2	C	Charter	4,6	72,9	C	10	77,7	C	5	76,3	C	3
5	Transavia.com France	Frankreich	76,3	-	C	Charter	5,1	77,8	C	1	76,3	C	7	73,8	C	4
6	SunExpress	Türkei	74,9	-	C	Charter	6,3	39,8	E	101	74,9	C	9			
7	Thomas Cook Airlines	UK	74,7	72,9	C	Charter	6,6	54,5	D	64	78,6	B	3	68,8	C	9
8	Air Europa Express	Spanien	73,4	-	C	Regional	0,2	73,4	C	9						
9	Condor Flugdienst	Deutschland	71,8	72,9	C	Charter	7,3	42,9	E	92	77,6	C	6	65,7	C	20
10	Juneyao Airlines	China	70,9	61,6	C	Net Carrier	13,3	69,4	C	15	71,0	C	15			
11	Jet2.com	UK	70,8	73,8	C	Charter	6,7	68,4	C	21	70,8	C	16	73,8	C	4
12	Air Europa	Spanien	70,7	65,6	C	Net Carrier	10,7	70,4	C	13	74,1	C	10	68,3	C	12
13	Air New Zealand	Neuseeland	70,5	60,8	C	Net Carrier	15,2	75,4	C	5	75,1	C	8	66,5	C	17
14	Vietnam Airlines	Vietnam	70,4	64,3	C	Net Carrier	20,6	63,9	D	40	69,3	C	22	76,9	C	2
15	Beijing Capital Airlines	China	69,8	58,1	C	Net Carrier	13,1	68,7	C	18	70,0	C	18			
16	Siberia Airlines[2]	Russland	69,2	65,6	C	Net Carrier	9,5	66,2	C	33	69,7	C	20	67,4	C	14
17	KLM	Niederlande	68,9	68,1	C	Net Carrier	30,4	64,8	D	37	71,6	C	13	68,5	C	11
18	Virgin Australia International	Australien	68,5	67,0	C	Net Carrier	19,7	71,6	C	11	69,8	C	19	61,4	D	31
19	Air New Zealand Link	Neuseeland	68,3	64,4	C	Regional	3,0	68,5	C	19	62,9	D	52			
20	Air Caraibes	Guadeloupe	68,2	-	C	Net Carrier	1,4	74,0	C	7	70,3	C	17	67,6	C	13
21	Avianca	Kolumbien	67,9	61,7	C	Net Carrier	29,5	67,9	C	22	68,2	C	26	67,4	C	14
22	Alaska Airlines	USA	67,4	67,6	C	Net Carrier	24,4	20,9	F	119	67,3	C	31	70,2	C	7
22	Shandong Airlines	China	67,4	55,8	C	Net Carrier	18,6	68,5	C	19	67,3	C	31			
22	Sichuan Airlines	China	67,4	65,6	C	Net Carrier	23	64,5	D	38	68,5	C	25	48,6	E	65
22	Thai Airways International	Thailand	67,4	65,3	C	Net Carrier	18,2	70,8	C	12	69,6	C	21	65,8	C	19
26	Air Transat	Kanada	67,1	65,7	C	Charter	4,4	67,0	C	26	71,3	C	14	64,5	D	22
27	UTair Aviation	Russland	66,9	46,5	C	Net Carrier	6,7	70,1	C	14	66,3	C	37	68,6	C	10
28	Air India Express	India	66,8	-	C	Regional	3,2	38,9	E	103	67,1	C	35			
29	Hong Kong Airlines	Hong Kong	66,2	61,7	C	Net Carrier	6,5	74,3	C	6	66,2	C	38	61,7	D	29
30	Shenzhen Airlines	China	66,1	65,7	C	Net Carrier	27,6	66,7	C	27	66,1	C	40			
31	Xiamen Airlines Company	China	66,0	53,8	C	Net Carrier	24,5	66,6	C	28	65,8	C	43	66,8	C	16
32	Air Canada	Kanada	65,6	55,5	C	Net Carrier	44,8	57,7	D	55	63,2	D	49	69,0	C	8
32	Hainan Airlines	China	65,6	60,6	C	Net Carrier	27,4	69,2	C	16	66,2	C	38	61,8	D	27
34	Iberia	Spanien	65,0	59,8	C	Net Carrier	17,8	66,5	C	30	67,9	C	27	58,9	D	35
35	Ural Airlines	Russland	64,9	55,1	D	Net Carrier	6,5	62,3	D	43	66,0	C	42	58,6	D	36
36	Finnair	Finnland	64,4	57,4	D	Net Carrier	10,9	61,7	D	44	67,5	C	28	61,9	D	26
37	China Eastern Airlines	China	64,0	59,5	D	Net Carrier	80,9	66,5	C	30	68,7	C	24	44,6	E	74
38	Japan Airlines	Japan	63,9	53,1	D	Net Carrier	32,9	73,6	C	8	72,3	C	11	53,9	D	48
39	Air India	Indien	63,4	57,4	D	Net Carrier	19,8	59,7	D	51	65,3	C	45	61,8	D	27
40	El Al Israel Airlines	Israel	63,2	54,8	D	Net Carrier	5,5	66,1	C	34	67,3	C	31	56,1	D	41
41	Air China	China	63,1	58,0	D	Net Carrier	62,4	64,2	D	39	62,8	D	53	64,0	D	23
42	Batik Air	Indonesia	62,5	-	D	Net Carrier	7,6	61,2	D	45	62,8	D	53	62,2	D	25
43	Royal Air Maroc Express	Marokko	62,3	57,0	D	Regional	0,5	65,5	C	35	53,9	D	78			
44	Garuda Indonesia	Indonesien	61,9	58,8	D	Net Carrier	23,9	65,2	C	36	62,8	D	53	57,5	D	37
45	Cathay Pacific Airways	Hong Kong	61,8	63,2	D	Net Carrier	24,4	0,0	G	124	66,1	C	40	60,1	D	33
45	Delta Airlines	USA	61,8	59,7	D	Net Carrier	183,7	58,6	D	53	66,5	C	36	54,7	D	46
47	Corsair	France	61,6	60,7	D	Charter	1,2	35,5	F	107	56,9	D	73	61,6	D	30
48	TAP Portugal	Portugal	61,5	61,5	D	Net Carrier	11,7	45,9	E	84	65,2	C	46	56,9	D	38
49	Qantas Airways	Australien	61,4	58,2	D	Net Carrier	28,2	75,8	C	4	72,3	C	11	48,8	E	64
50	Aerolineas Argentinas	Argentina	60,4	58	D	Net Carrier	8,3	67,1	C	25	63,8	D	48	53,5	D	50
50	United Airlines	USA	60,4	59,7	D	Net Carrier	143,2	60,5	D	46	67,2	C	34	52,3	D	54
52	China Southern Airlines	China	60,3	59,3	D	Net Carrier	84,9	60,3	D	48	61,6	D	58	52,6	D	53
53	TianJin Airlines	China	60,0	48,9	D	Regional	12,1	56,1	D	59	62,3	D	56	51,2	D	57
54	Icelandair	Island	59,9	60,4	D	Net Carrier	3,7	35,1	F	108	60,3	D	62	59,6	D	34
55	Shanghai Airlines	China	59,8	59,0	D	Net Carrier	14,3	60,0	D	50	59,9	D	64	56,9	D	38
56	Cathay Dragon	Hong Kong	59,6	-	D	Net Carrier	9,9	55,9	D	61	60,1	D	63	55,3	D	44
57	Hawaiian Airlines	USA	59,0	57,0	D	Net Carrier	11,1	51,6	D	71				60,3	D	32
58	American Airlines	USA	58,7	55,1	D	Net Carrier	198,7	51,9	D	70	64,1	D	47	47,2	E	68
58	MASwings	Malaysia	58,7	56,8	D	Regional	1,4	58,7	D	52						
58	Ukraine Int. Airlines	Ukraine	58,7	55,9	D	Net Carrier	6,0	41,0	E	100	61,2	D	59	56,3	D	40

*EP: Efficiency points; EK: Efficiency class; Pax: Number of passengers (data from Air Transport Intelligence, a service of ICAOData.com, IATA WATS, and other sources); Type: The division of the airlines in categories was based on Air Transport Intelligence and other sources. In the event of ties, airlines are listed alphabetically.

The following airlines were not evaluated due to data gaps: Gol, Anadolu Jet, Travel Service Airlines, Globus.

[1] also TAM Linhas Aereas
[2] also S7 Airlines

		Overall ranking						Distance-based ranking								
								<800 km			800-3800 km			>3800 km		
Rank	Airline	Country	EP* '16	EP* '15	EK*	Type*	Pax (in Mio.)*	EP*	EK*	Rank	EP*	EK*	Rank	EP*	EK*	Rank
61	All Nippon Airways	Japan	58,4	48,1	D	Net Carrier	52,1	67,6	C	24	63,2	D	49	50,5	E	59
61	Malaysia Airlines	Malaysia	58,4	45,5	D	Net Carrier	13,9	52,2	D	68	61,8	D	57	54,2	D	47
63	Copa Airlines	Panama	58,2	54,8	D	Net Carrier	8,5	43,7	E	87	54,5	D	76	64,7	D	21
64	Aeromexico	Mexico	58,1	50,2	D	Net Carrier	11,2	56,1	D	59	56,2	D	74	63,1	D	24
65	Alitalia	Italien	57,2	57,8	D	Net Carrier	23,1	60,5	D	46	60,7	D	61	52,2	D	55
66	Lufthansa	Deutschland	56,9	55,2	D	Net Carrier	62,4	58,1	D	54	67,4	C	30	49,4	E	61
67	Singapore Airlines	Singapore	56,5	35,1	D	Net Carrier	19,0	41,8	E	97	61,1	D	60	55,5	D	43
68	Aeroflot Russian Airlines	Russland	56,4	55,7	D	Net Carrier	39,2	52,7	D	66	57,8	D	70	53,5	D	50
69	Turkish Airlines	Türkei	56,2	59,4	D	Net Carrier	62,8	63,9	D	40	58,6	D	67	49,2	E	63
70	Asiana Airlines	Südkorea	56,1	53,1	D	Net Carrier	19,3	66,3	C	32	58,3	D	68	50,2	E	60
71	Korean Air	Südkorea of	55,9	49,3	D	Net Carrier	26,9	66,6	C	28	63,1	D	51	50,6	E	58
72	Srilankan Airlines	Sri Lanka	55,6	56,0	D	Net Carrier	4,4	57,3	D	58	57,8	D	70	53,2	D	52
73	Air France	Frankreich	54,5	55,0	D	Net Carrier	49,8	67,7	C	23	67,5	C	28	46,4	E	70
74	British Airways	UK	54,4	51,7	D	Net Carrier	44,5	57,6	D	56	65,8	C	43	47,6	E	67
75	Iberia Regional	Spanien	54,3	51,3	D	Regional	2,2	55,9	D	61	50,4	E	87			
76	Royal Air Maroc	Marokko	54,0	45,3	D	Net Carrier	6,8	42,2	E	96	53,9	D	78	55,7	D	42
77	QantasLink	Australien	53,6	59,9	D	Regional	6,2	55,8	D	63	46,5	E	94			
78	SAS Scandinavian Airlines	Schweden	53,4	52,0	D	Net Carrier	29,4	50,2	E	74	59,3	D	65	44,7	E	72
79	EVA Airways	Taiwan	53,2	62,1	D	Net Carrier	11,2	52,0	D	69	58,7	D	66	49,4	E	61
79	SilkAir	Singapore	53,2	56,3	D	Regional	4,1	42,7	E	94	54,0	D	77			
81	Austrian Airlines	Österreich	51,6	51,6	D	Net Carrier	11,4	43,3	E	90	53,2	D	81	54,9	D	45
82	China Airlines	Taiwan	51,4	57,5	D	Net Carrier	14,7	49,7	E	76	53,7	D	80	48,4	E	66
83	Virgin Atlantic Airways	UK	51,3	40,9	D	Net Carrier	5,4	0,0	G	124				51,4	D	56
84	Brussels Airlines	Belgium	50,5	49,0	E	Net Carrier	7,7	48,8	E	80	53,2	D	81	46,6	E	69
85	South African Express	Südafrika	50,3	41,6	E	Regional	0,3	52,5	D	67	43,7	E	99			
86	Air Algerie	Algerien	50,2	-	E	Net Carrier	6,1	57,6	D	56	49,6	E	90	44,8	E	71
87	Pakistan Int. Airlines	Pakistan	50,1	52,5	E	Net Carrier	5,5	43,3	E	90	58,0	D	69	38,2	E	84
87	Philippine Airlines	Philippinen	50,1	50,1	E	Net Carrier	13,4	51,5	D	72	57,2	D	72	37,1	E	85
89	Swiss	Schweiz	49,7	46,8	E	Net Carrier	18,0	60,1	D	49	69,0	C	23	38,5	E	83
90	Alaska Horizon	USA	49,5	48,9	E	Regional	7,8	49,0	E	78	50,3	E	88			
91	Jazz Aviation	Kanada	49,1	45,6	E	Regional	10,5	51,3	D	73	47,3	E	91			
92	PAL Express	Philippinen	48,8	49,5	E	Regional	5,1	48,4	E	82	51,1	D	86			
93	ANA Wings	Japan	48,6	49,6	E	Regional	0,2	49,1	E	77	44,0	E	98			
94	Nordic Regional Airlines	Finland	48,3	44,3	E	Regional	2,8	63,9	D	40	36,6	E	110			
95	Gulf Air	Bahrain	47,3	44,2	E	Net Carrier	5,2	35,1	F	108	52,7	D	83	41,6	E	77
96	Etihad Airways	VAE	47,2	49,8	E	Net Carrier	18,5	49,8	E	75	55,8	D	75	44,1	E	75
97	LOT - Polish Airlines	Polen	47,0	44,2	E	Net Carrier	5,5	43,6	E	88	38,2	E	106	70,6	C	6
100	Qatar Airways	Qatar	46,4	46,1	E	Net Carrier	32	44,0	E	85	51,7	D	85	44,7	E	72
101	Egyptair	Ägypten	44,7	41,1	E	Net Carrier	8,2	49,0	E	78	45,9	E	96	40,1	E	80
102	BA CityFlyer	UK	43,6	39,7	E	Regional	2,2	42,3	E	95	44,7	E	97			
103	Oman Air	Oman	43,4	40,5	E	Net Carrier	7,7	38,4	E	104	46,3	E	95	40,5	E	79
104	HOP!	France	42,9	-	E	Regional	6,0	46,7	E	83	38,0	E	107			
104	Kuwait Airways	Kuwait	42,9	42,2	E	Net Carrier	2,9	43,5	E	89	46,7	E	92	38,7	E	82
106	Ohana by Hawaiian	USA	42,8	38,8	E	Regional	0,4	42,8	E	93						
107	J-Air	Japan	41,1	41,3	E	Regional	3,5	41,3	E	98	40,5	E	104			
108	Emirates	VAE	40,7	39,6	E	Net Carrier	56,1	36,4	E	106	46,7	E	92	39,5	E	81
109	Swiss Global Air Lines	Schweiz	40,3	46,8	E	Regional	1,1	39,4	E	102	40,9	E	102			
110	Saudi Arabian Airlines	Saudi-Arabien	40,2	40,3	E	Net Carrier	28,2	41,2	E	99	42,1	E	100	36,9	E	86
111	South African Airways	Südafrika	39,5	41,4	E	Net Carrier	6,6	53,9	D	65	51,9	D	84	29,1	F	88
112	Aeromexico Connect	Mexico	38,6	30,6	E	Regional	8,5	34,1	F	110	40,9	E	102			
113	Austral Lineas Aereas	Argentinien	37,7	33,2	E	Regional	3,2	37,3	E	105	37,8	E	108			
114	Royal Jordanian	Jordanien	37,4	34,7	E	Net Carrier	3,0	20,2	F	120	31,5	F	114	53,9	D	48
115	Ethiopian Airlines	Äthiopien	36,5	26,5	E	Net Carrier	8,2	23,8	F	117	32,4	F	112	40,8	E	78
116	Virgin Australia Regional	Australien	36,0	40,4	E	Regional	4,6	33,7	F	111	36,2	E	111			
117	Air Astana	Kasachstan	34,8	36,0	F	Net Carrier	3,7	26,9	F	115	37,5	E	109	28,3	F	89
118	Mahan Air	Iran	33,9	39,0	F	Net Carrier	5,9	27,4	F	114	40,4	E	105	29,8	F	87
119	United Express	USA	31,1	32,0	F	Regional	22,0	29,2	F	112	31,9	F	113			
120	TAP Express	Portugal	30,6	37,0	F	Regional	1,3	17,5	G	121	31,5	F	114			
121	Delta Connection	USA	28,5	29,5	F	Regional	39,0	21,6	F	118	31,3	F	116			
122	Envoy	USA	28,2	32,8	F	Regional	11,8	25,0	F	116	30,3	F	117			
123	Kenya Airways	Kenia	27,6	19,5	F	Net Carrier	4,5	10,9	G	122	18,4	G	118	43,3	E	76
124	Egyptair Express	Ägypten	25,4	22,0	F	Regional	1,2	28,3	F	113	17	G	119			
125	South African Airlink	Südafrika	2,3	2,6	G	Regional	0,50,5	3,7	G	123	1,6	G	120			

* EP: Efficiency points; EK: Efficiency class; Pax: Number of passengers (data from Air Transport Intelligence, a service of ICAOData.com, IATA WATS, and other sources); Type: The division of the airlines in categories was based on Air Transport Intelligence and other sources. In the event of ties, airlines are listed alphabetically.

b. Low cost carriers

Low Cost Carrier[1]		
Efficiency Class	Type	Airlines
A	Low Cost Carrier	----
B	Low Cost Carrier	IndiGo Air, Indonesia AirAsia, Lion Air, Norwegian, Ryanair, Scoot, SpiceJet, Spring Airlines, Transavia.com
C	Low Cost Carrier	Aer Lingus, Air Arabia, AirAsia, China United Airlines, Citilink Indonesia, Easyjet, Eurowings, Frontier Airlines, germanwings, Go Air, Jeju Airlines, Jetstar Airways, Lucky Air, Nok Air, Pegasus Airlines, Southwest Airlines, Spirit Airlines, Thai AirAsia, Tigerair Taiwan, VietJet Air, Volaris, Vueling, Wizz Air
D	Low Cost Carrier	Airasia X, Allegiant Air, Azul Airlines, Cebu Pacific Air, Flydubai, JetBlue Airways, Virgin America, Westjet
E	Low Cost Carrier	Interjet
F	Low Cost Carrier	----
G	Low Cost Carrier	----

[1] In alphabetical order within one efficiency class

Appendix VI
Descriptives and data generating process for the OLS-dataset

A novel aggregated dataset at the department level is constructed based on the subset of the dataset, restricted to those trips that can be linked to an individual staff member of the university. The contributions of distance, total CO2 emissions, amount of frequent flyers,… are summed for all individuals belonging to each department, to obtain the aggregated dataset. This dataset is subsequently further supplemented with relevant parameters at the department level that can be obtained from the dataset provided by the Department of Personnel and Organisation, e.g. the total number of staff members, the gender ratio in the department, total number of professorial staff, the total number of academic assisting staff,…

All these variables are divided by the number of employees linked to the department. For example, the variable emissions is divided by staff and shows the average emitted emissions per staff member. group of gues professors becomes guest professors/Staff and shows the fraction of Guest professors of the total staff. By dividing through the number of staff members of the department, the variables are normalized and the influence of the size of the staff is nullified.

The number for the total staff as well as for other variables as AAP, ZAP, Guest professors, etc. is constructed with the headcount of the staff instead of FTE, the percentage amount an employee works for an employer. The reasoning for using headcount is the fact that even someone who's paid for only a 0,2 FTE, can still fly frequently for that department. 5 employees of 0,2 FTE are not the same as 1 VTE when considering the size of the department.

In addition to this, variables from various Ghent University sources are included that are relevant for policymakers. This includes variables such as the number of A1 publications of the department during the period 2018 - 2019 and the amount of so-called Personnel Point (P Point) the department receives from the university.

- P-points are a measure for the number of staff members that the university has on its payroll, and any additional staff members have to be hired from other income sources such as research projects. The total number of P-points for each department were obtained from the latest personnel policy plans of each faculty for 2020, approved by the Board of Governors on the 22nd of October 2019.

- It can be relevant to consider this parameter in combination with the total number of A1 publications as a proxy for the competitiveness and research output of a department. This number of publications were obtained for 2018 and 2019 from biblio.ugent.be, filtered on each departments. The A1 publication is then divided by the total number of academic staff members, so ZAP + AAP, which leads to an average number of A1 publications per academic staff member.
- The number of P-points can be further differentiated based on their origin. In 2013 – 2014, several educational programs and research groups transferred from colleges to the universities. Over the past years, these research groups that originated in colleges have been integrated into existing research groups. However, it is probable that the research culture in these groups, such as the internationalisation context, differs from groups with a long-standing tradition in research. As such, the subset of the total P Points that is reserved for the integrated research groups is also taken as a relevant parameter to describe observed differences between research groups in the regression model.

To summarise, the parameters included in the aggregated dataset at the department-level are listed in the Table below. Only the absolute values are included here, as relative parameters such as CO2 emissions per staff member can be calculated by dividing the CO2 emissions by the total amount of staff members.

Normalized Emissions	AAPperZAP	FractionGuestProfessors
Percentage of women in the staff	Percentage P-points	Percentage P-points linked to integration curricula
Number of A1 publications	Frequent Flyers	Median Ticket Price

Appendix VII
Dataset OLS

Part 1

Department	Faculty	Norm. Emissions	MedianTicketPrice	% of Women	AAPperZAP
di02	di	0,331777778	224,02	0,644444444	5,5
di04	di	0,427134831	398,54	0,56741573	10,3
di05	di	0,414336283	285,435	0,646017699	7,888889
di06	di	0,454736842	756,18	0,666666667	6,6
di07	di	1,103157895	375,755	0,486842105	4,181818
di08	di	0,502352941	385,9	0,571428571	13,83333
di09	di	0,03452381	223,5	0,857142857	8
di10	di	0,1214	267,23	0,58	4,5
di11	di	0,121525424	189,7	0,677966102	9
di12	di	0,127192982	207,89	0,614035088	6,75
eb21	eb	0,120472973	573,32	0,27027027	3,107143
eb22	eb	0,328315789	376,555	0,368421053	3,166667
eb23	eb	1,505342466	380,46	0,568493151	2,821429
eb24	eb	0,425471698	202,065	0,20754717	3,7
eb25	eb	2,6736	365	0,44	3
fw01	fw	0,098202247	252,18	0,511235955	10,81818
fw02	fw	0,378111111	339,01	0,455555556	13,2
fw03	fw	0,064081633	211,67	0,714285714	12,4
ge30	ge	0,163117647	210,93	0,488235294	10,25
ge31	ge	0,34931677	565,85	0,586956522	5,935484
ge32	ge	0,086213018	373,635	0,544378698	1,611111
ge33	ge	0,02	329,735	0,392857143	1,333333
ge34	ge	0,0024	116,69	0,66	1,605263
ge35	ge	0,194506667	436,28	0,554666667	1,62
ge36	ge	0,654552846	470,69	0,43902439	4,571429
ge37	ge	0,015844156	191,78	0,658008658	6,5
ge38	ge	0,276705426	261,8	0,46124031	1,375
ge39	ge	0,427781065	285,855	0,680473373	4,485714
la20	la	0,423	437,3	0,384	10,76471
la21	la	0,639705882	430,745	0,434640523	12,82353
la22	la	1,045265957	716,21	0,446808511	13,2
la23	la	0,662436548	608,26	0,573604061	7,823529
la24	la	0,687936508	411,04	0,396825397	9,76
la25	la	0,2775	414,615	0,509868421	12,36842
la26	la	0,787407407	553,395	0,333333333	8
la27	la	2,370952381	753,54	0,464285714	5,9
lw01	lw	0,113758865	690,775	0,375886525	5,6875
lw02	lw	0,472407407	172,26	0,444444444	6,363636

lw03	lw	0,175475285	383,1	0,384030418	5,448276
lw06	lw	0,182114804	282,605	0,673716012	5,0625
lw07	lw	0,045283019	276,76	0,630188679	4,210526
lw21	lw	0,771969112	472,38	0,517374517	8,631579
lw22	lw	0,058613861	265,755	0,653465347	4,62963
pp01	pp	0,364081633	253,415	0,530612245	4,875
pp02	pp	0,357826087	403,48	0,434782609	6
pp04	pp	0,580365854	314,875	0,597560976	9,571429
pp05	pp	0,187864078	304,36	0,684466019	8,368421
pp06	pp	1,01064	857,8	0,688	8,363636
pp07	pp	0,327444444	193,565	0,711111111	6,181818
pp08	pp	0,111372549	155,91	0,607843137	8
pp09	pp	0,144590164	383,22	0,573770492	4,666667
pp10	pp	0,116701031	351,24	0,731958763	14
ps01	ps	0,442590674	210,92	0,497409326	8,333333
ps03	ps	0,2854	247,89	0,346666667	5,888889
ps05	ps	0,960537634	631,765	0,419354839	7,111111
re21	re	0,259714286	341,815	0,473469388	4,081081
re22	re	0,123548387	241,64	0,5	7,166667
re23	re	0,547788945	373,025	0,582914573	6,526316
tw01	tw	0,54702381	290,12	0,327380952	7,866667
tw03	tw	0,044271845	639,675	0,145631068	9,428571
tw05	tw	0,426835279	428,65	0,169909209	12,32075
tw06	tw	0,524405458	294,88	0,231968811	5,918033
tw07	tw	0,188817204	389,48	0,215053763	9,3125
tw08	tw	0,743932927	489,71	0,182926829	7,6
tw11	tw	0,415144357	350,63	0,307086614	12,5
tw14	tw	0,767354839	348,98	0,258064516	7
tw15	tw	0,364197531	564,53	0,234567901	6,5625
tw16	tw	0,14255814	1088,085	0,23255814	4,571429
tw17	tw	0,082071429	276,075	0,378571429	12,44444
tw18	tw	0,0425	582,225	0,173913043	6,6
we01	we	0,210178571	412,9	0,142857143	2,428571
we02	we	0,147232143	272,1	0,294642857	3,6
we04	we	0,36	440,71	0,21	7,4
we05	we	0,688676471	296,64	0,200980392	5,681818
we06	we	0,169104478	262,13	0,348258706	6,571429
we07	we	0,313585859	306,68	0,303030303	12,5
we09	we	0,062638298	284,27	0,461702128	11,96429
we10	we	0,045666667	194,98	0,527777778	9,230769
we11	we	0,688095238	439,57	0,510582011	10,29167
we12	we	1,0411875	613,88	0,375	9,818182
we13	we	0,52189781	493,48	0,270072993	4,789474
we14	we	0,022199313	196,495	0,580756014	7,736842
we16	we	0,452162162	351,32	0,216216216	3,714286

Part 2

Fraction Guest Professor	AAPperZAP	Frequent Flyer Percentage FFP	PercP	AvgA1	PercInt
0,022222	5,5	0	0,196888889	2,230769231	0
0,02809	10,3	0,016853933	0,120617978	1,044247788	0
0,035398	7,888889	0,008849558	0,196725664	2,225	0
0,035088	6,6	0,01754386	0,151754386	2,684210526	0
0,065789	4,181818	0,013157895	0,1875	1,561403509	0
0,033613	13,83333	0,008403361	0,143613445	1,382022472	0
0	8	0	0,254761905	1,240740741	0
0,02	4,5	0	0,2838	2	0
0,016949	9	0,016949153	0,251864407	1,675	0
0	6,75	0	0,207368421	1,709677419	0
0,081081	3,107143	0	0,426182432	0,869565217	0,38319461
0,252632	3,166667	0	0,393763158	0,6	0,352736751
0,164384	2,821429	0,02739726	0,377705479	1,23364486	0,404751111
0,037736	3,7	0	0,526226415	0,957446809	0,483865185
0,12	3	0,02	0,40836	0,388888889	0,909393672
0,016854	10,81818	0	0,154817416	1,538461538	0
0,033333	13,2	0	0,236055556	1,563380282	0
0,061224	12,4	0	0,200127551	2,597014925	0
0,047059	10,25	0	0,228323529	1,814814815	0
0,009317	5,935484	0,00310559	0,128703416	1,313953488	0
0,065089	1,611111	0	0,140414201	3,617021277	0
0,02381	1,333333	0	0,244821429	2,866071429	0
0,1	1,605263	0	0,20975	3,652525253	0
0,064	1,62	0,008	0,142006667	3,050763359	0
0,04065	4,571429	0,016260163	0,170365854	0,679487179	0
0,073593	6,5	0	0,282857143	1,043333333	0,472604836
0,077519	1,375	0,015503876	0,182412791	3,01754386	0,019654714
0,065089	4,485714	0,00591716	0,158357988	2,857291667	0,009715086
0,02	10,76471	0,008	0,17398	1,54	0,158064145
0,009804	12,82353	0,009803922	0,160784314	1,242553191	0,222052846
0,047872	13,2	0,015957447	0,17162234	1,288732394	0,318146598
0,005076	7,823529	0,005076142	0,191027919	1,326666667	0,493589318
0,003175	9,76	0,022222222	0,188888889	1,353159851	0,321848739
0,019737	12,36842	0,003289474	0,1409375	1,251968504	0,277745361
0,027778	8	0,018518519	0,236064815	2,122222222	0,05099039
0,047619	5,9	0,047619048	0,255178571	1,52173913	0,059015629
0,106383	5,6875	0	0,214858156	0,738317757	0
0,027778	6,363636	0,018518519	0,193564815	0,728395062	0
0,041825	5,448276	0,003802281	0,185532319	0,28342246	0
0,02719	5,0625	0,006042296	0,138867069	0,417525773	0
0,071698	4,210526	0	0,215150943	0,338383838	0
0,057915	8,631579	0,003861004	0,173544402	0,366120219	0

0,019802	4,62963	0	0,461608911	0,315789474	0,996031959
0	4,875	0	0,436734694	1,638297872	0
0,026087	6	0,008695652	0,273391304	2,306122449	0
0,036585	9,571429	0,036585366	0,241097561	0,648648649	0
0,029126	8,368421	0	0,199660194	1,539325843	0
0,032	8,363636	0,008	0,27272	0,563106796	0
0,011111	6,181818	0	0,328666667	1,835443038	0
0,058824	8	0	0,310784314	0,488888889	0
0,098361	4,666667	0	0,399344262	1,078431373	0
0,061856	14	0	0,174845361	0,9	0
0,036269	8,333333	0,010362694	0,222901554	0,648809524	0
0,053333	5,888889	0,006666667	0,303466667	0,516129032	0,062609842
0,043011	7,111111	0,010752688	0,17311828	0,534246575	0
0,028571	4,081081	0,008163265	0,291510204	0,069148936	0
0,05914	7,166667	0	0,249677419	0,238095238	0
0,030151	6,526316	0,015075377	0,244572864	0,377622378	0
0,095238	7,866667	0,011904762	0,276785714	0,210526316	0,061290323
0,07767	9,428571	0	0,178737864	0,780821918	0
0,006485	12,32075	0,003891051	0,105732815	0,610481586	0,473981845
0,011696	5,918033	0,011695906	0,158957115	0,687203791	0,133055368
0,021505	9,3125	0,005376344	0,147822581	0,575757576	0,198036007
0,036585	7,6	0,012195122	0,218132622	0,798449612	0,376078829
0,020997	12,5	0,020997375	0,171811024	0,946127946	0,463030859
0,116129	7	0,019354839	0,220709677	1,240384615	0,453522362
0,08642	6,5625	0	0,160462963	0,611570248	0,144643201
0	4,571429	0	0,146511628	0,897435897	0
0,021429	12,44444	0	0,162857143	1,223140496	0,289473684
0,065217	6,6	0	0,338940217	0,539473684	0,667201154
0,053571	2,428571	0	0,307679875	0,375	2,858848951
0,0625	3,6	0	0,454558101	1,543478261	0,633759154
0,02	7,4	0	0,604052289	1,714285714	0,624321805
0,029412	5,681818	0,024509804	0,210039934	1,965986395	1,392108142
0,029851	6,571429	0,014925373	0,282491994	2,012578616	0,758905996
0,045455	12,5	0,015151515	0,399601528	1,12345679	0,326386002
0,006383	11,96429	0	0,117593838	0,749311295	0,3878297
0,005556	9,230769	0	0,150972282	0,962406015	1,017227463
0,087302	10,29167	0,007936508	0,060209036	1,623616236	0,933476225
0,04375	9,818182	0,025	0,172769795	1,621848739	0,709488166
0,058394	4,789474	0	0,155072993	1,709090909	2,030535254
0,010309	7,736842	0	0,067396907	1,379518072	2,323178245
0,054054	3,714286	0,027027027	1,165911391	1,303030303	0,679263207

Appendix VIII

Interaction effect in the OLS-regression

This appendix considers into the interaction effect of the OLS-regression of chapter 6. An interaction effect occurs when considering the effect of one variable (X_1) on an outcome(Y) depends on the state of a second variable (X_2). Interaction effects in the regression-model are constructed by multiplying the two variables where an interaction effect is assumed.

<u>Model 1</u>

Model is constructed with the variables MedianTicketPrice, FFP, FractionGuest and with dummy variables for the faculties and interactions between the faculties and FractionGuest. However, the first model only shows a signicant interaction effect at the 5%-significance level for the

```
Call:
lm(formula = PercEmissions ~ FractionGuest * Faculty + FFP, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.65600 -0.13546 -0.02864  0.10020  1.39537

Coefficients:
                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                -0.09077    0.17013  -0.534   0.5956
FractionGuest               9.63010    5.46953   1.761   0.0834 .
Facultyeb                   0.87660    0.33010   2.656   0.0101 *
Facultyfw                   0.34054    0.43884   0.776   0.4408
Facultyge                   0.34319    0.29347   1.169   0.2469
Facultyla                   0.23537    0.25268   0.931   0.3553
Facultylw                   0.15298    0.29343   0.521   0.6040
Facultypp                   0.40212    0.24693   1.628   0.1087
Facultyps                   0.77453    1.15575   0.670   0.5053
Facultyre                   0.18081    0.56370   0.321   0.7495
Facultytw                   0.22629    0.22181   1.020   0.3117
Facultywe                   0.07932    0.23733   0.334   0.7394
FFP                        25.31230    4.05621   6.240 4.86e-08 ***
FractionGuest:Facultyeb    -9.74549    5.76792  -1.690   0.0963 .
FractionGuest:Facultyfw   -11.50532   11.19629  -1.028   0.3083
FractionGuest:Facultyge   -12.40100    6.68861  -1.854   0.0686 .
FractionGuest:Facultyla     3.81587    8.64063   0.442   0.6604
FractionGuest:Facultylw    -8.01780    6.90147  -1.162   0.2499
FractionGuest:Facultypp   -12.31376    6.62072  -1.860   0.0678 .
FractionGuest:Facultyps   -17.66819   26.12454  -0.676   0.5014
FractionGuest:Facultyre    -9.01324   14.04143  -0.642   0.5234
FractionGuest:Facultytw    -8.73477    5.94154  -1.470   0.1468
FractionGuest:Facultywe    -5.73699    6.52239  -0.880   0.3826
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3099 on 60 degrees of freedom
Multiple R-squared:  0.6513,    Adjusted R-squared:  0.5235
F-statistic: 5.094 on 22 and 60 DF,  p-value: 2.624e-07
```

```
Call:
lm(formula = PercEmissions ~ MedianTicketPrice + FractionGuest *
    Faculty + FFP, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-0.74409 -0.14271 -0.00558  0.10510  1.40316

Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)             -1.832e-01  1.758e-01  -1.042   0.3014
MedianTicketPrice        4.165e-04  2.416e-04   1.724   0.0899 .
FractionGuest            7.943e+00  5.470e+00   1.452   0.1518
Facultyeb                8.261e-01  3.261e-01   2.533   0.0140 *
Facultyfw                3.015e-01  4.324e-01   0.697   0.4884
Facultyge                2.125e-01  2.985e-01   0.712   0.4795
Facultyla                1.619e-01  2.523e-01   0.642   0.5234
Facultylw                1.935e-01  2.897e-01   0.668   0.5068
Facultypp                3.536e-01  2.446e-01   1.446   0.1536
Facultyps                7.003e-01  1.138e+00   0.615   0.5407
Facultyre                8.376e-02  5.575e-01   0.150   0.8811
Facultytw                1.013e-01  2.300e-01   0.440   0.6613
Facultywe                6.809e-02  2.336e-01   0.291   0.7717
FFP                      2.504e+01  3.994e+00   6.270 4.59e-08 ***
FractionGuest:Facultyeb -8.154e+00  5.750e+00  -1.418   0.1614
FractionGuest:Facultyfw -9.278e+00  1.109e+01  -0.836   0.4063
FractionGuest:Facultyge -9.134e+00  6.848e+00  -1.334   0.1874
FractionGuest:Facultyla  3.077e+00  8.513e+00   0.361   0.7190
FractionGuest:Facultylw -8.279e+00  6.792e+00  -1.219   0.2277
FractionGuest:Facultypp -1.079e+01  6.574e+00  -1.641   0.1061
FractionGuest:Facultyps -1.558e+01  2.573e+01  -0.605   0.5473
FractionGuest:Facultyre -5.829e+00  1.394e+01  -0.418   0.6773
FractionGuest:Facultytw -6.618e+00  5.974e+00  -1.108   0.2724
FractionGuest:Facultywe -5.082e+00  6.429e+00  -0.790   0.4324
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.3049 on 59 degrees of freedom
Multiple R-squared:  0.6681,    Adjusted R-squared:  0.5386
F-statistic: 5.163 on 23 and 59 DF,  p-value: 1.838e-07
```

Appendix IX

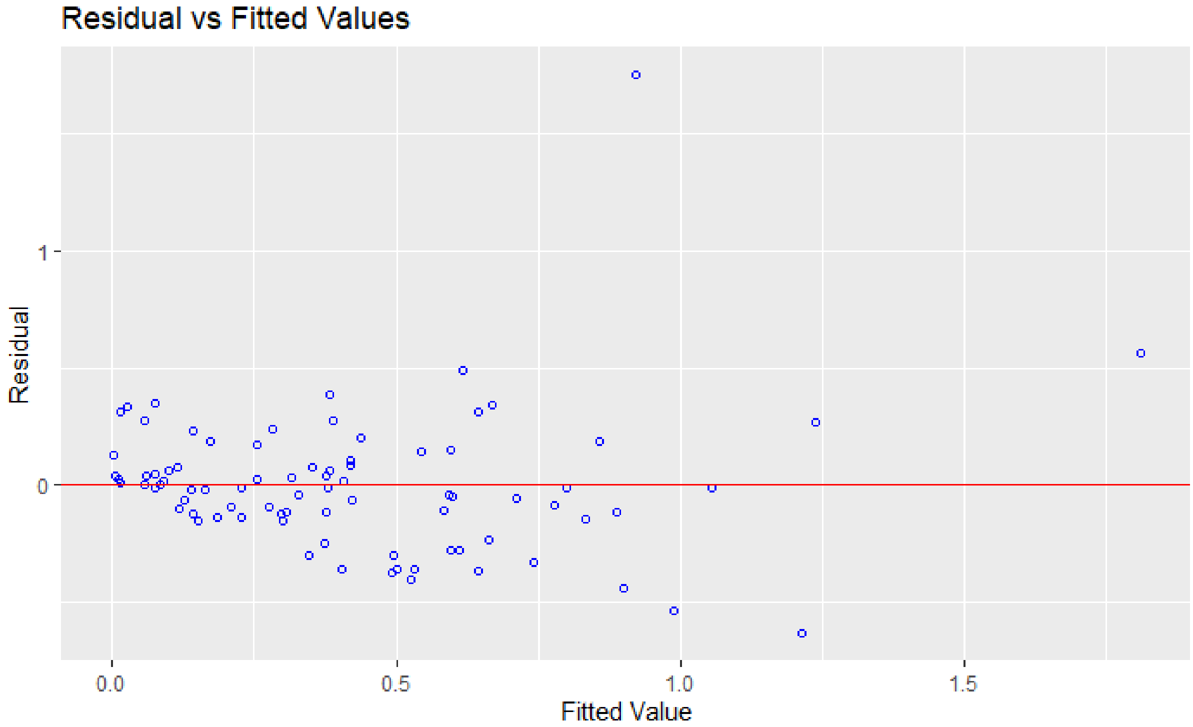
Gauss-Markov assumption for the chosen OLS-model

In chapter 6, model 2 is proposed as the most optimal model. This appendix tests the underlying assumptions for performing an Ordinary Least-Squares regression. The following table gives the results.

Gaus-Markov Assumptions	**Test**	**Model 2**
Linearity in the parameters	Plotting Residuals versus Fitted	No pattern
X deterministic	/	/
Error terms are on average zero	Mean of residuals	P-value= -4.829272e-18
Homoscedasticity	• Goldfeld-Quandt Test • Breusch Pagan Test	• P-value= 0.02853 • Prob > Chi2 = 3.583e-12
No autocorrelation	• Breusch-Godfrey test • Durbin Watson Test	• P-value = 0.5186 • P-value = 0.179
N. observations > # parameters	/	3 parameters, 83 observations
No perfect multicollinearity	VIF (Variance Inflation Factor)	VIF for every parameter is 1-1.1
Error terms normally distributed	Jarque-Berra test	P-value = 2.2e-16

Two assumptions are violated in the chosen model 2. The error terms are not normally distributed and there is heteroscedasticity. Therefore a GLS-model instead of an OLS model could be more appropriate. The GLS of the model is given on the last page.

Linearity in the parameters



Heteroskedasticity/ Homoscedasticity

```
Breusch Pagan Test for Heteroskedasticity
 -----------------------------------------
 Ho: the variance is constant
 Ha: the variance is not constant

                  Data
 -----------------------------------------
 Response : PercEmissions
 Variables: fitted values of PercEmissions

         Test Summary
 ------------------------------
 DF            =    1
 Chi2          =    48.34003
 Prob > Chi2   =    3.58361e-12
```

```
        studentized Breusch-Pagan test

data:  model
BP = 9.058, df = 3, p-value = 0.02853
```

Multicollinearity

```
        Breusch-Godfrey test for serial correlation of order up to 1

data:  model
LM test = 0.41659, df = 1, p-value = 0.5186


        Durbin-Watson test

data:  model
DW = 1.8143, p-value = 0.179
alternative hypothesis: true autocorrelation is greater than 0
```

Multicollinearity

```
          Variables Tolerance      VIF
1 MedianTicketPrice 0.9615927 1.039941
2     FractionGuest 0.9973545 1.002653
3               FFP 0.9605664 1.041052
```

Error terms normally distributed

```
        Jarque Bera Test

data:  model$residuals
X-squared = 587.86, df = 2, p-value < 2.2e-16
```

Generalized Least Square Model

```
 Generalized Least Squares Fit by REML

  Gls(model = PercEmissions ~ MedianTicketPrice + FractionGuest +
      FFP, data = data)


  Obs   83        Log-restricted-likelihood-24.80
  Clusters83      Model d.f.3
  g 0.359         sigma0.3067
                  d.f.     79

                      Coef    S.E.    t     Pr(>|t|)
  Intercept          -0.1164 0.0906 -1.29  0.2024
  MedianTicketPrice   0.0006 0.0002  2.85  0.0056
  FractionGuest       2.0286 0.8669  2.34  0.0218
  FFP                29.4144 3.5623  8.26  <0.0001
```