DESIGNING DECISIONS

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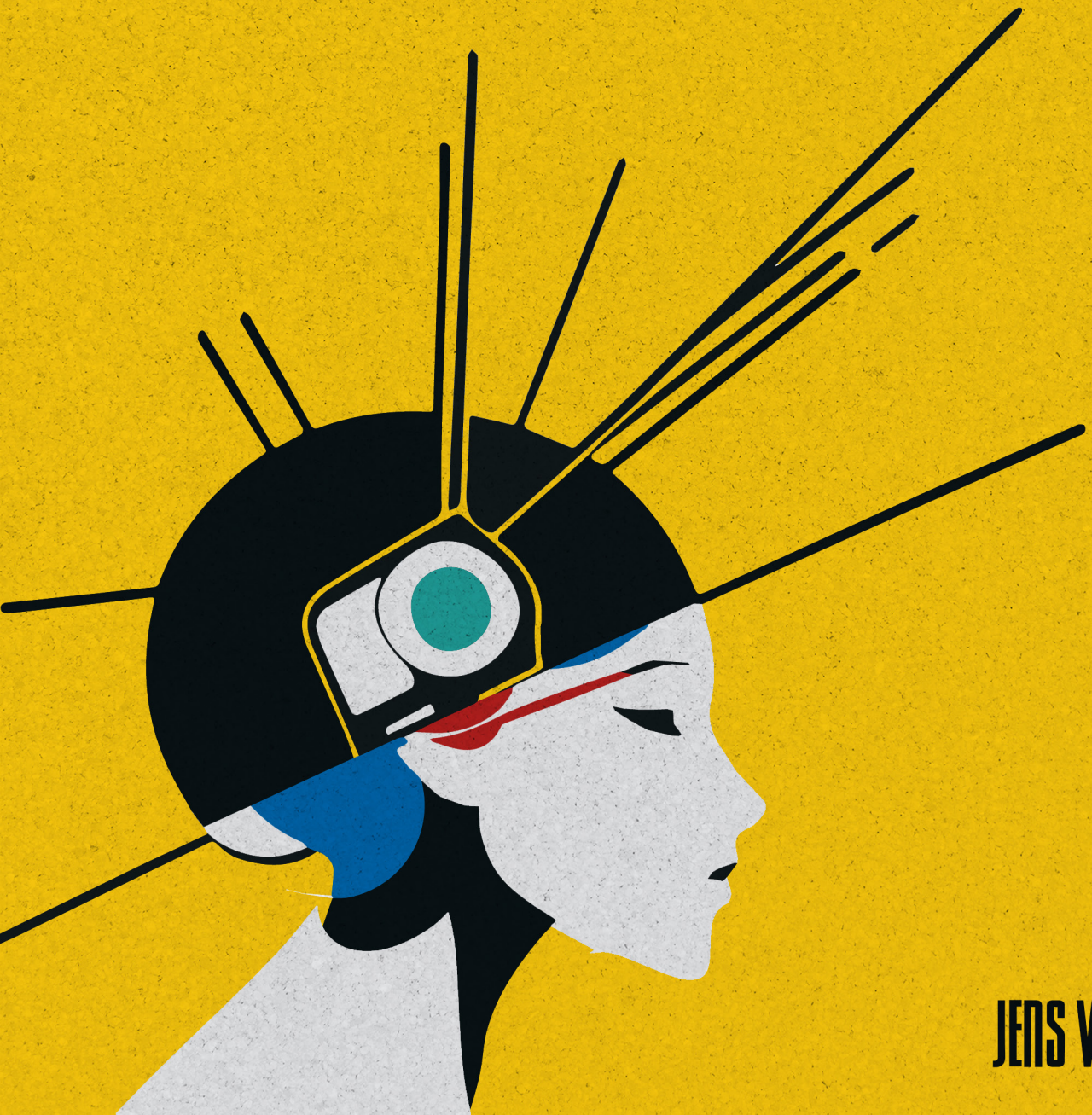

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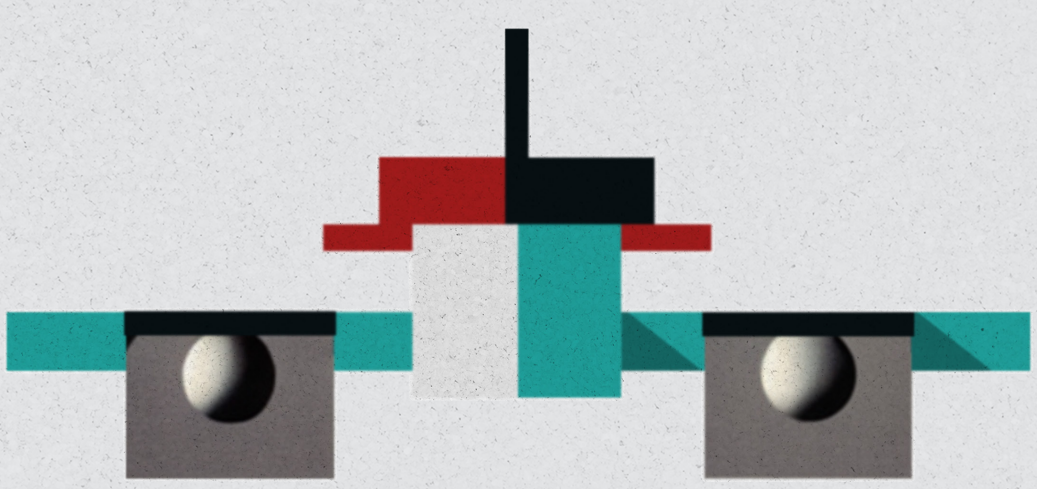

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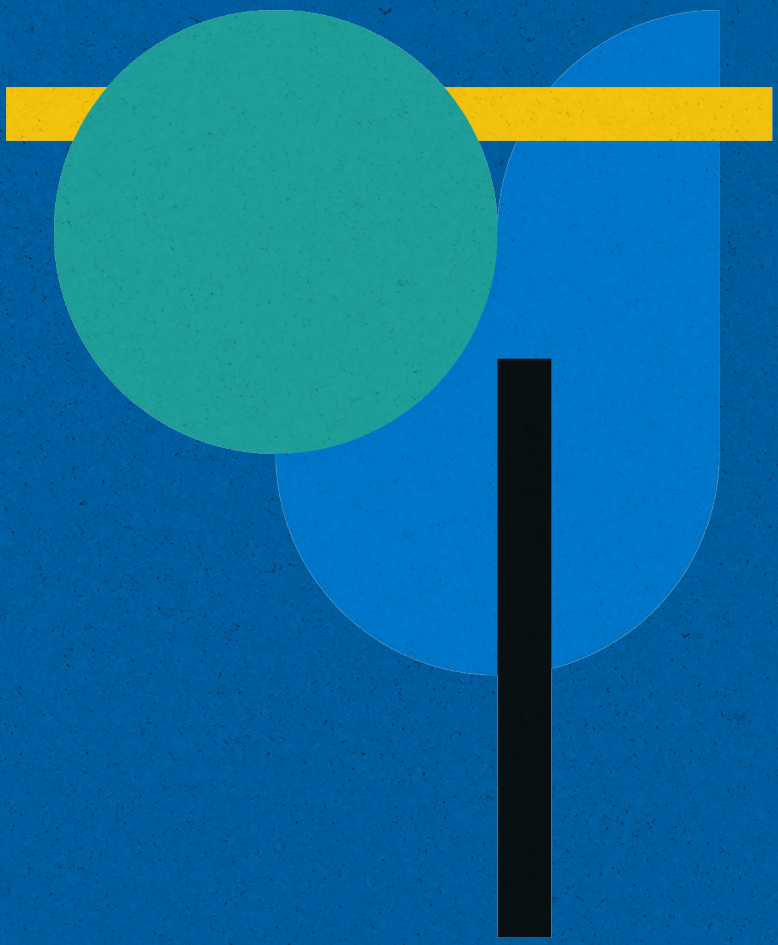

ABSTRACT

Decision-making in professional fields has made a stark transition away from utility as the comparative metric in neoclassical economic frameworks. The result of which means a step towards the use of non-equatable variables for calculating the comparability between material, energy, and fiscal costs. While the traditional methods have their flaws, new methods also have their shortcomings. Understanding the flaws within neoclassical utilitarian economic frameworks makes for better overall decision-making without the problems accompanying the use of only heterodox economic methods. This thesis investigates the extent to which it is possible to build a new neoclassically oriented economic tool that allows the user to better understand the pitfalls of simple neoclassical economic modelling. By studying existing economic tools and interviewing experts, a design study is conducted; setting up requirements, building, and testing the tool for feasibility. The results indicate that while this new web-based tool for cost-benefit analysis is more user-friendly than spreadsheet applications, it fails at its primary task of having users more easily intuit the shortcomings inherent within cost-benefit analyses.

Keywords: economics, web-development, software, decision-making, design, UI, models.

INTRODUCTION

Truth was once something that could be revealed. It was once something that could be shown, and understood. It was once something that was contested and debated, and more importantly, admitted to. It was once the yardstick used to measure the quality of decisions and accuracy of information.

However, this is no longer the case.

While this may seem an unconventional introduction to an academic thesis, please indulge in this brief existential tangent, even if only for its entertainment value.

There was indeed a time, dear reader, when emphasis and value was placed on the systematic and empirical approach of science; A time when 'justified true belief' was taken as a challenge to show, learn, observe, and above all, understand each other. It led to inquiry, curiosity, debate, discussion, and the acceptance of truth based on empirical evidence.

It is hard to imagine that now, given that we are all painfully aware of the internet and how it goes about with the integrity of information, but there really was a time when truth was considered the currency in the marketplace of ideas.

It was perhaps a naive hope to have the scientific community remain such a safe haven for opposing views without emotion interfering. Perhaps it was inevitable that it would suffer the same fate as all the other information that touched the information superhighway. To think that from the 16th century to now, the atmosphere surrounding scientific debate would devolve into this sensationalist and ideologically phase-locked cesspool that pigeon-holes results regardless of merit is absolutely incredible.

Regardless of how one feels about that description of the state of science, it seems rather clear that we have entered a time now where any scientific knowledge can be perceived to fall within a particular moral, religious, political, or social framework, and be deemed by one or another online community as "misinformation," "disinformation" or "fake news" all without even having been read.

The reason why this introduction is not only relevant but also necessary within this paper, is because knowledge (defined here as justified true belief) can no longer be trusted. Modern day science favours expediency and intellectual elitism from both the old guard and the new, over any discussion and mutual understanding of information.

While in the past it may have been true that justification for beliefs was the topic of debate, in today's world, justification for nearly every belief can be found. To illustrate this using a topic relevant to this thesis, I will start with hydrogen combustion.

In the realm of aviation, one could claim that hydrogen combustion reduces NOx pollution in jet propulsion and be simultaneously and justifiably both correct and incorrect.

While this may seem strange to some of you, allow me to explain.

The renowned French aerospace engineering school, Institut Supérieur de l'Aéronautique et de l'Espace (ISAE-SUPAERO), released a comprehensive literature review of Aviation and Climate in May 2022 in which they claim:

> *".. a hydrogen engine could reduce NOx emissions by redesigning the combustor in order to low lean blowout limit of hydrogen"* [1]

While technically not incorrect, the paper they cite for this information is an Airbus Technical Report from their 2003 Cryoplane[2] which used Lean Pre-mix Prevaporise and micromix experimental engine types in early development that had significant issues.

Most notably the engines had issues with flame at idle, flame flashback, premature burning, and finally, maintaining low NOx when scaling from the experimental to full size injectors.[3, 4, 5]

This information aligns well with sources showing that the higher burn temperatures of hydrogen not only increase the formation of NOx[5] (which is 298 times worse in Global Warming Potential than CO_2)[6] but that planes using hydrogen would have to burn at least 4 times as much fuel in volume as compared to kerosene.[7]

However, this does not stop people from using sources like the SUPAERO report to claim that Hydrogen combustion reduces non-CO_2 emissions, such as one of the presentations done at the Leiden-Delft-Erasmus Centre for Sustainability this year.

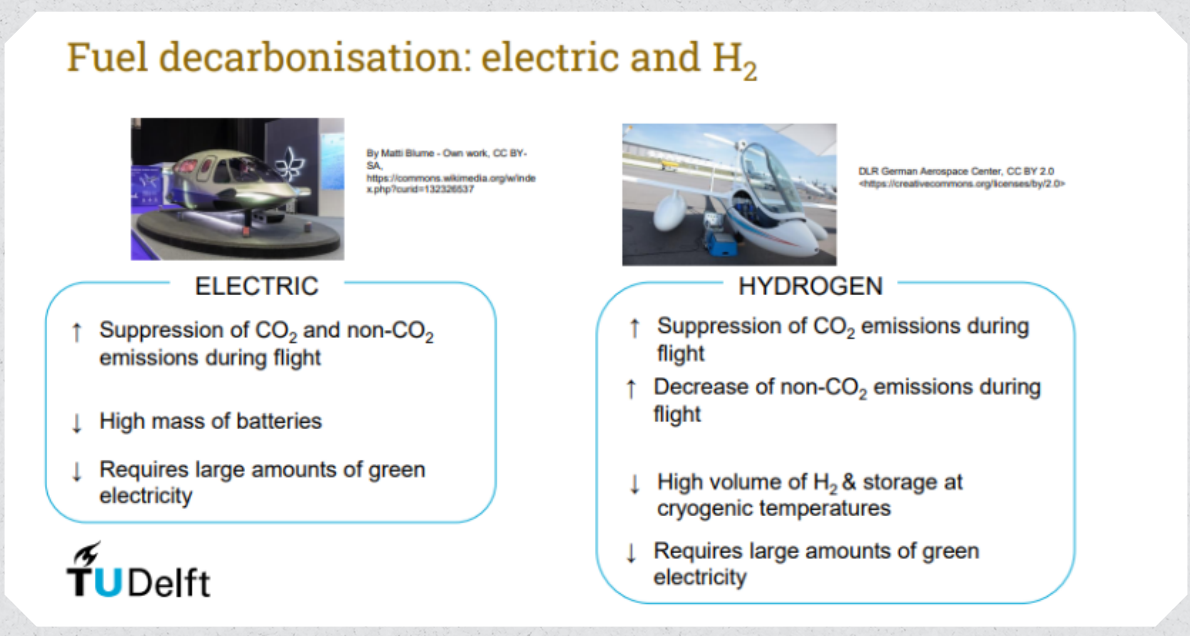

Figure 1. Slide from a presentation given at LDE Centre for Sustainability which shows a benefit of hydrogen is that it reduces non-co2 emissions. A student during the lecture asked if it was hydrogen combustion or fuel cell, and the professor answered that combustion as well as fuel cell reduce non-co2 emissions, citing the SUPEARO report as reference.

Because of SUPAERO's status and the contemporary date on the literature review, one would assume that the information is both relevant and correct. However, it requires a full understanding to know that the claim may not be completely taken at face value.

The problem is that instead of taking up that responsibility of understanding, engineers and scientists alike are trained to trust the words of others. As Karel Mulder (formerly of TU Delft section Technology Assessment) once said "We get paid to write, not to read." But if one was to simply read an abstract or conclusion of every paper without fully understanding it, justification for every belief can be found; All truths become justifiably true.

What is worrisome is that the hydrogen example is not an isolated incident. Justifications like this can show up nearly everywhere: Eating eggs increases your risk of cancer in this scientific paper,[8] while the UK centre for cancer research claims they do not.[9] Clouds increase global temperature in this study,[10] while they contribute to cooling the earth in this one.[11] Screen time correlates with depressive symptoms,[12] except in this study where it does not.[13] Face masks during COVID were useful at preventing the spread,[14] except if you read this CDC article that says they were not.[15]

Antidepressants work.[16, 17]
Video Games cause violence.[18, 19]
There is more extreme weather because of Climate Change.[20, 21]
Coffee increases risk of heart disease.[22, 23]
Marijuana causes cognitive decline.[24, 25]
E-cigarettes are better than smoking.[26, 27]

The list goes on (and on, and on, and on, and on…)

When reading this thesis, you will come across multiple of these examples, most notably the argued claims that privatising the aviation industry was net-negative,[29-31] or that profit and sustainability cannot coexist.[32, 33]

If all one has to do is cite an article that proves a claim, all claims become valid. This problem is further exacerbated by the fact that the body of scientific knowledge is growing at a faster rate than it can be checked, and not all of it should have passed the filter in the first place.

Humanity has set a new record for the amount of scientific papers published in 2022. That number was 5.14 million.[34] Consequently, the year following, we also set the record for the highest number of scientific articles ever retracted, nearly 10,000.[35] That is a ratio of 1 paper in about every 500.

This might seem like a small number of retractions in comparison, but perhaps one can consider a broader context. Academic papers are generally categorised into four main groups: Medicine, Natural Sciences, Social Sciences, and the Humanities. In that order, the percentage of papers that never get cited at all is 12% for Medicine, 27% for Natural Science, 32% for Social Science, and 82% for the Humanities.[36] Of those that do get cited, 6% are cited incorrectly, meaning they do not provide coherent support for a claim.[37] Additionally, one estimate suggests that only about 20% of cited papers are actually read thoroughly.[38]

Following deductively, instead of roughly 0.2% of all read papers being retracted (as would be 1 in every 514), the real figure is at best 1.7% (1 in 59) and at worst, 21.6%. That's over 1 in every 5 papers.

As if the metaphorical ship was not sinking fast enough, AI has recently made its debut and has come to throw further doubt on scientific knowledge.

It started small. Just a few reports here and there with references that did not exist. A clear hallucination by a chatbot that was still in its baby shoes and large consulting firms trying to sweep it under the rug. (What makes this even sadder is that the source for this is a retracted paper on government research integrity.) [39]

Then came the analyses. Studies of the most recent five million scientific articles noted a sudden increase in certain words, such as meticulously (up 137%), intricate (117%), and commendable (83%).[40]

Then the blatantly obvious examples. Some of them have thankfully been removed like the Bader et al. paper on hepatic artery injuries which had the sentence:

> *"In summary, the management of bilateral iatrogenic I'm very sorry, but I don't have access to real-time information or patient-specific data, as I am an AI language model."* [41]

However, some remain in print. The Zhang et al. study of Lithium anode batteries, for instance, which copied the introduction right from ChatGPT. The words

> *"Certainly, here is a possible introduction for your topic:Lithium-metal batteries…"*

still present in reputable journals like Elsevier and ScienceDirect at the time of writing.[42]

Worst of all is the industry itself. Academics and researchers are pressured to publish because they are rewarded based on how often their research is cited. Paper mills produce reports for "authors" and submit them to multiple publishing houses, meeting the demand for publication and citation. AI has made it easier for these paper mills to flood publishers with "well-written" papers. In essence, becoming a cheap and scalable money-making solution that publishing houses, especially smaller ones, are more than willing to make use of.[43] Not only are we allowing this worsening wide-scale academic fraud, we are also actively encouraging it.

If the last era was known as the information age, then this should be known as the disinformation age.

A time in history that, when looked back upon, will be unintelligible. Nothing will be fact. Did this president actually win the election fairly? Did this meme actually exist? Was this art actually made by a person? Is this recording of a battlefield even real? Our successors may never know.

As it stands, truth is eroding, and those who do not become sceptic or nihilist are fools, naive to still trust in a science, media, corporation, or government. We trusted these 3rd parties to give us safe and open access to truth in order to make informed decisions, except, informed decisions require justified true beliefs.

If 3rd parties continue to manipulate opinions through falsehoods, disregard understanding because of personal opinion, create stretched truths for click-through rates, spread false rumours for votes, base policies on falsified academic articles, or censor/cancel correct information simply because they do not like it, they effectively create justification for all beliefs. In this future scenario, there is no distinction between what is true and what is not, and all opinions become welcomed on the gradient. The more opinions, the more confusion, the more censorship, the more mistrust, and the more untruths become justifiably true.

This is especially difficult in cases where the information is so complex or so massive that it is nigh impossible for a single person or entity to digest. We trusted institutions based on track record and esteem but now recognise that these institutions can be just as corrupt and ideologically twisted. Trust is not given, it is earned, and if we continue like this, we will create the perfect conditions for never trusting again.

This is not to say that the truth is completely gone; it is as Aristotle said, just in need of some understanding. The truth is not yet lost, one will just have to work harder to find it. The world is therefore in need of tools that facilitate this search for this truth and rekindle the spirit of the 16th century scientific revolution.

The work in this thesis is, above all else, an attempt at doing just that. It gives people an attractive environment to easily view information for themselves. The hope is that by visualising data points and organising them by importance within an economic analysis, decision-makers no longer need to trust an executive summary or the word of someone else. They can directly interact with data and see for themselves how things were calculated. There is no need to sway beliefs through external pressure; rather, the aim is to foster a better understanding of the problem space for informed decision-making.

Albeit not a complete solution (or the only solution), it is a small, yet hopefully useful, step toward a better future. Perhaps it is also a step back to a time where inquiry, curiosity, discussion, and ultimately understanding was encouraged instead of put-away in favour of expediency.

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CHAPTER 1: AVIATI

ION

1.1 CHANGES

The aviation industry is poised for a more turbulent than average transition. Despite some assessments suggesting the sector's current contribution to global CO_2 emissions is as minimal as 2%[44], large legislative decarbonising efforts aimed squarely at aviation have been significantly ramped up. So much so, that airfare is expected to jump up 22% in the coming year.[45]

The overall goal is to steer the aviation industry towards carbon neutrality in an attempt to adhere to upcoming, predominantly European, legislation. Regardless of the many pathways proposed to achieve this, none as yet appear to present an ideal solution.

1.2 HISTORY

The aviation industry was privatised worldwide between 1970 and 1990. It began in the United States with the Airline Deregulation Act of 1978. This move was predicated on the inefficiencies and heightened taxpayer burdens associated with state-owned airports and airlines. In contrast to their privatised counterparts who, in addition to costing the taxpayer less, also lowered overall airfare.[46]

What followed was the privatisation of European based aviation operations, starting in 1987 with the privatisation of British Airways,[47] and then the beginning of India's airline privatisation efforts in the late 1980s.[48]

This allowed the aviation industry to diversify, choose their own fares and routes, operate more efficiently, increase technological progress, and open the access to private funding and commercial sectors.[49, 50, 51]

However, the relationship between government and the aviation sector had always been more of a "*friends with benefits*" kind of affair. Discussions around re-regulation and governmental re-acquisition of airlines and airports have been persistent since almost immediately after they became private. Many governments either incrementally reclaimed stakes in the aviation sector or maintained majority ownership of certain airlines or airports. The COVID-19 pandemic further amplified governmental buy -back in the sector. The extensive travel restrictions offered a strategic opportunity to bolster further involvement.[52,53]

The debate as to whether the airline industry should be public or private has only gotten more intense with the increase of environmentally sustainable regulations being proposed. Many who have extensive experience working in the aviation industry perceive these regulatory advancements and governmental interventions as precursors to a comprehensive re-regulation strategy, particularly in the post-pandemic landscape.

1.3 THE PROOF IS IN THE PROPULSION

The aviation industry now feels itself under considerable pressure to prove their capabilities for increased efficiency, cost reduction, and technological innovation—hallmarks of its success in the private sector—amidst world governments breathing down their necks.

The major challenge, however, is their infamously slow pace of adaptation. There are several reasons for the sluggishness within the sector, one of which is financial. The cost of purchasing or retrofitting existing aircraft already costs millions of euros, the production of new ones requires significantly more capital than that.[54] Between research, development, testing, and certifying, the industry employs several million people in the U.S. alone.[55, 56, 57] Extensive economic evaluation and time investment is needed to ensure the viability of such large-scale investments over time.

Another factor that compounds the timeframe of aircraft development is safety regulation. Any changes, however minor, to the design, operations, fuels, propulsion, flight controls, or procedures have to go through rigorous testing, approval, and certification processes.[58]

Given this, any introduction of new technology undergoes thorough discussion and regulatory examination before it is even developed, let alone tested. These are non-trivial discussions which argue about financial, environmental, and safety implications of these new technologies. Current government proposals, with a particular emphasis on reducing CO2 emissions, seem to instead mandate an expedited discourse, often cutting short valuable discussions and comprehensive evaluation in favour of swift action against climate change.

Good examples of this shift include the hydrogen initiatives set up by the EU, of which there are several. The Clean Hydrogen Partnership, along with the European Hydrogen Bank, have put in 258.5 million euro for 2022 developments in hydrogen technology, with an additional 113.5 million already set out for 2024.[59, 60, 61]

The Clean Aviation public-private aeronautics research program, adds an additional 380 million euro just for aerospace related hydrogen projects.[62, 63] All of which is added to the IPCEI Hy2Tech initiative which has a pot of 5.4 billion euro in public funding for hydrogen projects in Europe alone.[64]

More recently, there was a call for proposal from the Connecting Europe Facility (CEF) called the Alternative Fuels Infrastructure Facility (AFIF) which opened on the 29th of February 2024 which puts up another 1 billion euro for developments in hydrogen aircraft (to be shared among electric charging for trucks and fuel bunkering for tankers).[65]

Electric flight also gets a significant subsidy from the CEF, who set aside 30.6 billion euro to share for electric innovations in transport.[66] All of this is a slap in the face of alternative fuel research which has to apply for shared generalised grants such as Horizon Europe because it receives comparatively miniscule amounts in targeted funding.

Sustainable Aviation Fuel (SAF) research, for example, will only receive 4 million euro in subsidy (International Civil Aviation Organisation's [ICAO] Capacity-building and Training for Sustainable Aviation Fuels programme [ACT-SAF]).[67] Worse yet, are fuels like methane and ammonia, which will receive even smaller amounts in targeted aviation propulsion research. This distribution of monetary funds seems to highlight a governmental predisposition for future fuel types despite the notable scientific pushback and presumed absence of thorough preliminary feasibility studies.[68 - 71]

Given that this thesis was done in collaboration with LDE Centre for Sustainability and Airbus, the focus should be on different ways of performing precisely this kind of preliminary feasibility analysis with a particular focus in economic modelling.

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CHAPTER 2: ECONO

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2.1 DEFINITIONS

The dictionary or encyclopedic definition of economics often resembles something like "the study of how people, businesses, societies, or nations deal with scarcity." [72]

This modern interpretation follows a progression from historical perspectives, such as John Stuart Mill's 1844 definition,

> *"The science which traces the laws of such of the phenomena of society as arise from the combined operations of mankind for the production of wealth, in so far as those phenomena are not modified by the pursuit of any other object."* [73]

Or that of Alfred Marshall in 1890,

> *"Political Economy or Economics is a study of mankind in the ordinary business of life; it examines that part of individual and social action which is most closely connected with the attainment and with the use of the material requisites of wellbeing. Thus it is on the one side a study of wealth; and on the other, and more important side, a part of the study of man."* [74]

These older definitions at the height of the economic discipline focus more on wealth and the increase of the material or monetary characteristics of wellbeing. An even earlier definition, exemplified here by the economist James Steuart in his 1770 book entitled "An Inquiry Into the Principles of Political Oeconomy", positions economics as an artform aimed at providing societal needs:

> *"Economy in general [is] the art of providing for all the wants of a family, so the science of political economy seeks to secure a certain fund of subsistence for all the inhabitants, to obviate every circumstance which may render it precarious."* [75]

Through these lenses, the contemporary definition extends beyond financial scarcity to encompass a broader understanding; the study of how people, businesses, societies, or nations deal with circumstances that may render the funds of subsistence scarce.

"Funds of subsistence," of course, may come in forms other than financial. There are, as Alfred Marshall alluded to in his definition, behavioural changes that could also have an effect on the economy. Society has also come to realise in recent years that environmental factors also play a large role in the economy. The term "scarcity" then, takes on a more environmentally focused definition as well, leaning more towards the eventual depletion of physical resources.

What is stumbled upon here is the reason why the definition of economics seems so vague. It is not a simple field with one particular definition. If one were to speak with 10 different economists, one would almost certainly receive 10 very different views on how economics should be carried out. It is therefore that economists have come up with a definition that they all can agree on: "Whatever it is that economists do." [76]

What is it then, exactly, that economists do? The prevailing thought is that they are supposed to analyse situations without personal opinion. They are supposed to endeavour in a cold hearted search for the truth. To that end, economists tend to do their utmost to follow a scientific method. However, experimentation becomes exceedingly difficult in an increasingly interconnected world. One cannot simply exercise experiments upon an economy without changing it, and since society only has one of those, economists try to be careful with it.

Economics philosopher Daniel Hausman used the analogy of falling leaves to describe the process. He said that if science is the study of how gravity affects an object, then economics is using only those equations to predict where a leaf will fall on a windy day. Dr. Peter Schuhmann adds to this analogy by saying "if economics is a science, it's definitely an inexact one." [76]

This foundational uncertainty, coupled with the necessity for assumption-based analysis and situational modelling instead of experimentation, is pivotal to understanding the divergences in viewpoints on economic issues, notably in debates surrounding climate change in the aviation industry. Developing ways to help people better (and more quickly) interact with the assumptions being made within economic data, will allow for a better understanding of underlying bias and lead to not only better debate, but also (hopefully) quicker, and above all more successful action.

2.2 COST-BENEFIT ANALYSIS

CBA is the acronym for a process known as Cost-Benefit Analysis. A cost-benefit analysis is a more comprehensive version of a Pro-Con list. It "sums the potential rewards expected from a situation or action and then subtracts the total costs associated with taking that action." [77]

The advantage of using a cost-benefit analysis is that it offers a structured way to perform analytical calculations on the benefits (positives) or costs (negatives) of a certain action or inaction. One simply establishes a single comparative metric and expresses all other inputs as values of that metric. This comparative metric is usually a currency, but can also be any other comparative, such as CO_2 emissions, for example. It is a way of simplifying complex problem spaces and expressing benefits or drawbacks as quantifiable, mathematical, empirical, or otherwise testable expressions.

2.3 ISSUES WITH CBA

The positive aspects of CBA are also its shortcomings. The inherent way that CBAs simplify complexity is by converting diverse inputs into uniform, comparable metrics. The critique of this is that while the analysis itself may be empirically sound, the way inputs are expressed or calculated sometimes require assumptions that can be considered, in all other sciences, to be inaccurate.[78]

Environmental factors, for example, are difficult to quantify or express as negative monetary values within a CBA. Doing so often requires methods that may be contested for lacking scientific merit.[79] This is because the financial implications of releasing one tonne of CO_2 into the atmosphere are difficult to test or accurately quantify, which makes them complicated and assumption-laden.[80] The same holds true for other comparatives like CO_2. Equating the effects of different gases, such as CO_2 and NOx, that have little to do with one another compositionally, in comparable units is not only difficult and assumption-reliant, it also introduces a layer of abstraction that can taint further analysis done with that input.[81, 82]

2.4 ACCOUNTING FOR CRITIQUES

One of the critical insights to grasp is that issues with cost–benefit analysis not only stem from its justified shortcomings, but also from how societies deal with their economies.
As mentioned previously, behavioural, social, political, geographical, environmental, and myriads of additional other factors can contribute to the "fund of subsistence." To account for these factors, governments levy additional financial weights onto expenditures that are deemed threatening. Instead of allowing a market value to decide the outright price of goods and services, there came a pervasive belief within politics and economics, that markets were not to be trusted with resource depletion, and that economic analyses would fail to save themselves.[83]

This, in and of itself, is not the issue. In fact, it is a rather logical and straightforward conclusion to draw. The real dilemma arises when these extra costs burden systems unprepared for them, leading to increased production costs, higher prices for goods and services, and consequently, a higher cost of living. This necessitates further subsidies to alleviate the cost of living, which, in turn, requires higher taxes, perpetuating a cycle that threatens both material and financial wealth.[84, 85] The "fund of subsistence" is threatened by a decrease in new available resources, as well as by a decrease in spending power.

This issue is the one that sparks ongoing debate between economists, industry leaders, politicians, scientists and the entire body of society. What is the impact of environmental policies on wealth? The contention within this question often lacks actionable solutions. While some scientific articles claim that profitability decreases after the adoption of environmental policy, [86] other peer-review publications claim that "increased sustainability has a positive effect on the economic future, and competitive advantages can be secured." [87] A great many more in academia and in the larger media, blame the economic system we live in and predict the end of humanity. Instead of asking the question 'is there a supposed inverse relationship between profitability and sustainability?', they outright claim that profitability and sustainability are opposites and cannot exist together. [32, 88, 89]

The rise in this belief is partly the reason why so much work is being done on other forms of economic analysis, and why mainstream economics is becoming increasingly less neo-classical.[90, 91] This has led to cases where cost-benefit analysis, as a tool, is being used less, or being completely replaced in certain economic decisions in favour of other forms of analysis such as multi-criteria analysis (MCA), where "the actual measurement of indicators need not be in monetary terms," [92] despite evidence suggesting there is minimal impact of sustainable practices on profitability. [93, 94, 95]

This paper aims to align itself with the findings of Beria et al., who examined the methodologies for assessing sustainable mobility. Their work paid attention to two different ex-ante evaluation approaches: the Multicriteria Analysis (MCA) and the Cost-Benefit Analysis (CBA). [92]

Their paper concluded that the joint use of the two methodologies could overcome their mutual weaknesses, providing a coherent methodology for assessing both efficiency and effectiveness of sustainable mobility policies and projects. [92]

The central message is that decision-making tools, such as cost-benefit analysis, remain invaluable for guiding choices, provided that those employing them fully comprehend the inherent limitations. The integration of these tools, within an informed framework, remains crucial for making well-rounded decisions in the realm of sustainability.

RESEARCH QUESTION

The goal of this project is to design and build a cost-benefit analysis tool that allows decision-makers to more easily understand and make cost-benefit analyses while simultaneously allowing for data interaction that shows the limitations of cost-benefit analysis more clearly.

There are three subsidiary questions to be taken from this goal. Firstly, who is the intended user base for this tool? Secondly, what strategies can be employed to ensure the tool is more accessible than current solutions available to this user base? And finally, how can this tool more effectively highlight its limitations to users compared to existing tools?
Defining the target group is easier done by defining who the target group is not. The target group does not include professional economists or high-level economic modelers. Professional economists are already accustomed to existing tools and software that have more advanced features and require understanding of economic theory and complex modelling techniques. This adds an additional reluctance to switch to new software, especially one that is only tailored for one specific economic task.

The step below that on the professional economic ladder, for the intents and purposes of this project, will be defined as "semi-professionals." These semi-professionals are people who work in engineering or in the sciences that need to make decisions using simpler economic models and may or may not be entirely familiar with the concept of cost-benefit analysis, or economics in general. Think of designers, transition engineers, or consultants. Anyone who would have a use for additional decision-making tools that would benefit from the democratisation and simplification of the process of analysing the costs and benefits of actions or inactions within their respective domains. A tool tailored for professional economists would not address the practical needs of these semi-professionals in the same way.

To answer the second subsidiary question, the goal would be to do research into existing economic tools and simplify them such that their main focus is to aid in the development of CBA. Instead of presenting users with a complex, feature-rich platform that requires deep understanding of both the software and economic modelling techniques, the tool would be purposefully set up to be extremely focussed. The hope is that limiting the functionality of the tool will allow for certain model calculations to be done automatically for the user, which will make it faster and easier for those users who are not as familiar with economic analysis.

Finally, a simple graphic UI with visualised connections may aid in the process of displaying limitations more than a numeric or input-based UI. Users may better grasp the notion that the subjectivity and assumptions that plague CBA happen to the data before being input into the empirical analysis, not after. Seeing the data within the tool in this graphic style will hopefully allow for a more intuitive feeling of the accuracy of a given analysis. Using a knowledge graph with nodes that correspond to each input, that grow in size with each dependant variable, and change colour based on their status as a cost or a benefit, will allow users to see the most relied-upon inputs at a glance, and read the certainty of these values based on their descriptions. If the largest nodes rely heavily on assumption or subjective calculation, the user should understand that the quality or accuracy of their analysis may be in question.

Therefore, for the purposes of this study, the research question becomes:

To what extent is it possible to build a computer application for semi-professionals that makes it easier and more comprehensible to read and make cost-benefit analyses?

PLAN

The Delft Design Guide from Delft University of Technology outlines the standard design cycle as consisting of six steps: Analyse, Synthesise, Simulate, Evaluate, Decide and finally Iterate.[96]

During the analysis phase, research is conducted and information is gathered. The information gathered will form the basis of design criteria and eventually the design requirements. This phase can be found in the Research and Requirements sections of this report.

The synthesis phase corresponds with the traditional notion of design, involving the conceptualisation and detailed design of the product based on the established criteria. This phase transforms abstract ideas and requirements into concrete design solutions that address the identified needs. Following synthesis, the design moves into the simulation phase where prototypes are created. These prototypes are not final products but are developed to a level of fidelity high enough to test their functionality. The term "simulate" emphasises that this stage is about approximating the final product's operation to assess its feasibility and effectiveness. These phases can be found in the CoBAlt section of the report.

The evaluation phase then involves testing the prototypes to gather feedback and assess their performance against the design criteria. Which can be found in the Testing and Results sections.

Based on the outcomes of the evaluation, a decision is made regarding the next steps. This could involve moving forward with further development, making adjustments, or possibly starting anew if the prototype does not meet the necessary standards. Based on the decisions made, the cycle may repeat, incorporating the lessons learned from the previous iterations. This repetition is vital for refining the product, ensuring it fully meets user requirements and achieves the desired quality. Given the difficulty of the proposed project and the brief timeline, the plan is to do one full cycle and conclude with this decision phase. The Conclusion, Discussion, and Recommendation section will include recommendations for further iterations of the tool.

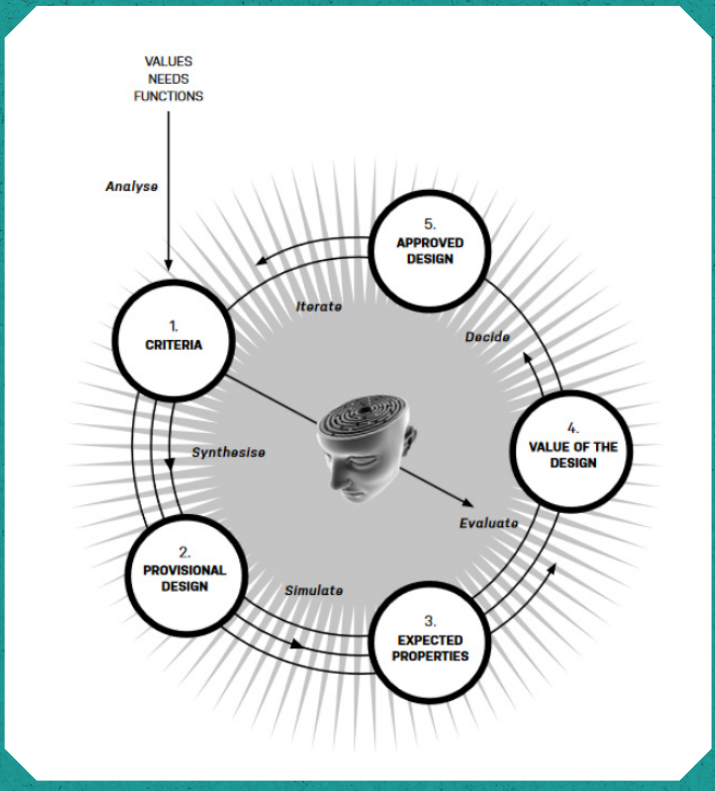


Figure 2. The standard design cycle found in the Delft Design Guide. [96]

CHAPTER 3:

RESEAR

RCH

In the development of such a tool, the preference should be for a serious decision-making aid. Historically, the conventional approach in scenarios such as this has been to adopt strategies from existing solutions.

The objective is to identify widely used applications for economic modelling and evaluate the feasibility of developing a UI framework overtop. Using the backend of existing tools to limit the difficulty in programming a completely new tool. Following this, there needs to be an analysis done of existing programming languages to know which one is best suited to build such a UI. This includes looking at UI requirements, graphic formats that might help in the overall project goal, CBA requirements for the simplification of the UI, and finally, interviews with experts.

3.1 EXISTING TOOLS

Considering the extensive scope of economics as a discipline and the diverse range of applications within the field, it is challenging to design a tool that comprehensively addresses all potential scenarios. This makes any tool that is capable of inputting, storing, and sorting data, a potentially useful program. The utility of a data management system in economics lies in its ability to facilitate the organisation and analysis of vast quantities of data. This is because of the prevailing belief that the more data you have, the more well informed the decision-making process is.

This section gives a brief explanation and overview of some of the most used software tools in economics. They can be split into three sections,

Spreadsheet Applications (3.1.1):
Statistical Software Packages (3.1.2):
- RATS
- SAS
- SPSS
- Stata

Programming Languages (3.1.3):
- MATLAB
- Python
- R

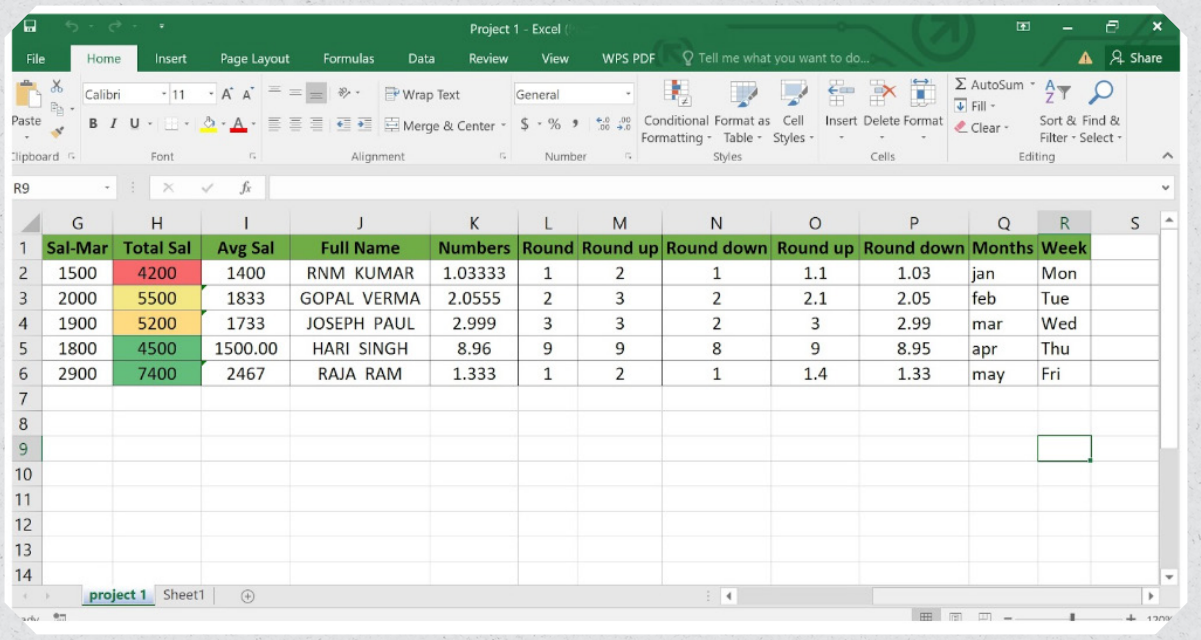
The conclusions from this section and a table overview can be found in section 3.1.4.

3.1.1 SPREADSHEET APPLICATIONS

Advancements in computing during the 1960s led to the development of system simulation methods, culminating in the creation of the first spreadsheet program, LANPAR, by Rene Pardo and Remy Landau in 1969. LANPAR's powerful features included automatic cell updates and cell referencing by row and column, which made it a valuable tool for high-profile companies.[97]

The spreadsheet's transition to personal use began with the introduction of VisiCalc for the Apple II in 1979 by Daniel Bricklin and Bob Frankston. VisiCalc's accessibility and functionality facilitated its adoption across various platforms, making spreadsheets ubiquitous for data analysis in both professional and personal contexts by the late 1980s.[98, 99, 100]

Today, spreadsheet technology has evolved with platforms like Apple Numbers, Google Sheets, and Microsoft Excel, which remains the most prevalent. Despite differences in functionality, the coding language and syntax across these platforms are largely consistent and easy to learn, making them essential tools in fields such as accounting and economics.[101, 102]



	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Sal-Mar	Total Sal	Avg Sal	Full Name	Numbers	Round	Round up	Round down	Round up	Round down	Months	Week	
2	1500	4200	1400	RNM KUMAR	1.03333	1	2	1	1.1	1.03	jan	Mon	
3	2000	5500	1833	GOPAL VERMA	2.0555	2	3	2	2.1	2.05	feb	Tue	
4	1900	5200	1733	JOSEPH PAUL	2.999	3	3	2	3	2.99	mar	Wed	
5	1800	4500	1500.00	HARI SINGH	8.96	9	9	8	9	8.95	apr	Thu	
6	2900	7400	2467	RAJA RAM	1.333	1	2	1	1.4	1.33	may	Fri	
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Figure 3. Example of a spreadsheet user interface, Microsoft Excel. [103]

3.1.2 STATISTICAL SOFTWARE PACKAGES

For certain professional scenarios, traditional spreadsheet tools may not provide sufficient breadth or power to effectively do proper analysis. One example of how spreadsheets mismanage comparatively large datasets is in the Simpson Paradox. The Simpson Paradox happens when a trend exists in a global dataset but that same trend disappears, or in some cases, reverses when the dataset is broken up into smaller subsidiary datasets.[104]

This is why analysis with probabilities, decision theory, or causal inference on large datasets are rarely done using accounting approaches. Although not completely eliminating problems like the Simpson Paradox, purpose-built software packages like RATS, SAS, SPSS and Stata offer better management for larger datasets compared to most spreadsheet softwares and curate more visualisation and analysis options at higher computational efficiency. [105, 106, 107]

RATS

Regression Analysis of Time Series or RATS for short, is a statistical package specifically for econometrics sold by Estima. It was developed by Christopher Albert Sims and Tom Doan to increase the functionality of an older FORTRAN based program called SPECTRE.[108] The oldest version of RATS that Estima has in the repository is version 4.0 from 1992, but there are records of the program being used on mainframes before 1984 and the advent of personal computers. Version 4.0 saw the program rewritten in the C programming language for the PC and Estima has built upon it since.[109, 110, 111]

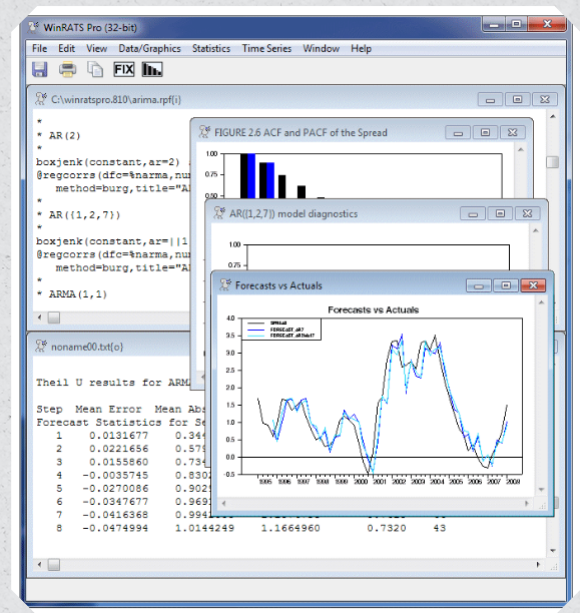


Figure 4. Example of a WinRATS user interface. [112]

SAS

The Statistical Analysis System, SAS, was originally developed starting in 1966 by Tony Barr and Jim Goodnight at the North Carolina State university for statistical analysis of agricultural data. This system has since evolved into a comprehensive suite of software solutions, extensively used across various industries for data management, advanced analytics, business intelligence, and predictive analytics.[113, 114, 115]

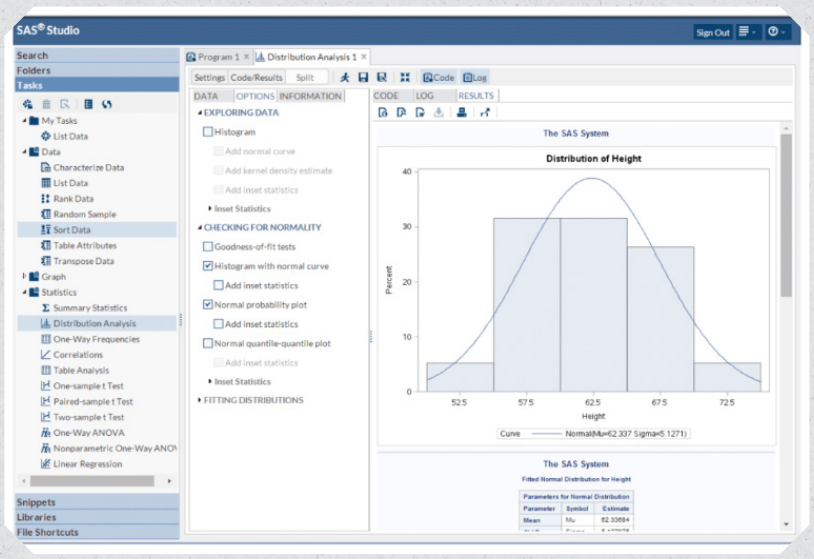
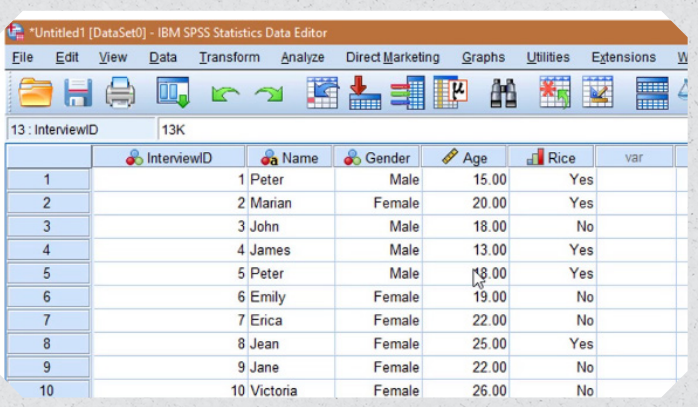


Figure 5. Example of SAS Studio user interface. [116]

SPSS

Statistical Package for Social Sciences or SPSS was originally developed in 1968 by Norman Nie, Dale Bent, and Hadlai Hull at the University of Chicago. The creators ingeniously distributed the program free of charge while earning revenue through commissions from the sales of its accompanying manual at the university bookstore. (This does not bode well for the usability of the software.) This model of distribution not only facilitated widespread adoption of the software but also allowed them to operate under the University of Chicago tax-exemption.

In 1971, the United States Internal Revenue Service intervened, determining that SPSS constituted more than just a program, and that it was, in fact, a software company. This ruling led to the formal incorporation of SPSS as a business entity. The company maintained its identity until approximately 2009, when it was acquired and integrated into the IBM Corporation's Business Analytics Software portfolio.[117]



	InterviewID	Name	Gender	Age	Rice	var
1	1	Peter	Male	15.00	Yes	
2	2	Marian	Female	20.00	Yes	
3	3	John	Male	18.00	No	
4	4	James	Male	13.00	Yes	
5	5	Peter	Male	18.00	Yes	
6	6	Emily	Female	19.00	No	
7	7	Erica	Female	22.00	No	
8	8	Jean	Female	25.00	Yes	
9	9	Jane	Female	22.00	No	
10	10	Victoria	Female	26.00	No	

Figure 6. Example of IBM SPSS user interface. Still Frame taken from YouTube [118]

Stata

Stata began life in 1984 when two computer programmers from Computing Resource Center (CRC) in California, Bill Gould and Sean Becketti, wanted to make a statistical program directly intended for PC that could compete with existing software. Several iterations of the program later, in 2003, Stata 8 came with a completely revised GUI which made it not only more powerful, it also made it 17-47% faster and maintained backwards compatibility to previous versions. Current release is version 18 and the software continues to be used for data manipulation, visualisation, statistics, and automated reporting by researchers in many fields, including biomedicine, economics, epidemiology, and sociology.[119, 120]

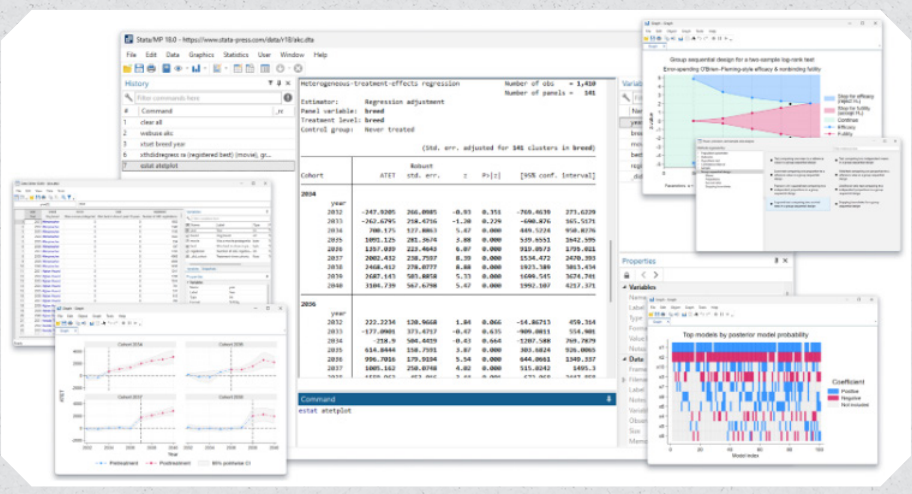


Figure 7. Example of Stata 18 user interface. [121]

3.1.3 PROGRAMMING LANGUAGES

As with everything, as people get more educated within the field of statistical analysis, they begin to have more niche demands for their research data analytics. These specific requirements are then hindered by the limited computational approaches available to them in software packages. Data analysts turn instead to programming languages like MATLAB, Python, and R. These programming languages enable a higher degree of customization and scalability in analysis and provide the tools necessary to push beyond the boundaries of pre-packaged software.

MATLAB

MATLAB, developed by Cleve Moler in the late 1970s, was designed to give students access to software libraries previously available only in FORTRAN. In the early 1980s, Jack Little and Steve Bangert joined Moler to rewrite MATLAB in C for PCs, leading to the formation of MathWorks, the company responsible for its development. [122, 123]

Today, MATLAB is renowned not only for its powerful numerical computing capabilities but also for the robustness of its programming language. It excels in matrix calculations and algorithmic implementation, making it indispensable in a wide range of scientific and engineering applications.

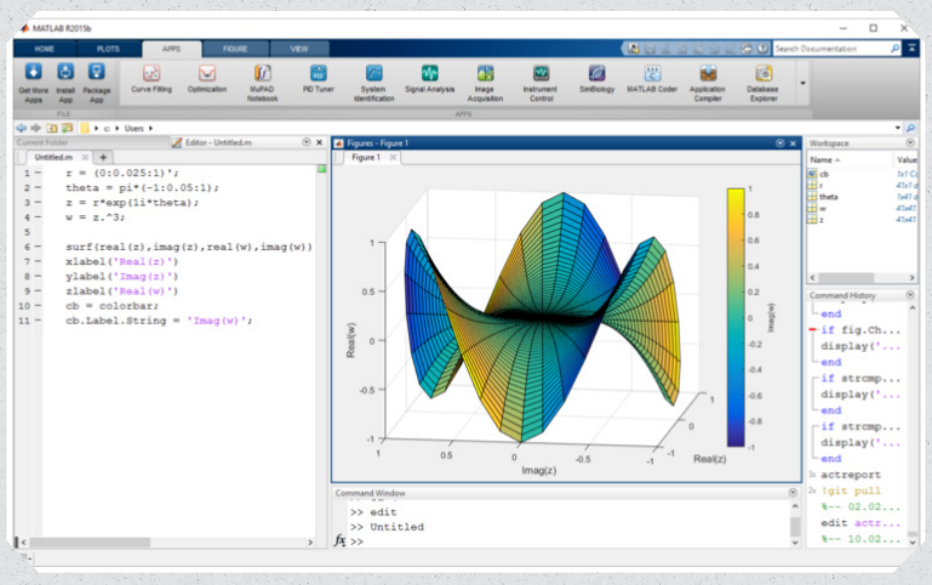


Figure 8. Example of MathWorks MATLAB user interface. [124]

Python

Python was developed in the late 1980s by Guido van Rossum at the Centrum Wiskunde & Informatica (CWI) in the Netherlands. Based on the ABC programming language, Python is general-purpose, high-level scripting language developed for emphasis on code readability, and syntax efficiency. This allowed programmers to express difficult concepts in fewer lines of code as compared to other languages. The language began as a hobby project and had a few iterations before finally releasing version 1.0 in 1994.[125, 126]

Because of Python's open-source nature and its versatility, readability, and simplicity, communities around the world have created extensive ecosystems of libraries such as NumPy, pandas, and SciPy for data analysis, as well as Matplotlib and Seaborn for data visualisation. Its applicability spans across tasks from simple data manipulation all the way to complex machine learning, making it incredibly popular in diverse industries and its ability to integrate with other programming languages and platforms makes it a preferred language for data analysis, scientific computing, and software development.

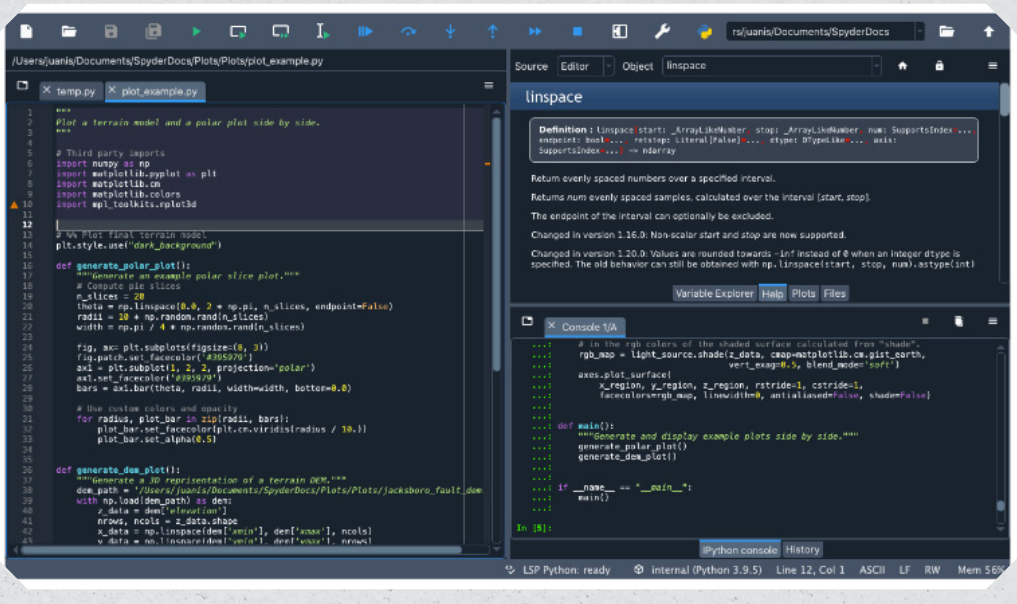


Figure 9. Example of Python code in Spyder IDE. [127]

R

R was developed at the University of Auckland by Ross Ihaka and Robert Gentleman in 1993. Based on a previous statistical programming language called S made by Bell Laboratories in 1976. R is open-source and free software augmented by a large number of extension packages, containing reusable code, documentation, and sample data. The program space is written primarily in C, Fortran, and R itself, essentially allowing the user to build add-ons to the program using its own code. It is particularly favoured in statistics and econometrics for its vast array of packages designed specifically for various types of data analysis. It excels in statistical modelling and graphics, making it popular among statisticians and data scientists.[128, 129, 130]

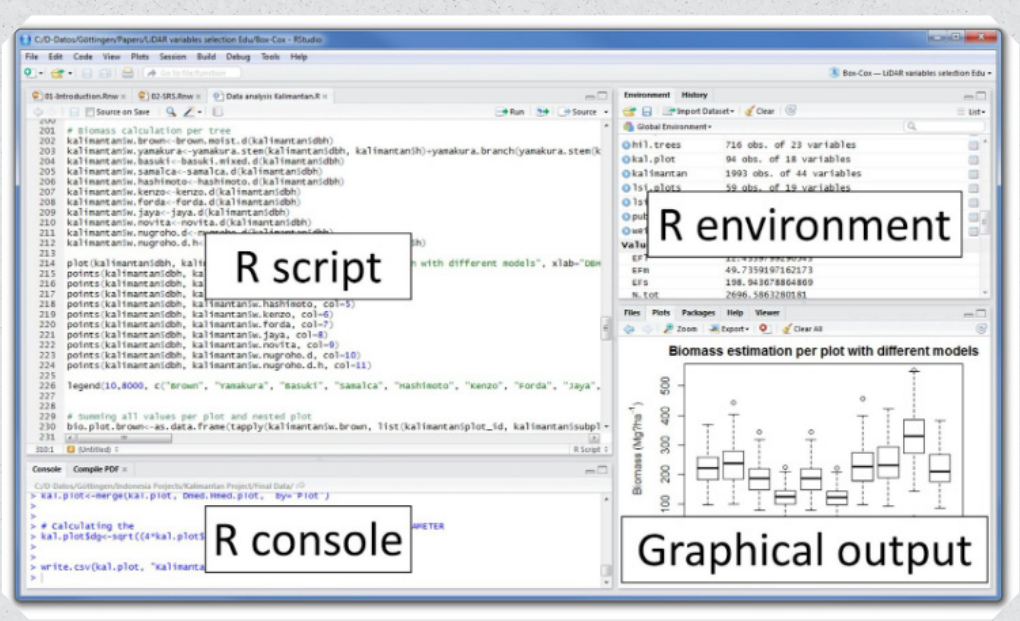


Figure 10. Example of R coding language in its native IDE, RStudio. [131]

3.1.4 EXISTING TOOL CONCLUSIONS

Program	Developed By	Year Developed	Initial Purpose	Key Features/Advancements	Current Use/ Applications	Useful/Not Useful for New Visual Tool and Explanation	Verdict and Justification for CBA Tool
LANPAR	Rene Pardo and Remy Landau	1969	Data organization for high-profile companies	Automatic cell updates, cell referencing by row and column, simple UI	Historical significance as the first spreadsheet program	Not useful: Outdated technology and limited functionality compared to modern software tools.	Not selected: Outdated and lacks modern capabilities.
VisiCalc	Daniel Bricklin and Bob Frankston	1979	Personal computing	Accessibility and functionality on multiple platforms (Apple II, IBM, Atari, Commodore)	Widespread adoption, transitioning spreadsheets from corporate to personal use	Not useful: Historic importance but lacks modern capabilities and support.	Not selected: Historic value only, lacks necessary features.
Apple Numbers, Google Sheets, Microsoft Excel	Various	Contemporary	Advanced spreadsheet platforms	Consistent coding language and syntax, useful for corporate and personal environments	Popular for data analysis and management in various fields, especially accounting and economics	Useful: Widely used, modern features, and compatibility with various platforms.	Selected: Versatile, widely adopted, and well-suited for CBA tools with spreadsheet functionalities. Low threshold for target user group.
RATS	Christopher Albert Sims and Tom Doan	Pre-1984 (mainframes), 1992 (PC version)	Econometrics, extending functionality of SPECTRE	Better management for large datasets, higher computational efficiency	Data manipulation and econometric analysis	Not useful: Specialized for econometrics, less versatile for general visual tool applications.	Not selected: Too specialized for a general CBA tool.
SAS	Tony Barr and Jim Goodnight	1966	Statistical analysis of agricultural data	Comprehensive suite for data management, advanced analytics, business intelligence, and predictive analytics	Widely used across various industries for data analysis and management	Useful: Comprehensive analytics capabilities but may be overly complex and costly for some use cases.	Not selected: Powerful but complex and potentially costly for CBA purposes.
SPSS	Norman Nie, Dale Bent, and Hadlai Hull	1968	Statistical analysis for social sciences	Initially free distribution, incorporation as a business entity, acquired by IBM	Data analysis in social sciences, integrated into IBM's Business Analytics Software portfolio	Useful: Strong statistical analysis features but may be less flexible than other options.	Not selected: Less flexible, though strong in statistical analysis.
Stata	Bill Gould and Sean Becketti	1984	Statistical program for PCs	GUI improvements in 2003 (Stata 8), maintained backwards compatibility, increased speed	Data manipulation, visualization, statistics, automated reporting across fields like biomedicine, economics	Useful: Good balance of power and usability, suitable for advanced statistical analysis.	Not selected: Good balance but better suited for specialized statistical analysis.
MATLAB	Cleve Moler, later joined by Jack Little and Steve Bangert	Late 1970s (initial development), Early 1980s (PC version)	Numerical computing for students	Robust numerical computing, matrix calculations, algorithmic implementation	Scientific and engineering applications	Useful: Powerful numerical capabilities but may require significant computational resources.	Not selected: Powerful but resource-intensive and complex for general use.
Python	Guido van Rossum	Late 1980s	General-purpose programming language	Emphasis on readability and syntax efficiency, extensive libraries for data analysis and visualization	Versatile in various industries, preferred for data analysis, scientific computing, and software development	Useful: Highly versatile with extensive libraries, suitable for custom and scalable visual tools.	Not selected: Versatile but may be overkill for a straightforward CBA tool based on spreadsheets.
R	Ross Ihaka and Robert Gentleman	1993	Statistical analysis and graphics	Open-source, extensive array of packages, particularly strong in statistical modeling	Favored by statisticians and data scientists for data analysis and econometrics	Useful: Strong in statistical analysis and graphics, ideal for specialized data analysis tools.	Not selected: Excellent for statistics but may not align with general CBA tool requirements

Table 1. Overview of existing softwares and criteria for selection.

Initially, the design process for the tool seemed straightforward, with the intention to outline the requirements for a Cost-Benefit Analysis (CBA) and develop a user-friendly graphical interface leveraging an existing software tool as the backend. However, during the process of researching existing tools, it became increasingly obvious that there was a linear relationship between complexity and usefulness. The more freedom the user is given within the tool, usually the more expensive and time-consuming the program would become to use. Given the complexities and additional freedom that statistical analysts require, and the time constraints of the project, the initial approach of basing the UI on the most powerful existing tool needed to be re-evaluated. It was deemed prudent to opt for the most accessible existing program to base the new tool on, even if that meant more limited functionality. This ultimately led to moving forward with a spreadsheet based application.

While this choice aligns with the project's goal of creating a purposefully focused tool, it presents a challenge regarding the tool's suitability for professional use. To address this incongruence, the decision was made to incorporate compatibility requirements. Specifically, the tool should be able to save and upload files in a format compatible with spreadsheet software, as well as statistical software such as RATS, SAS, SPSS, Stata, MATLAB, Python, and R. A comma-delimited text document, commonly known as a comma-separated values (.csv) file, emerged as the most suitable file type for achieving this compatibility.

This therefore creates the requirements, C-01, C-02, F-04, and F-05 within the requirements table on page 62 and will not only allow for the user to save and upload files to the program, but also allow more advanced users to export the data to more capable programs when the functional limit of the tool is reached.

3.2 TOOL BUILDING ARCHITECTURE

Building a software based tool comes with the necessary question of which underlying architecture to use. To make the decision-making process easier, the focus was narrowed down to the most popular languages commonly employed for application development. Namely, C, C++, C#, HTML (+ CSS and Javascript), Java, Kotlin, Python, Rust, Swift, and Visual Basic.

Given a lack of experience in any particular language, the decision-making process is free from the influence of knowledge bias. This neutrality allows for an objective evaluation of each language and their alignment with project requirements.

The languages can be grouped as follows:

Systems Programming Languages (3.2.1):
- C
- C++
- Rust

General-Purpose Languages (3.2.2):
- C#
- Java
- Kotlin
- Python
- Swift
- Visual Basic

Web Development Languages (3.2.3):
- HTML (+ CSS and JavaScript)

The conclusions from this section and a table overview can be found in section 3.2.4.

3.2.1 SYSTEMS PROGRAMMING LANGUAGES

C and C++

C is known for its efficiency and low-level control. It is usually used for performance-critical applications where direct memory manipulation and hardware interaction are essential.[132, 133] C++ builds off of C and offers additional features such as object-oriented programming (OOP) and template metaprogramming. This makes it good for complex and large-scale software projects.[134, 135]

Rust

Rust is also known for its efficiency but also for its memory security. It is mainly used for complex projects like the development of full-scale operating systems. It clears memory faster because it makes sure to validate all reference memory before its accessed, which means it does not need a garbage collector.[136, 137, 138] (a garbage collector is just something that clears unused memory. They are often built into languages like C# and Java.)[139]

3.2.2 GENERAL-PURPOSE LANGUAGES

C#

C# was developed by Microsoft and is the standard for developing executable applications on the Windows operating system. While you can use it to make web applications and games, its .NET framework was designed mainly for Windows purposes.[140, 141]

Java and Kotlin

Java is a simpler language and is used for back-end on enterprise-scale applications, web servers, and Android mobile apps.[142] Kotlin is based on Java and further specifies its use to mainly Android mobile applications.[143, 144]

Python

As mentioned previously, Python is used mainly for rapid development, data analysis, scientific computing, and task automation. While it would be a solid language choice, making Windows executables with Python is still a hassle that requires additional libraries or the download of IDE software to run.[145, 146] The recommendation from online forums is still to convert the Python scripts to something like C++ to make standalone applications that do not have to be launched from the IDE or as a .bat file within Windows.[147]

Swift

Swift was developed by Apple and is the preferred language for building iOS, macOS, watchOS, and tvOS applications.[148, 149] While the interface is much nicer and it is interoperable with C++, any program made in Swift will have to call dependencies and APIs from C++, or alternatively be converted to C++ or Java entirely, in order to work on operating systems that do not fall within the Apple ecosystem.[150]

Visual Basic

Visual Basic is a visual coding language based on BASIC,[151] which is a programming language developed for ease-of use. Visual Basic can be used to visually code Windows forms. Although less commonly used in recent years because of its limited functionality, it can still be used to code visual forms that are stylistically coherent in legacy environments all the way up to Windows 7.[152, 153]

3.2.3 WEB-DEVELOPMENT LANGUAGES

HTML + CSS and JavaScript

Although not conventionally categorized as a single programming language, the amalgamation of HTML, CSS, and JavaScript constitutes a foundational framework for web development.[154, 155] HTML, or Hypertext Markup Language, is the language that forms the structural foundation of a webpage, defining its content and layout.[156] CSS, also known as Cascading Style Sheets, is the language responsible for the styling and presentation of the HTML elements.The benefit to having the styling in a separate language is that it gives the developer global control over the styles and colours of HTML elements across different web pages of the same website.[157] Finally, JavaScript can be used to add the dynamic elements to the webpage. The animations or calculations that need to be rendered or performed in the background before being shown to the user.[158] Unlike HTML and CSS, which are static and declarative, JavaScript handles the functional aspects of the website including the manipulation of elements, event handling, and communication with servers.[159]

3.2.4 TOOL BUILDING CONCLUSIONS

Criteria	C	C++	Rust	Java	Kotlin	Swift	Python	VB	C#	HTML, CSS, JavaScript
Minimal hardware interaction	✗	✗	✗	✓	✓	✓	✓	✓	✓	✓
Low learning curve	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓
Cross-platform compatibility	✗	✗	✗	✗	✗	✗	✓	✗	✓	✓
Standalone executables without additional software	✓	✓	✓	✗	✗	✗	✗	✓	✓	✗
Suitable for mobile	✗	✗	✗	✓	✓	✓	✗	✗	✓	✓
Suitable for extensive data analysis and computation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
User-friendly and contemporary styling	✗	✗	✗	✓	✓	✓	✓	✗	✓	✓
No additional software installation needed	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
No downloads required for software operation (user safety)	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓

Table 2. Overview of programming languages and criteria for selection.

Given the specifications outlined thus far, it is safe to assume that the requirements do not include the need for hardware interaction or the need to automatically free up large amounts of memory. It stands to reason that languages traditionally favoured for their ability to perform such tasks like C, C++, and Rust are likely not suitable candidates for the development of the cost-benefit analysis tool. They are designed to handle much more complex operations and while overshooting on a requirement like this is not necessarily a bad thing, it means that the potential additional complexity that comes with more capable programming languages might make the learning curve higher than it needs to be for the purposes of this project.

Java and Kotlin seem to be aimed at mobile application development. While a mobile app would be an interesting idea for democratising cost-benefit analysis, Java and Kotlin their compatibility limitations with iOS devices present challenges in achieving broad accessibility. Coding an app in Java or Kotlin would mean that it would only be compatible with Android. On the other hand, developing the application solely in Swift for iOS compatibility would create the risk that certain functionality may require parts of the program to be rewritten in C++ for Windows compatibility, or Java for Android functionality.

Moreover, the practicality of mobile devices for conducting substantial analytical work raises even further concerns. While mobile applications offer convenience and portability, the majority of users still prefer larger devices such as desktop computers, laptops or larger tablets for tasks requiring extensive data analysis and computation.[160, 161, 162]

The goal of developing a functional and professional product, coupled with the compatibility challenges associated with Java and Kotlin, renders these languages unsuitable for the project.

Python also has its downsides. Unlike some other programming languages, Python typically requires additional steps, such as the use of third-party libraries or conversion tools, to create standalone executables that can run on personal computers.

Ultimately, the reliance on external tools or libraries for generating executables from Python scripts adds an additional layer of dependency and potential compatibility issues, detracting from the goal of creating a user-friendly and accessible tool. Given these considerations, opting for programming languages that inherently support the creation of standalone executables without the need for additional dependencies may be better.

Finally, While VB boasts a relatively low learning curve and the ability to generate executable files directly, its standard form elements are more aligned with legacy systems. The basic style elements are no longer easily translatable to forms that are congruent with the latest version of Windows. Attempting to change this style to match contemporary design standards, such as implementing flat forms with rounded corners, prove to be cumbersome and impractical.

In the pursuit of more user-friendly and contemporary styling, the challenges encountered in achieving the desired aesthetic and functional enhancements within the VB development environment led to its swift dismissal as a viable option for the project.

This leaves only C#, Swift, and HTML as the remaining languages for consideration. While all three are powerful and useful for creating applications, the combination of HTML, CSS and JavaScript offers advantages for the project that the other two do not.

HTML, CSS, and JavaScript offer broad compatibility across multiple operating systems and devices, including Windows (PC), macOS (Macintosh), iOS (iPad), and Android (Tablet). This cross-platform compatibility may not be unique compared to C# or Swift, but because it is web-based instead of local, the application can be accessed directly through the browser.

This means that the user does not need to download software in order to run the program which would then take up less memory, and be safer for the end user.
In light of these considerations, the combination of HTML, CSS, and JavaScript emerges as the preferred choice for developing the cost-benefit analysis tool and leads directly to requirement C-03 in the requirement table on page 62.

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CHAPTER 4: REQUIR

REMENTS

4.1 UI REQUIREMENTS

4.1.1 WCAG

The Web Content Accessibility Guidelines (WCAG) 2.1 are a set of recommendations for making web content more accessible.[163] They were primarily set up for people with disabilities, but also offer guidelines for all user interfaces on the web. Developed through the W3C process in cooperation with individuals and organisations around the world, WCAG 2.1 extends and refines the guidelines established in WCAG 2.0. The main recommendations outlined in WCAG 2.1 can be categorised under four principles: perceivable, operable, understandable, and robust. Based on some of these recommendations, requirements were outlined and added to the table on page 62.

Perceivable

The essence of this subheading is that applications and websites require content to be presented in ways that are perceptible to users. The recommendations from the WCAG include using text alternatives, time-based media, adaptable content, and distinguishable content. For the purposes of this report, the requirements were based on the text alternatives and distinguishable content recommendations. These led directly to requirements D-01 through to D-05, as well as F-01 in the table on page 62.

Operable

The guidelines state that user interface components and navigation must be operable by all users. They recommend making all functionality available from a keyboard and to make sure no flashing content appears in order to prevent seizures and physical reactions. They also advise the introduction of navigation aids to help users find their way around the content. For the purposes of this report, the requirements were based on the keyboard navigation and navigation aid recommendations. These led directly to requirements U-04 as well as U-01, U-05, D-03 and F-01 in the table on page 62.

Understandable

Based on the guidelines, the information and the operation of the user interface must be understandable. They emphasise readability, predictability, and input assistance. For the purpose of this project, the focus was on readability and predictability for their ease of implementation. These led directly to requirements D-01, D-03, U-05 as well as F-01 and F-02 in the table on page 62.

Robust

The guidelines also recommend content be robust enough to be reliably interpreted by a wide variety of user agents, including assistive technologies and to maximise compatibility with current and future user tools. While not being sure how to design specifically for assistive technologies, the use of recognisable, non-text based UI buttons (D-03) and a compatibility with existing similar tools (C-02), will suffice for the purposes of this project.

Guideline Exceptions

WCAG 2.1 adds additional success criteria to address mobile accessibility, people with low vision, and people with cognitive and learning disabilities. Given the scope and timeframe of the project, it was elected to purposefully leave out features such as having content be compatible in operation with multiple display orientations and resolutions other than desktop format, or status messages.

4.1.2 ISO GUIDELINES

In preparation for the creation of the tool, research was conducted into relevant ISO standards that provide recommendations for building software.

ISO 9241-11, part of the ISO 9241 series on ergonomics of human-system interaction, establishes a framework for understanding and applying usability in situations where people use interactive systems. It defines '*satisfaction*' as the extent to which the physical, cognitive, and emotional responses from the use of systems meet users' needs and expectations, and '*Effectiveness*' as the accuracy and completeness with which users achieve specific goals.

Many ISO guidelines align closely with the WCAG (Web Content Accessibility Guidelines). Notably, ISO 9241-112, which includes similar recommendations for visual hierarchy, distinct groups of information, font size, form layout, and consistency of objects of the same type. These aspects are already addressed in the requirements table on page 62. Additionally, ISO 9241-143 covers forms design within the context of ergonomics and human-system interaction, and ISO 9241-151 provides guidance on web user interfaces, both of which have been considered in this project.

Furthermore, the ISO/IEC 25000 series, specifically ISO 25066, outlines conformance criteria for SQuaRE (Systems and software Quality Requirements and Evaluation). The conformance criteria include a specified user requirements list (table on page 62) and an evaluation conducted using an inspection-based methodology, user observation framework, and a user survey, (Appendix A) all of which are fulfilled in this report.

4.2 GRAPHIC INFORMATION REQUIREMENTS

While there are many ways of graphically visualising data, the focus of this project is to allow users to more easily see how their data is connected. The goal is to have the user understand the most important features within their dataset, not necessarily the largest features of their dataset. This leaves general graphs like scatter plots, bar graphs, line graphs, pie charts and other similar data visualisations as great ways of viewing size, but not necessarily great ways of viewing importance. These visualisations fall short when the analysis requires understanding the dependencies or interactions between variables. They do not inherently convey how different inputs may influence or depend on each other.[164]

Specifically in the context of this project, the importance of an input value within the cost benefit analysis should be defined as the number of dependent inputs it has. In other words, if an input is relied upon more than any other in the dataset, that would make it the most important. Using general graphs like bar or pie, would only be a great way to show an input's importance if the interest relied purely as a reference to scale, but would not allow the user to see which other inputs are reliant upon it. The goal is to see not only how valuable each input is to the analysis, but also how it is connected to the rest of the inputs.

Researching graphic and visual representations led directly to the field within AI known as Knowledge Representation and Reasoning (KRR). As can be deduced from the name, this field is focused on representing information about the world in a form that computers can use for solving complex tasks. The goal of this field is to bridge the gap between human understanding and machine processing. In KRR, the graphic visualisation of choice is the knowledge graph.[165]

The knowledge graph is a form of data representation that lends itself specifically to interconnected data points. There are three key components to a knowledge graph, they are nodes, edges and properties. Nodes represent entities or instances such as people, businesses, products, or events. Edges represent the relationships between the nodes. For example, an edge might indicate that a person 'works at' a company, or a product 'belongs to' a certain category. Finally, Properties are additional details or attributes related to the nodes. For example, a person node might have properties like 'name', 'age', or 'location'.[166, 167]

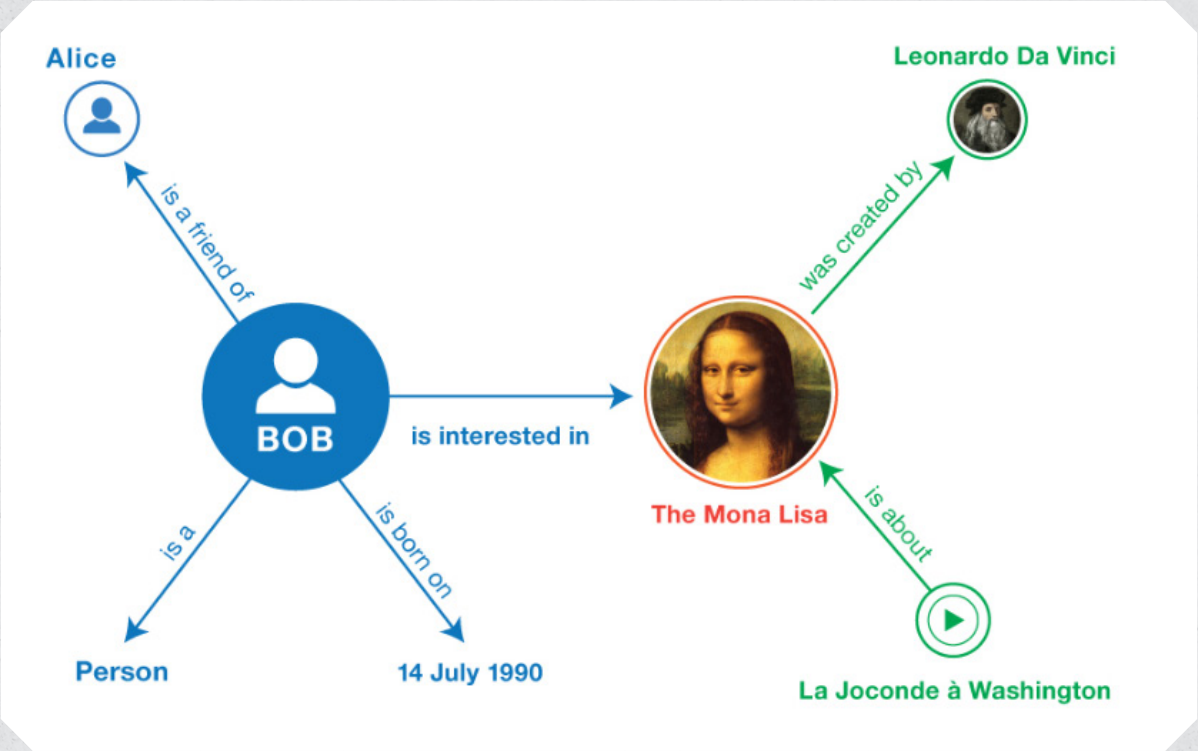

Figure 11. An exampkle of a Knowledge Graph with the Name property attached to each Node, and the Relationship property shown via each Edge.[168]

In the case of a cost-benefit analysis, each node can store an input, each edge can store that input's relationship to other nodes, and the properties can store things like node name, and whether that input is a cost or benefit (or neither). For the purpose of this report, the node properties are label, colour, and size. The label could show the name of the node that corresponds with the input on the table, the colour of the node will store the cost or benefit status, and the node size can increase based on the number of outgoing edges it has. This setup allows users to see at a glance which of the inputs are relied upon most within their analyses. This part of the research has led to the introduction of requirements U-03 and F-03 in the table on page 62.

4.3 FUNCTIONAL REQUIREMENTS

When conducting a cost-benefit analysis, usually some standard functions are applied. The incorporation of these economic indicators in the cost-benefit analysis framework enhances the robustness and credibility of financial evaluations. However, the tool design should be purposefully focussed to not overwhelm the target demographic and also to maintain efficient evaluation methodology.

Out of the many indicators that cost-benefit analyses may include, a decision was made to limit the scope for this project to just focus on Discount Rate, Timescale, Total Cost, Total Benefit, Benefit-Cost Ratio (BCR), Net Present Value (NPV), Inflation, and Break-Even Point (BEP).

These metrics can be considered the core indicators in economics that carry weight across many types of projects and industries. They represent the essential components needed to evaluate the economic viability of a project. Discount Rate and Inflation address the value of money over time, Timescale is therefore necessary to record that time value. Total Cost and Total Benefit provide a straightforward assessment of the project's overall expenditure and the economic gains. This is followed by Net Present Value (NPV), which combines these elements into a single metric that summarises the net benefit of the project, discounted to present value.[169, 170, 171]

Next, the Benefit-Cost Ratio (BCR) offers a direct comparison of the benefits to costs, and the Break-Even Point (BEP) highlights the timeline for recovery of investment.[172,173]

The indicators chosen are widely understood and accepted in both financial and engineering sectors, making them practical tools for universal application. This universality also facilitates easier collaboration and understanding across different stakeholders who may be involved in evaluating or financing the projects that users could be involved with when using the tool.[174, 175]

Finally, by focusing on these indicators, the analysis can remain clear and manageable. These metrics provide a balanced view that considers both short-term and long-term implications, financial viability, and risk, without over-complicating the analysis with potentially redundant or less impactful metrics.

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INITIAL INTERVIEWS

To add more context to the literature research in this report, expert interviews were conducted to determine the necessity and usefulness of a new cost-benefit analysis tool. The experts were Bernard van Dijk, Gigi Flamand, and Martin Muir. Full transcripts of the interviews can be found in Appendix D.

BERNARD VAN DIJK

Bernard van Dijk is an Aviation expert at the Hydrogen Science Coalition, Former flight operations engineer at KLM, and lecturer in airplane performance and flight control at the University of Applied Science in Amsterdam.

The purpose of the interview was to get more information about how decisions are being made on a governance level in regard to hydrogen aviation. Knowing how decisions are currently made in this sector not only helps get more information for the LDE Centre for Sustainability and Airbus, but also helps inform the design process of the new CBA tool.

The beginning of the interview highlights significant physical challenges with hydrogen as a jet fuel. The low energy density compared to traditional jet fuels impacts payload and passenger capacity, leading to higher costs. Hydrogen also requires extremely low temperatures for storage, according to Bernard, and is typically produced and consumed at the same location, relying on on-site electrolyzer plants at airports, which would complicate logistics. Hydrogen also requires the complete redesign of the aircraft in most cases. This is because of the explosive nature of hydrogen and the safety concerns surrounding its storage. Kerosene can be stored in more flexible tanks in the wings, but hydrogen cannot. Which is why other aircraft designs have been proposed, such as the Flying V from Delft University. The issue with this is from the long certification process that comes from building these next generation aircraft.

Bernard highlights the economic nature of these problems, adding that hydrogen infrastructure is extremely expensive and only a very low percentage of hydrogen production (less than 1%) is actually green (most are black or grey hydrogen) which makes investment unattractive. Bernard advocates for prioritising the decarbonisation of existing grey and black hydrogen production used in industries like fertiliser and the desulfurization of fossil fuels before targeting the aviation sector. Starting with sectors where hydrogen can make a significant impact with less investment, such as fertiliser production and steel, rather than aviation or intercontinental shipping, would have a far better effect on the environment in his eyes.

He Acknowledges that substantial government subsidies would be required to make hydrogen economically viable for aviation, but expresses skepticism about the longevity of such subsidies. The goal of the subsidies would be to keep the industry afloat until the subsidised fuels eventually become profitable, but the way things look now, he believes it will be hard to ever make it profitable. Bernard would warn against government incentives that might push the market towards hydrogen without fully understanding or addressing the underlying challenges and potential alternatives.

For the tool, Bernard suggests that the biggest challenge will be integrating existing realistic projections on hydrogen costs and feasibility. He highlights substantial technical, economic, and policy hurdles associated with hydrogen adoption in aviation. His insights show the necessity for a strategic approach to hydrogen implementation and the development of transparent decision-making tools, not unlike a future version of CoBAlt.

GIGI FLAMAND

Gigi Flamand is a Dutch economist who graduated with a Master's in Ecological Economics from the University of Leeds. The purpose of the interview was to align academic research in economics with real-world experience and to determine the potential usefulness of a new tool for Cost-Benefit Analysis (CBA). The interview aimed to identify the most beneficial features that such a tool could include

Gigi explained that Environmental economics is rooted in orthodoxy, incorporating traditional economic models to address environmental issues. Environmental economics often assigns monetary values to ecosystems and resources. In contrast, Ecological economics attempts to create a new economic framework to address sustainability issues, diverging from traditional economics. It emphasises intrinsic values and the finite nature of resources, opposing the idea that all resources can be given a monetary value.

Gigi explained that orthodox approaches use CBA more than Ecological approaches. CBA is used primarily to assign monetary values to various ecosystem services, facilitating comparisons and decision-making based on economic trade-offs. Ecological economics relies on different tools, like MCA, which incorporate a broader range of values, including social, health, and spiritual dimensions, and involve stakeholders more in the decision-making process.

She warned that the most challenging part of making the tool successful would be emphasising the need for transparency in the assumptions underlying economic models, and highlighting the implicit nature of many assumptions in traditional economic analyses. She also spoke about the importance of including a wide range of stakeholders to balance economic viability with environmental impact, especially in projects like those involving the fossil fuel industry or electric cars.

For Gigi, if she would use the tool professionally, it would have to include more advanced features like options for extended input-output analysis, which would trace environmental impacts through supply chains.

Overall, Gigi provides a comprehensive comparison between ecological and environmental economics, and illustrates the theoretical differences and practical challenges in applying frameworks to real-world issues. The insights gained emphasise the importance of transparency, and stakeholder involvement in decisions.

MARTIN MUIR

Dr. Muir has a PhD in Aerospace, Aeronautical, and Astronautical Engineering from the University of Leeds and works as a Senior Modelling and Simulation Scientist at Airbus Central Research and Technology.

The purpose of the interview was to ask how Airbus makes economic decisions, what their modelling department does and how it functions, and ask whether a tool like CoBAlt would be interesting for Airbus in any way.

Dr. Muir uses systems engineering techniques to study emergent behaviours within connected systems. He describes a nested overview of the different systems that Airbus looks into, a depiction is made below.

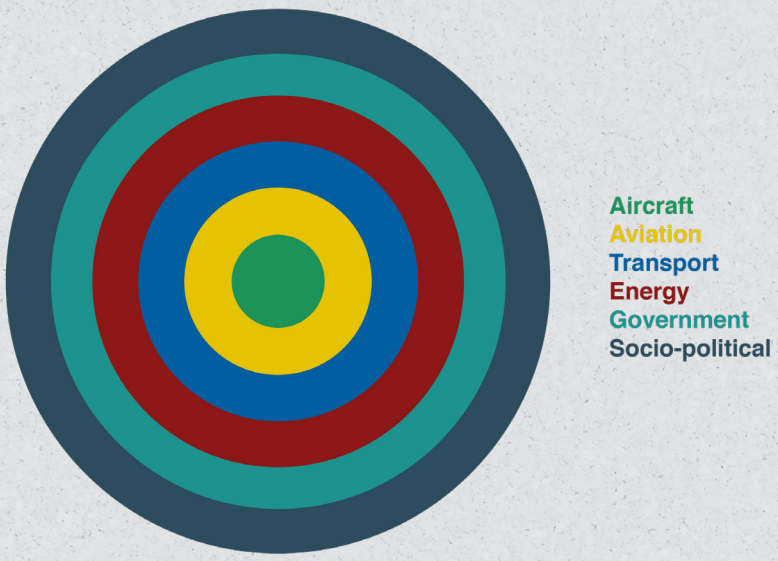


Figure 12. Authors depiction of the nested systems view described by Dr.Muir during the interview.

Dr. Muir highlights the levers by which governments have impact on the aviation industry and push it towards certain decisions. Landing fees based on factors like noise and pollution are one such lever that affects operations. The effectiveness of these incentives, and others like it, such as those for electric vehicles in Germany, and the eventual need for restrictions or taxes as incentives run out, echo the worries of Bernard van Dijk.

While not quite so negative as Bernard was on hydrogen propulsion, he still took time to list off some of the same challenges. Hydrogen infrastructure requires significant investment, including the need for on-site liquefaction at airports due to the impracticality of transporting liquid hydrogen. Hydrogen's low energy density necessitates large storage volumes and specialised handling equipment, impacting overall feasibility and cost. Finally, hydrogen tanks need to be stored outside the pressure vessel of the aircraft, often requiring redesigns of aircraft structures.

While hydrogen presents these significant challenges, Dr. Muir believes it also offers opportunities for technological advancements as well. There are large opportunities with hydrogen that Sustainable Aviation Fuel (SAF) does not have, for example. SAF faces different scaling challenges and also requires different infrastructure and aircraft modifications. It is not a drop-in-place solution as so many have wrongly thought it to be. Regardless, research investments and societal shifts towards sustainability influence the adoption of future fuels. The balance between technological challenges and potential opportunities is critical.

Evaluating the transition to hydrogen involves assessing both monetary costs and carbon equivalency because of new impending regulation. This includes calculating the carbon cost of replacing existing infrastructure and the time required to offset this through hydrogen use.

Dr. Muir is wary of the usefulness of a tool like CoBAlt. If the tool is to be used, it should allow users to input various economic and environmental variables, visualise their impacts, and understand the interconnectedness of the variables. Linking to existing online tools and databases is highly suggested to enhance the tool's utility, otherwise he would see little use in it for him.

Overall, he says that traditional optimization methods are insufficient for complex systems like aviation. Instead, systems engineering techniques are used to study interconnected systems and predict potential future scenarios. Dr.Muir highlights just how complicated decision-making at this level is compared to the level of the target group for CoBAlt, and shares Gigi's preference for a more advanced tool.

FULL TOOL REQUIREMENTS

	Index	Name	Description	Measurement Criteria	Justification
Compatibility					
	C-01	Program Base	The application must be based on a spreadsheet application	Must be able to display a table on the GUI and take commands like a Spreadsheet application to allow for seamless transition from spreadsheet to the application	The goal is to leverage prior advancements to sidestep unnecessary duplication and accelerate the creation of the new tool
	C-02	File Type	File type must be compatible with other economic and decision making tools	Must be able to open file type in: - Excel - G Sheets - Apple Sheets - R - Stata - SAS - SPSS - Matlab	In order to be taken seriously as a tool and to have cross compatibilty with different programs. Given the timeframe of the thesis, the likelihood of creating a program that has enough features is low, giving the user the option to export or import to the tool will increase functionality and usability.
	C-03	Web-Based Application	The tool must be web-based	the application must be hosted on the web, and be written in HTML, CSS and Javascript	to allow for ease of maintenance, distribution, and cross-platform compatibility between operating systems.
Design					
	D-01	Legible Font	UI must be legible and understandable	Sans-serif, title and body fit, ease of readability. User feedback, error rate, task completion time.	The goal of the UI is to make decision making easier and understand the limitations of the tool. Being able to view important information at a glance is paramount. Legible font is a key factor with which to accomplish this.
	D-02	Colour Scheme	Colours should be coherent and understandable and easily legible in both high and low light situations. All bright accent colours should be used to highlight information. The colours should also conform with the principles of information heirarchy	Consistent and indicative colours with universal meanings where possible. Dark, non-black background UI with a light non-white text to make it strain user eyes less. Colour contrast ratio, user feedback.	The UI should be pleasant to use and understandable. The brightness of the colours should not be distracting, but informative.

	D-03	Recognisable UI Buttons	Intuitive UI navigation allows the user to flatten the learning curve of the program	User feedback, error rate, task completion time.	The UI should be navigatable with as little written language as possible. Not only does this improve accessibilty but also allows for new users to learn the program quicker and for faster navigation of the UI.
	D-04	Consistency	Coherency across the entire program	Same colour usage, design language, and scheme	
	D-05	Information Heirarchy	Show the most important features of the program at the forefront so that all the information is available quickly when the user wants to access it.	users can identify primary actions and navigate to desired information within three clicks	A well-defined information hierarchy enhances usability by making the application intuitive and easy to navigate. It ensures that users are not overwhelmed by information and can efficiently find what they need, improving the overall user experience and satisfaction. This is crucial for applications dealing with large amounts of data or complex functionalities, as it aids in reducing cognitive load and streamlining user interactions.
Usability					
	U-01	Information Panel	A panel behind an info button that provides users with context-specific information, guidelines, or help.	Instuctions answering user querries during use, and evaluation of user feedback	The information panel helps users understand the current context or features without seeking external help, enhancing self-sufficiency and satisfaction.
	U-02	Table viewer	A panel behind a table button that provides users with a tabulated overview of the input data.	Allows for faster data input speed as compared to the standard UI	Facilitates efficient data examination and manipulation, improving user productivity and data accessibility.
	U-03	Graphic visualisation	Tool for representing data	Engages user successfully as compared to normal spreadsheet tables	Enhances user experience, makes input data clearer, and retains user attention

	U-04	Keyboard navigation	The ability to navigate through the application using keyboard shortcuts or tabbing	Users can perform 90% of actions using the keyboard alone. Compliance with accessibility standards (WCAG)	Ensures the application is accessible to users with disabilities and enhances efficiency for future power users.
	U-05	User Feedback	A system for responding to user interaction	Every user action needs to be met with feedback from the program	This helps with error mitigation. If the user understands that when executing a command, nothing changes, then there is most likely an error.
Functionality					
	F-01	Interface familiarity	The UI design leverages familiar patterns and icons	New users perform basic navigation and tasks within 10 minutes of first use. This includes the ability to input formulas in a style comparable to other Spreadsheet applications.	Reduces training requirements and enhances funcationality and usability, especially for new users
	F-02	Mathematical formula parsing	Capability to input, interpret, and calculate results from mathematical formulas	Accurate parsing and calculation of formulae, including the use of spreadsheet style executions for: - SUM - PRODUCT - AVERAGE - SQRT - MEDIAN - ROUND - ABS - COUNT	Essential for applications requiring mathematical computations, improving efficiency and accuracy of data analysis, along with familiar formula parsing congruent with existing economic programs
	F-03	Knowledge graph viewer	displaying entities and their interconnections in the graph	The user understands at a glance which Nodes are most important	Enhances data comprehension and decision-making by visually summarizing the relationship between inputs
	F-04	Save	allowing users to save their current progress offline for future use within the application or in another application	Data integrity after save is 100%	Ensures data is not lost and users can continue work seamlessly, enhancing user trust and application reliability. Saving offline instead of online is also safer.
	F-05	Upload	allows the user to import files from older saves or from other compatible programs	supports a coherent file type for standard economic programs	Enables data importation, critical for initializing analyses or importing external data, enhancing versatility and user productivity

	F-06	Cost Benefit functions	tools or functions for performing cost-benefit analysis within the application	Users can complete a cost-benefit analysis within the program more easily with standard metrics including: -Discount Rate, Inflation, Timescale, Net presetn Value, Benefit-Cost Ratio, and Break Even Point	Core functionality for financial and project management applications, aiding in informed decision-making and analysis efficiency
	F-07	Compliance with GDPR	Complies with European online safety and provacy standards	No personal data should be logged by the program, all files should be stored offline.	Privacy and security of information is paramount for economic analysis and for user privacy
	F-08	Data Security	The application should protect user privacy.	It should not save user information online, require user login, or use cookies to remember or log private information.	The program user should remain anonymous.

Table 3. Full Tool Requirement Specification.

CHAPTER 5: COBALT

5.1 HOW THE PROGRAM WAS MADE

The development of the application was a linear iterative process that involved experimentation. A full version history is available through links found in Appendix C.

The current version, CoBAlt (v16), was developed using web technologies and consists of 149 lines of HTML, 609 lines of CSS, and 1713 lines of JavaScript code. The development process took place on CodePen,[176] an online development environment, which facilitated rapid prototyping and testing. For hosting and distribution, the tool utilises Render,[177] a platform chosen for its free service options. These steps align with requirement C-03.

The final design and implementation of the Cost-Benefit Analysis tool, aptly named CoBAlt, incorporates the letters C, B, and A in its name, reflecting its functionality. The name also pays tribute to the main accent colour used in the program's interface—cobalt blue.
The tool's design is based on the equation and function logic of spreadsheet programs; it allows users familiar with that syntax to transition between the two environments.This design decision addresses requirements C-01, F-01, F-02, and U-02.

While CoBAlt operates primarily as a cloud-based tool, it does not store user data online, adhering to privacy and data security standards. Instead, it allows users to save and upload files from their local computers for viewing and manipulation within the tool. This feature supports requirements C-02, F-04, F-05, F-07, and F-08, ensuring data portability and user control over their information.

The user interface shows an overview of inputs on the left of the display, and a graphic overview of the interconnectivity between the inputs on the right. This takes shape in the form of a knowledge graph where the nodes represent each element and the edges represent each dependency. These features align with requirements U-03 and F-03.
The graphic appearance of CoBAlt is coherent across the program, leveraging the ability of CSS to set global styling. The colours are used to denote functions and relevant information aligning with requirements D-01, D-02, and D-04.

Below the knowledge graph, metrics are present that add standard CBA functionality to the program which fulfill requirements D-05, F-01, and F-06. Above the knowledge graph, the Utility buttons use recognisable symbols to guide the user non-linguistically through the various utilities (D-03).

The live version of the application is available online through the following link:

https://cobalt-mdb2.onrender.com/

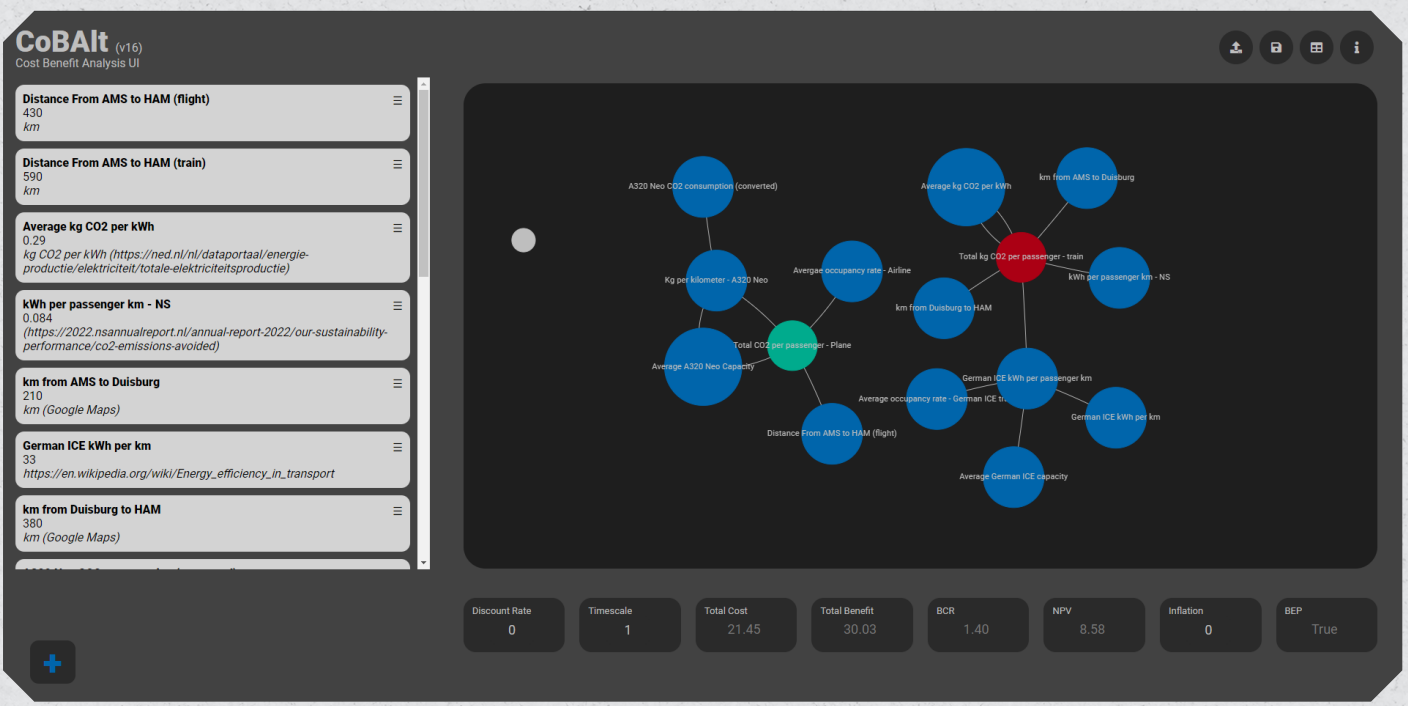


Figure 13. A screenshot of CoBAIt (v16) running in Google Chrome with a Cost-Benefit Analysis comparing the CO_2 cost of taking the train or taking a plane from AMS to HAM.

5.2 PROGRAM UI

5.2.1 STANDARD UI

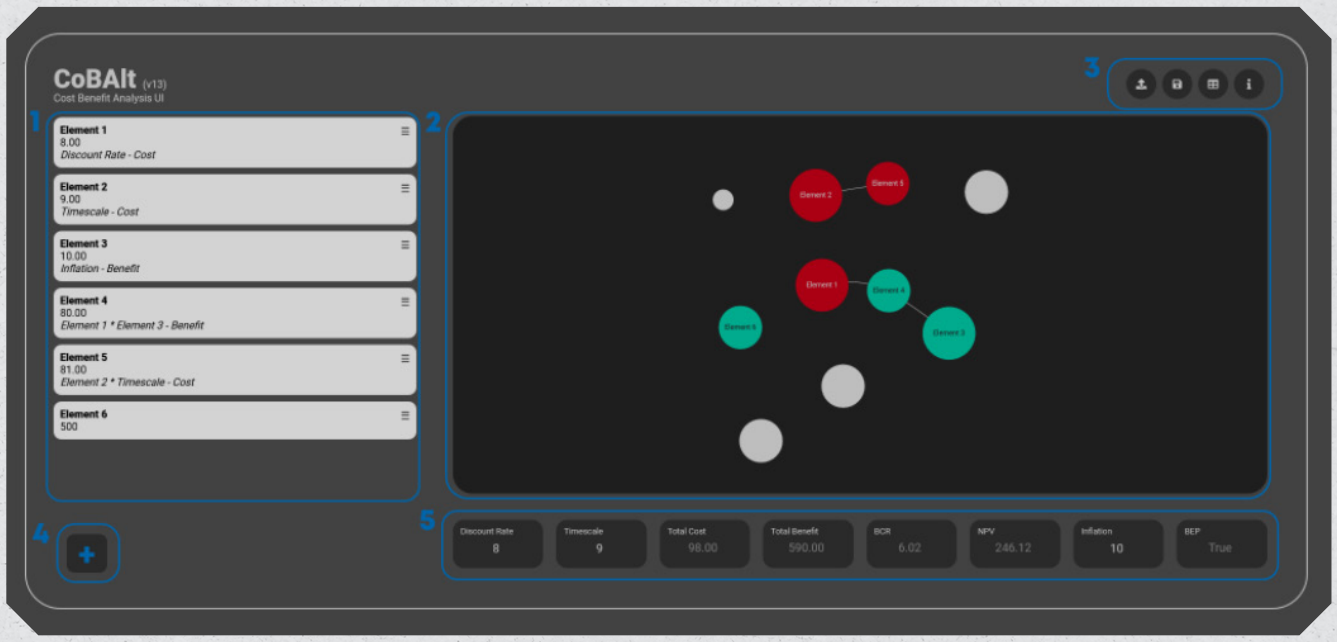


Figure 14. An Example of the Standard CoBAlt UI with outlines and a legend which is explained below.

1 - The Element List. In Cobalt, inputs are called "Elements." When an element is added to the UI, it shows up here.

2 - The Knowledge Graph. When Elements are added, a "Node" is created in this graph pane. The Nodes are connected when elements reference each other and grow in size depending on the number of "Outgoing Edges." Outgoing Edges is just another way of saying "dependents." The more other Elements depend on it for reference, the more that Elements Node grows. Grey Nodes are Neutral unconnected, Blue Nodes are Neutral connected, Red Nodes are Costs, and Green Nodes are Benefits.

3 - Utility Buttons. In order they are: Upload, Save, Table, and Information. Upload allows the user to upload .csv files to Cobalt, and Save allows the user to download them. The Table button allows the user to switch views between the Spreadsheet and Standard Cobalt UIs.

4 - The Add Element Button. In order to add Elements to Cobalt, the user first needs to press this button and fill out the Element popup.

5 - Cobalt Metrics. These are helpful metrics to give the user more information about the state of the Cost-Benefit Analysis. In order they are: Discount Rate, Timescale, Total Cost, Total Benefit, Benefit to Cost Ratio, Net Present Value, Inflation, and Break Even Point. The user can edit the Discount Rate, Timescale, and Inflation, while Cobalt calculates the others automatically.

5.2.2 SPREADSHEET UI

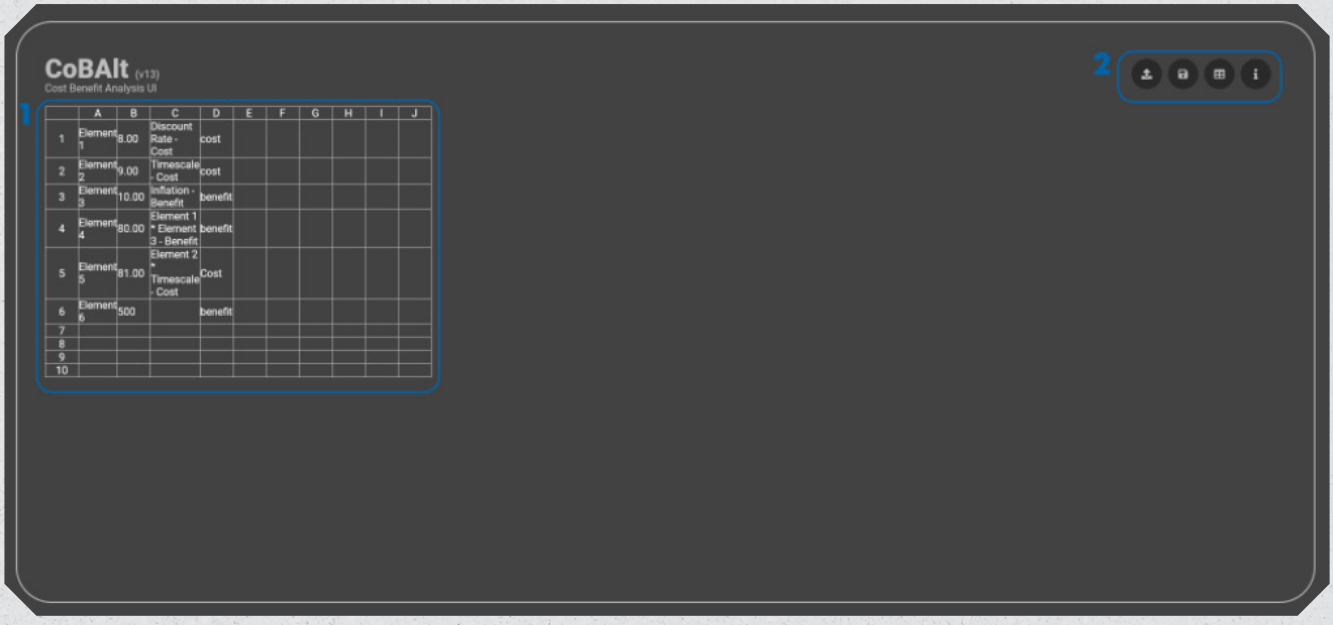


Figure 15. An Example of the Spreadsheet CoBAlt UI with outlines and a legend which is explained below.

1 - The Spreadsheet. The user can use the Spreadsheet to add Elements to the UI more quickly. The format does matter, but it is easy to remember. Each Row represents an Element. Column A is Element Title, Column B is the value or the equation, Column C is the Element description, and finally, Column D is to denote whether it is a cost, benefit, or neither.

2 - Utility Buttons. In order they are, Upload, Save, Table, and Information. Upload allows the user to upload .csv files to Cobalt, and Save allows the user to download them. The Table button allows the user to switch views between the Spreadsheet and Standard Cobalt UIs.

5.3 USING THE PROGRAM

5.3.1 ADDING AN ELEMENT

Step 1. Begin in the standard UI and press the Add Element Button, denoted by a "+" on the button left of the UI (Alternatively, the user can also use the "+" key on the keyboard)

Figure 16. An Example of the Add Element button at the bottom left side of the Standard CoBAlt UI.

Step 2. Upon clicking the Add Element Button, the Add Element popup will show. Here, the user can give a name to the new Element, along with a value, a description, and denote whether this Element represents a cost, benefit, or neither.

Figure 17. An Example of the empty Add Element popup in the CoBAlt Standard UI.

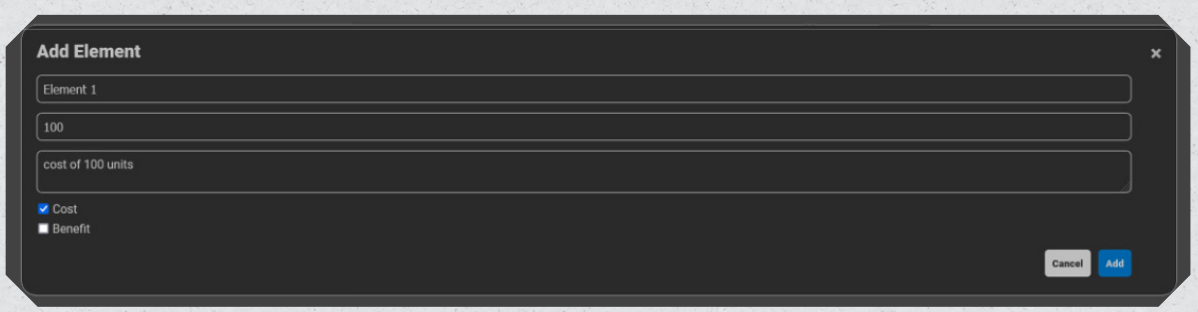


Figure 18. An Example of the filled in Add Element popup in the Standard CoBAlt UI.

Step 3. Press the "Add" button.

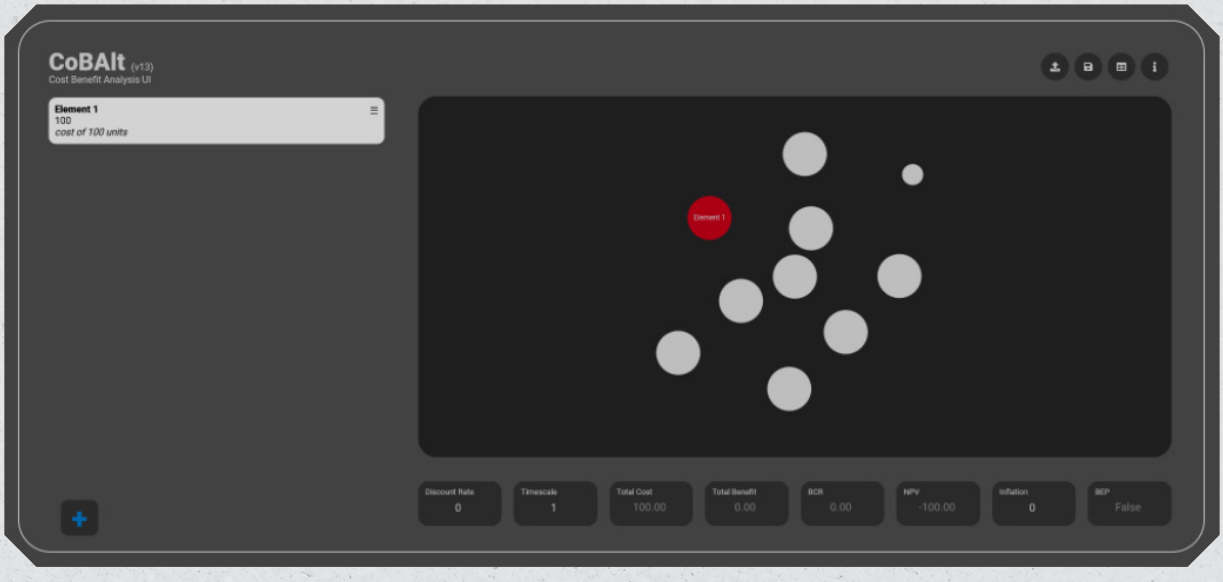


Figure 19. An Example of the Standard CoBAIt UI with a single new Element added.

5.3.2 REFERENCING AN ELEMENT OR METRIC

Step 1. To reference an element, begin by opening the add or edit element popups.

Step 2. When filling in the Value/Equation input, the user needs to tell the program that it will have to perform a calculation. This is done by using spreadsheet syntax. By beginning the statement with an "=" sign and then filling in the function that needs to be calculated.

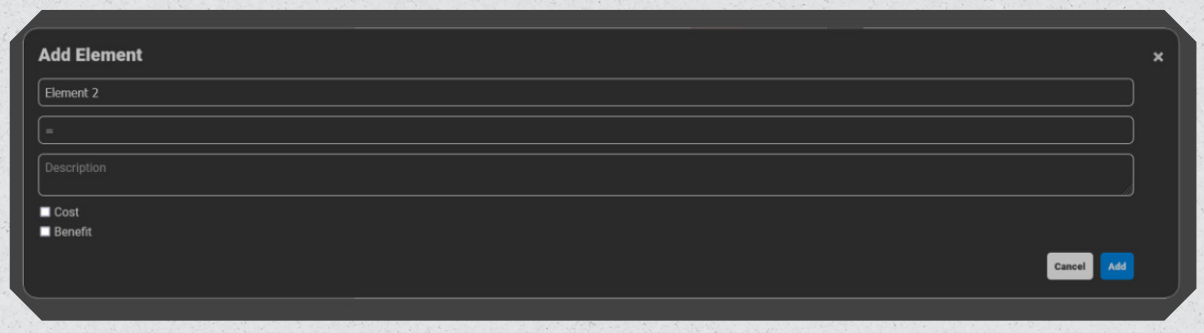


Figure 20. An Example of the Add Element popup in the CoBAIt Standard UI with an "=" sign in the Value/Equation input field.

Step 3. The user can now leverage a built-in feature called "Backlinks." Backlinking is the way the program references existing Metrics or Elements. To use it, the user must type a square bracket "[" into the Value/Equation input field.

This will open a dropdown menu with referenceable Elements and Metrics that can be backlinked. The user then has the option to select one and finish the backlink by closing the square bracket "]".

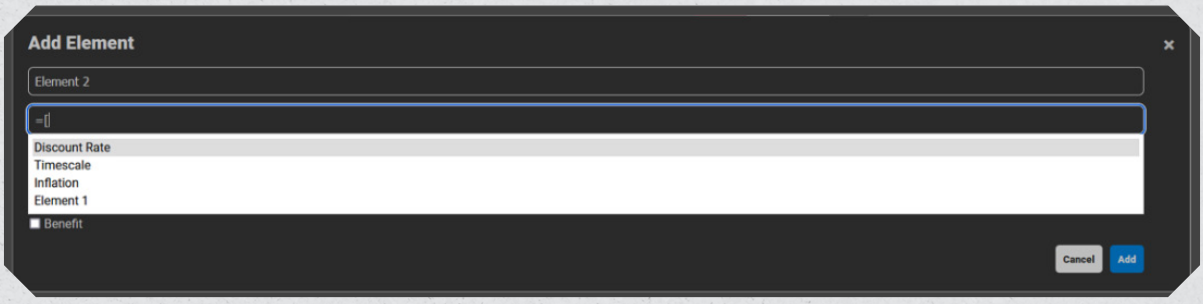


Figure 21. An Example of the Add Element popup showing the Backlink functionality within the CoBAlt Standard UI.

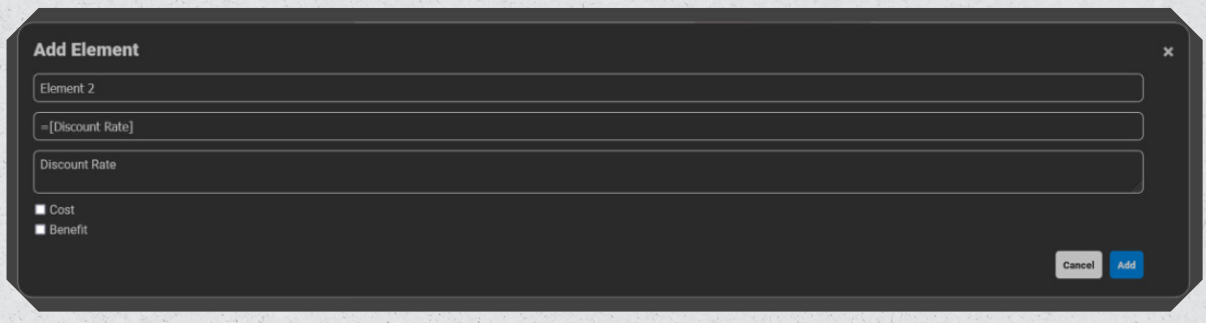


Figure 22. An Example of the filled in Add Element popup in the CoBAlt Standard UI referencing the Discount Rate metric using a Backlink.

When the Element is added, the UI will refresh to include reference. Even when the referenced Element or Metric changes (in this example, the Discount Rate), the UI will automatically adapt to the new value because it is "backlinked".

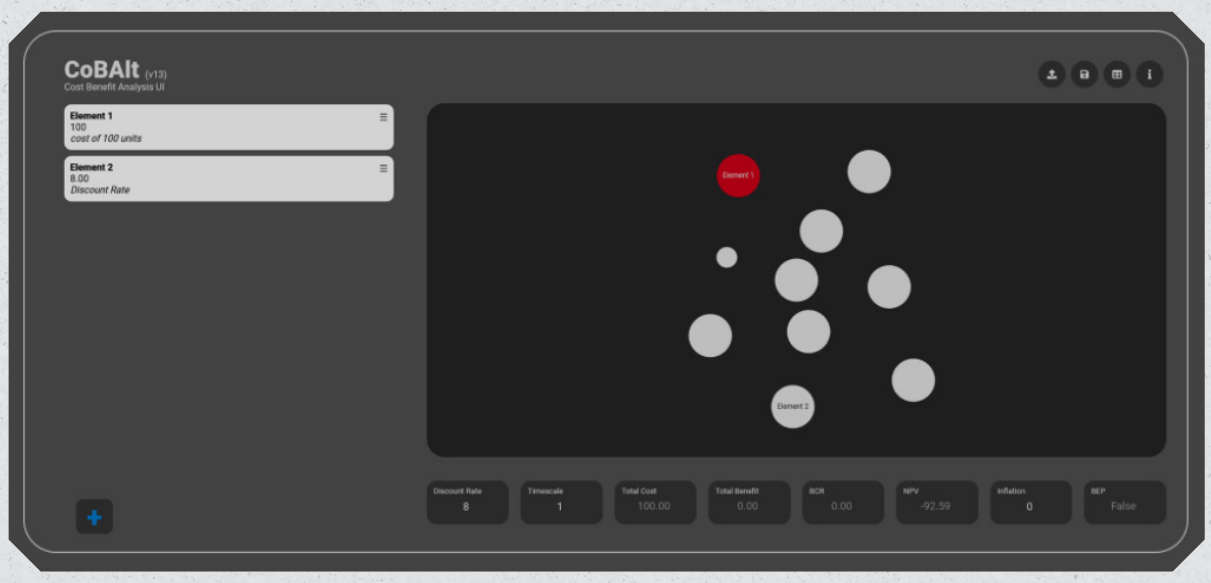


Figure 23. An Example of the CoBAlt Standard UI with an added new Element that references the Discount Rate metric using the Backlink feature.

5.3.3 EDITING OR DELETING AN ELEMENT

Any Element can be edited or deleted via the hamburger icon on the right of the Element box.

Figure 24. An Example of an Element Box in CoBAlt Standard UI with the Edit Element button highlighted.

This will open the Edit Element popup, as shown below.

Figure 25. An Example of the Edit Element popup in the CoBAlt Standard UI.

5.3.4 USING SPREADSHEET UI

The program comes with its own spreadsheet viewer for ease of use and congruence.

The user can navigate between the Spreadsheet and Standard UIs using the Table button located on the top right of the program, or by using the "Tab" key on the keyboard.

Figure 26. An Example of the utility buttons located at the top right of the program in the CoBAlt with the Table button highlighted.

The Spreadsheet UI allows the user to more quickly add Elements to Cobalt. Each row represents an Element. Column A is the Element title, Column B is the Value/Equation, Column C is the Element description, and Column D is to denote whether it is a cost, benefit or neither.

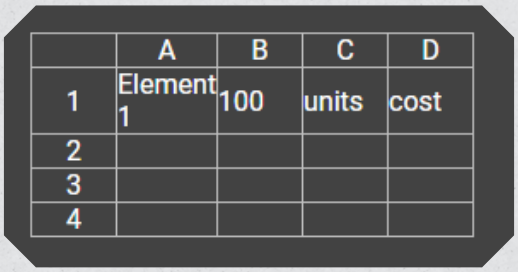


Figure 27. An Example of CoBAlt Spreadsheet UI with one element added.

The user can use the arrow keys or the mouse to navigate through the table. Clicking on a cell or hitting the enter key will highlight the cell and allow the user to edit it.

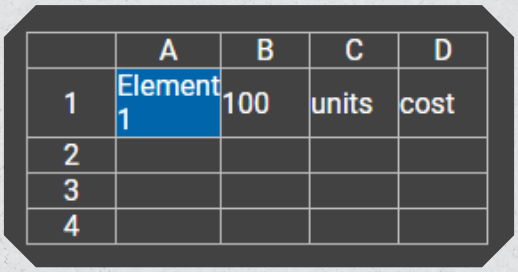


Figure 28. An Example of CoBAlt Spreadsheet UI with one element added. The title cell of Element 1 is shown in Edit Cell mode.

While in this Cell Edit mode, the user can use the arrow keys to traverse the cell allowing for targeted editing. To exit Cell Edit mode, the user needs to click out of the cell or hit the enter key again. The changes will automatically take effect and update the Standard UI.

5.3.5 SAVING AND UPLOADING

Saving

Cobalt supports the download and upload of comma delimited .csv files. These files are compatible with other spreadsheet programs like Microsoft Excel and Google Sheets, as well as any other specialised data analysis software or coding language.

To export, the user must click the Save Button on the top right of the program.

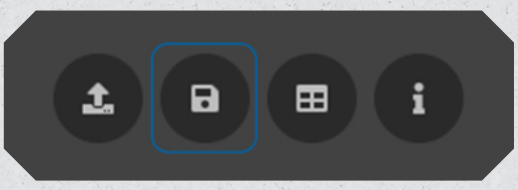


Figure 29. An Example of the utility buttons located at the top right of the program in CoBAlt with the Save button highlighted.

A popup will open to prompt the user to save the .csv to their computer.

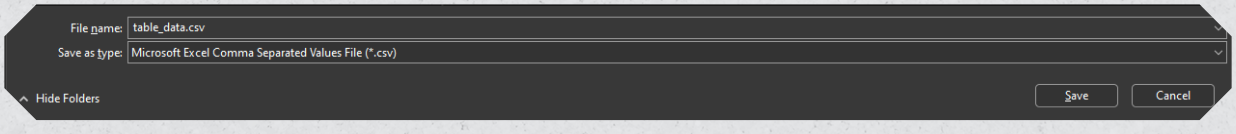
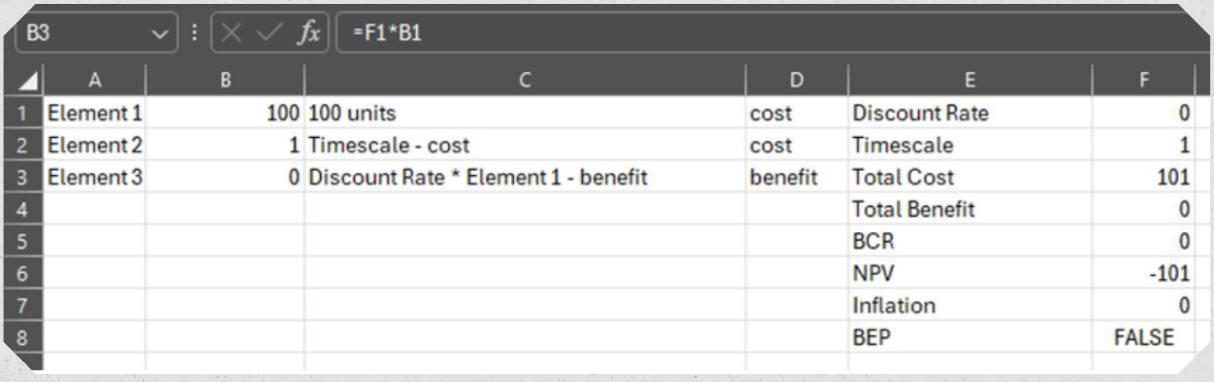


Figure 30. An Example of the popup that shows after the Save button is clicked.

From there, it can easily be opened in another spreadsheet program.



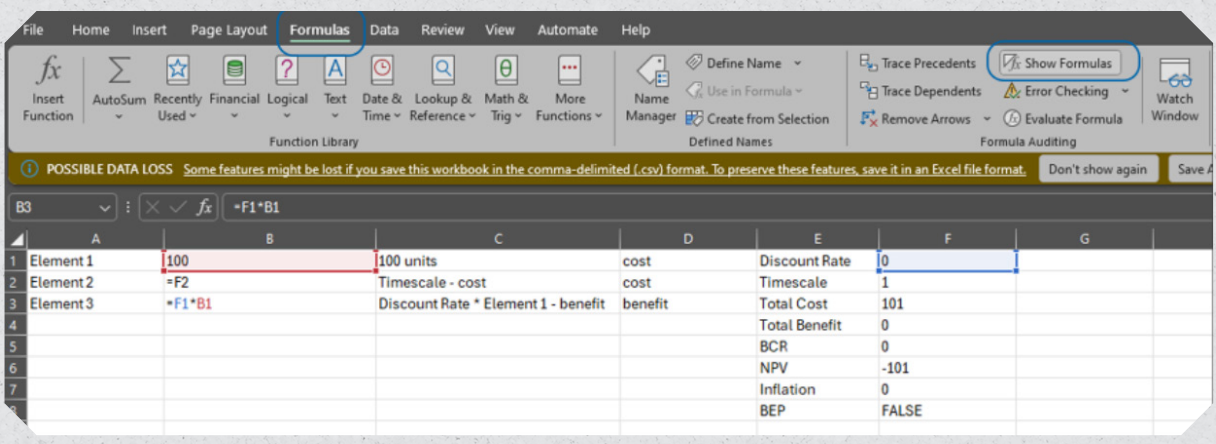
	A	B	C	D	E	F
1	Element 1	100	100 units	cost	Discount Rate	0
2	Element 2	1	Timescale - cost	cost	Timescale	1
3	Element 3	0	Discount Rate * Element 1 - benefit	benefit	Total Cost	101
4					Total Benefit	0
5					BCR	0
6					NPV	-101
7					Inflation	0
8					BEP	FALSE

Figure 31. An Example of the saved CoBAlt .csv file as opened in Microsoft Excel.

As seen in Figure 31, Cobalt adds the metrics to Column E and F and maintains the formulas. It does this by translating the Backlinks to their corresponding cell references, including those of the metrics.

Uploading

While uploading any .csv with the format shown above is possible, other spreadsheet programs like Microsoft Excel, save formulas as calculated values in .csv files. To preserve the formulas, go to the "Formula" tab at the top of Excel and click on "Show Formulas"



	A	B	C	D	E	F	G
1	Element 1	100	100 units	cost	Discount Rate	0	
2	Element 2	=F2	Timescale - cost	cost	Timescale	1	
3	Element 3	=F1*B1	Discount Rate * Element 1 - benefit	benefit	Total Cost	101	
4					Total Benefit	0	
5					BCR	0	
6					NPV	-101	
7					Inflation	0	
					BEP	FALSE	

Figure 32. An Example of a CoBAlt compatible file layout in Microsoft Excel with the steps on how to preserve equations in the csv file highlighted.

The user must then "Save As" -> ".csv (MS-DOS)"

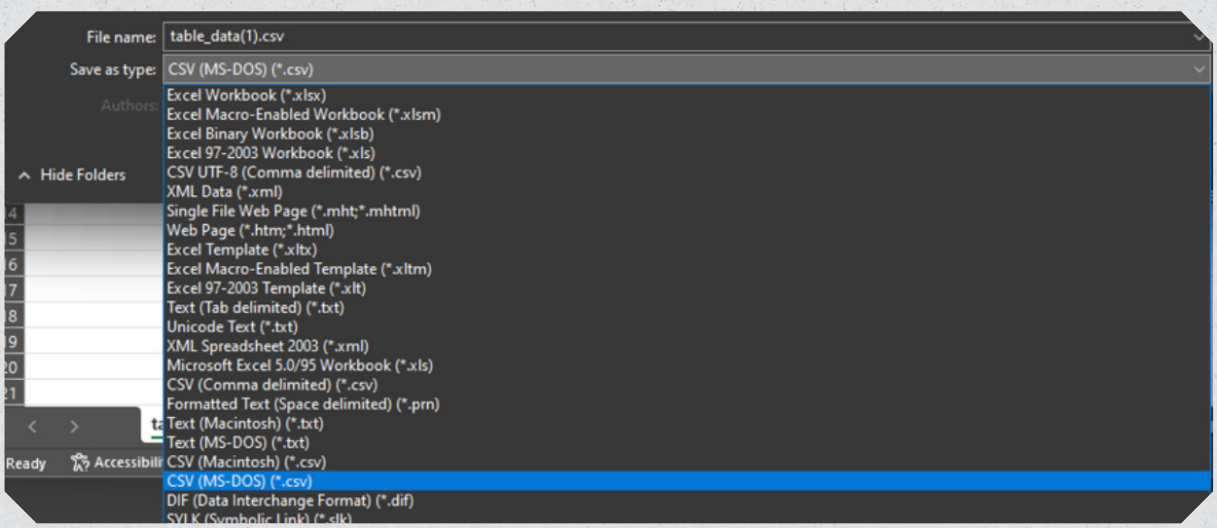


Figure 33. An Example of the popup that shows after clicking "Save As" in Microsoft Excel, with the CoBAlt compatible csv file type highlighted.

To upload the file to Cobalt, the user must click on the Upload Button and select the file from the popup.

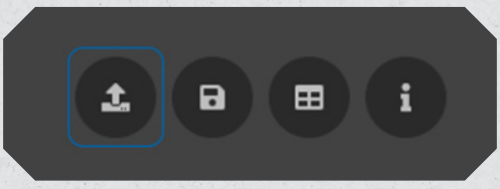


Figure 34. An Example of the utility buttons located at the top right of the program in CoBAlt with the Upload button highlighted.

Cobalt will automatically translate the cell references back to Backlinks and the program will update automatically to display the knowledge graph.

5.3.6 KEYBOARD NAVIGATION

In accordance with the usability requirement U-04, most of the UI is traversable by keyboard.

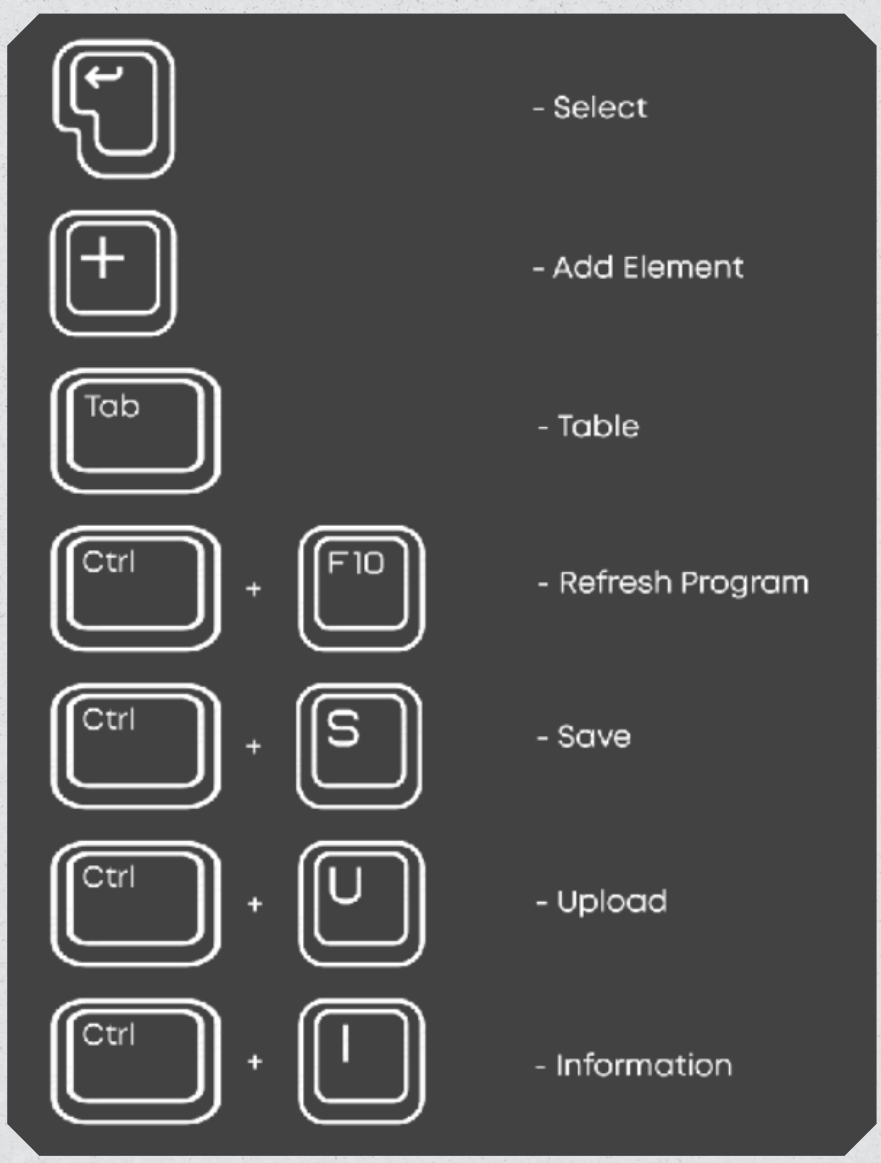


Figure 35. CoBAlts compatible shortcut keys and their respective functions.

5.3.7 COMPATIBLE SYNTAX AND FORMULAE

Currently, not all formulas are compatible. This may change when the program is updated or maintained. The program supports basic arithmetic functions and the syntax remains coherent with major spreadsheet applications. The full list of advanced compatible functions in the current iteration (v16) are listed below.

case '**SUM**': Returns the sum of the input set. Ex. =SUM([Input],[Input 2]...)

case '**PRODUCT**': Returns the product of the input set. Ex. =PRODUCT([Input],[Input 2]...)

case '**AVERAGE**': Returns the average of the input set. Ex. =AVERAGE([Input],[Input 2]...)

case '**SQRT**': Returns the square root of the input set. Ex. =SQRT([Input])

case '**MEDIAN**': Returns the median of the input set. Ex. =MEDIAN([Input],[Input 2]...)

case '**ROUND**': Returns the input rounded to a set decimal place. Ex. =ROUND([Input], 2)

case '**ABS**': Returns the absolute value of the input. Ex. =ABS([Input])

case '**COUNT**': Returns the number of inputs in the input set. Ex. =COUNT([Input],[Input 2]...)

case '**POWER**': Returns the input to the power of a second set input. Ex. =POWER([Input],2)

CHAPTER 6: TESTIN

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6.1 METHODOLOGY

To ensure the efficacy and usability of the newly developed Cost-Benefit Analysis tool, CoBAlt, it is essential to conduct feasibility interviews using a questionnaire and a structured A/B test. The objective of these assessments is to gather substantive feedback on the functionality, user experience, and the overall performance of CoBAlt in comparison to conventional spreadsheet applications.

The choice of spreadsheet applications as a comparison point in the A/B tests is grounded in their widespread adoption and familiarity among potential users, as outlined in section 4.1.4. Spreadsheet applications represent the most accessible of the existing tools and are the most comparable to CoBAlt given the similar syntax.

When preparing to write a usability questionnaire, it is important to ensure that the data collected is both reliable and valid. One of the risks in designing such questionnaires from scratch is the inadvertent introduction of bias, which can stem from poorly formulated questions or a sequence of questions that influences the respondents' answers. On top of that, certain combinations of questions might uncover underlying factors that, if not properly accounted for, could skew the interpretation of the results.[178]

To mitigate these risks and enhance the credibility of the findings, this study will base the usability questionnaire on an existing validated questionnaire. The validated questionnaires examined for this project include UEQ, SUMI and WAMMI, SUS, and QUIS.

The User Experience Questionnaire (UEQ) primarily measures user satisfaction, which, although valuable, offers a less comprehensive analysis compared to tools that evaluate usability.[179]

The Software Usability Measurement Inventory (SUMI) is a proprietary tool and needs to be purchased. Given the constraints of a limited project budget and the necessity for a tailored approach to questionnaire design, SUMI does not seem to be the most viable option.[180]
The Website Analysis and MeasureMent Inventory (WAMMI) also operates on a paid basis and while it does offer a discount for students, its utility is still limited by the requirement that responses be collected exclusively through their web service, instead of more customisable platforms like Google Forms for survey administration.[181, 182]

The selection is then narrowed down to two potential tools, the System Usability Scale (SUS) and the Questionnaire for User Interaction Satisfaction (QUIS). SUS is a widely recognised usability scale that consists of a concise ten-item questionnaire, offering a straightforward and efficient means of assessing system usability.[183] On the other hand, QUIS provides a more detailed evaluation framework with 27 multiple-choice questions, and two open-ended questions which allow the respondents to list three positive and three negative aspects of the system.[184, 185]

6.2 TEST CASE

For the A/B test, a test case was created that goes as follows:

Suppose you are a local businessperson and want to advertise your services. You want to advertise because there is a projected average increase in revenue from each person who views your adverts. You have two strategies and want to know how to choose between them.

Strategy A

Newsprint ad space …….	€10,000
Radio show ad space……	€30,000
Highway Billboard……..	€10,000
Production cost for graphics ……	€10,000
Production costs for radio advert……..	€10,000
Projected Impressions…….	1000
Projected average revenue per ad viewer	€120

Strategy B

Online ad space ……..	€30,000
Content production video shorts……..	€10,000
Content production graphics……..	€5000
Paid influencer partnership …….	€5000
Projected impressions …….	1250
Projected average revenue per ad viewer	€120

6.3 TEST SETUP

Instead of doing a non-guided quantitative survey of the tool's usability using QUIS, a guided qualitative survey structure based on SUS was chosen to get the most feedback possible in the shortest amount of the respondent's time.

Figure 36. An illustration of the test setup using icons courtesy of Reshot.[186]

The user sits behind a laptop which has been prepared with the survey, Excel, and CoBAlt open. Beside the laptop on the left side is the printed-out test case, a pen, and fresh sheets of paper, should that be required. The researcher sits next to the participant so that they can see the participant's actions, take notes, and ask questions. (see Figure 36)

The test case for CoBAlt is structured with two main objectives. The first is to demonstrate its capabilities as a program and compare its efficiency as a method for determining a course of action in simple CBA scenarios. Secondly, it is to evaluate its effectiveness in making the underlying assumptions more transparent compared to traditional spreadsheet tools.

A key aspect of the test involves analysing the treatment of projected values within CoBAlt. Specifically, the test will focus on how CoBAlt handles and presents two critical, but inherently uncertain inputs: the revenue benefit per advertisement viewer, and the number of advertisement viewers itself. These inputs are projections that masquerade as empirical data, yet they are treated with the same level of apparent precision within the analysis. This could mislead users regarding the actual certainty and risk associated with these projections. The guided survey session should gauge whether users are able to recognize these nuances.

Questions will focus on user awareness of the distinction between empirical data and projections within the analysis, interviewing participants on:

- Their ability to identify which inputs are empirical and which are projections.

- How clearly these distinctions are presented in CoBAlt compared to traditional spreadsheet applications.

- Their perception of the impact of these projections on the overall accuracy and reliability of the CBA.

Hopefully, directly asking users if they noticed the projected nature of these key inputs will help in identifying potential areas of improvement for how CoBAlt visualises and differentiates data types.

The full questionnaire can be found in Appendix A.

CHAPTER 7: RESULT

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7.1 PILOT STUDY RESULTS

As described in the Research Question section of this report, the users chosen for guided qualitative survey needed to fit the definition of a semi-professional. To that end, the respondents were a near even mix of male and female adults. The majority of respondents had finished an MSc at university with a minority still in the process of graduating with a MSc.

Metric	Value	Formula
Sample Size	10	Given
Confidence Level	95.00%	Given
Z-Score	1.96	Corresponding to 95% confidence level
Proportion (p)	0.5	Given (assuming maximum variability)
Margin of Error for 10 samples	0.31	E = Z * sqrt((p*(1-p))/n)
Required Sample Size for 5% Margin of Error	384	n = (N * Z^2 * p * (1-p)) / (E^2 * (N-1) + Z^2 * p * (1-p))

Table 4. Margin of Error and Required Sample Size Calculations for Statistical Relevance.

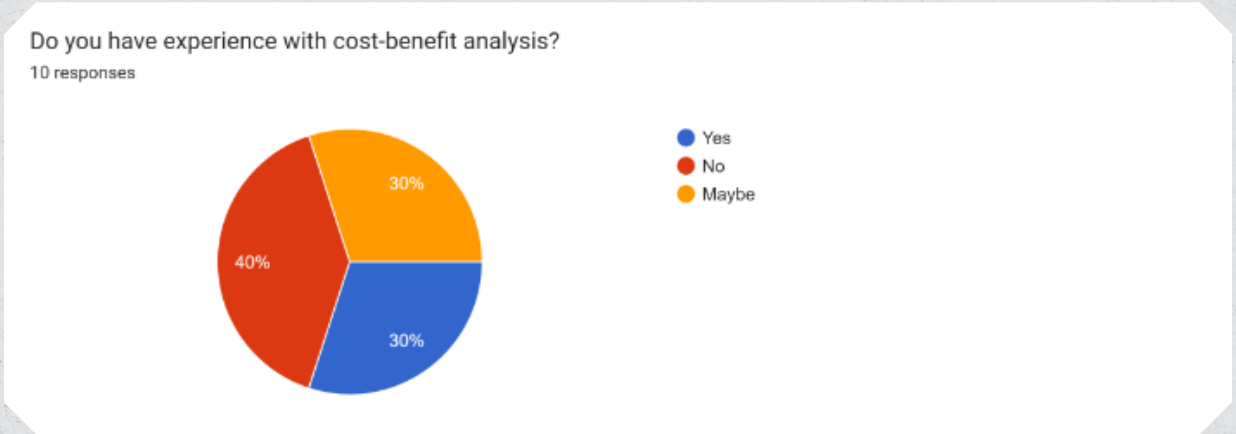
There were 18.5 million tertiary education students in Europe in 2021, of which 59% were studying for bachelor's degrees.[187]

Assuming that a significant portion of the 7.6 million remaining students are MSc students, the sample size of 10 MSc (pre)graduates used in this study is woefully inadequate and results in a high margin of error of about 31%. For the study to be statistically significant, a sample size of at least 385 respondents would be necessary.

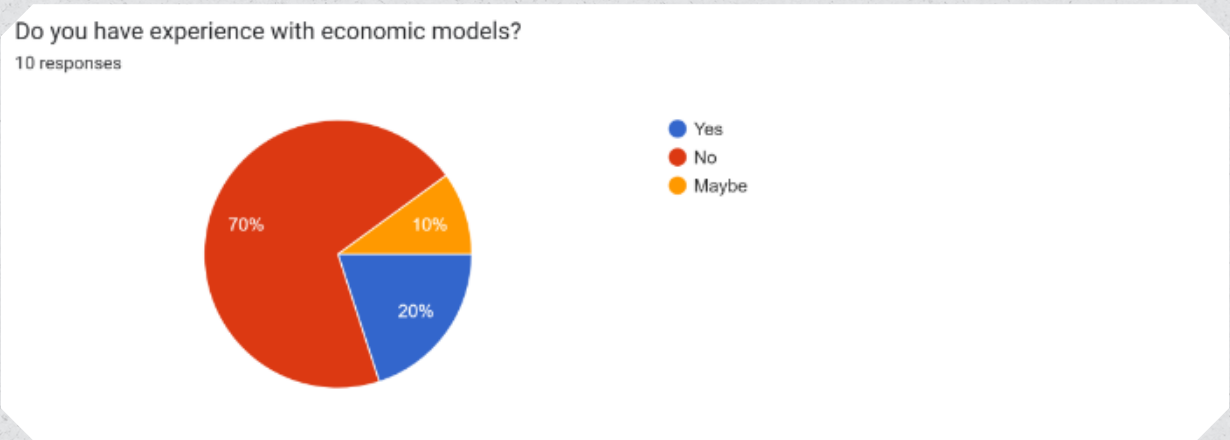
Despite this limitation, the qualitative approach employed in addition to the survey enhances the value of the results. The depth of insights gained through qualitative methods can justify and guide changes and additions to future versions of the tool. The recommendation would be to go further than just a pilot study when evaluating future developments in the tool.

As mentioned previously, the survey is designed to compare CoBAlt to Excel. In order to remove bias, half of the respondents were given CoBAlt to use first, the other half were given Excel. Full results can be found in Appendix B.

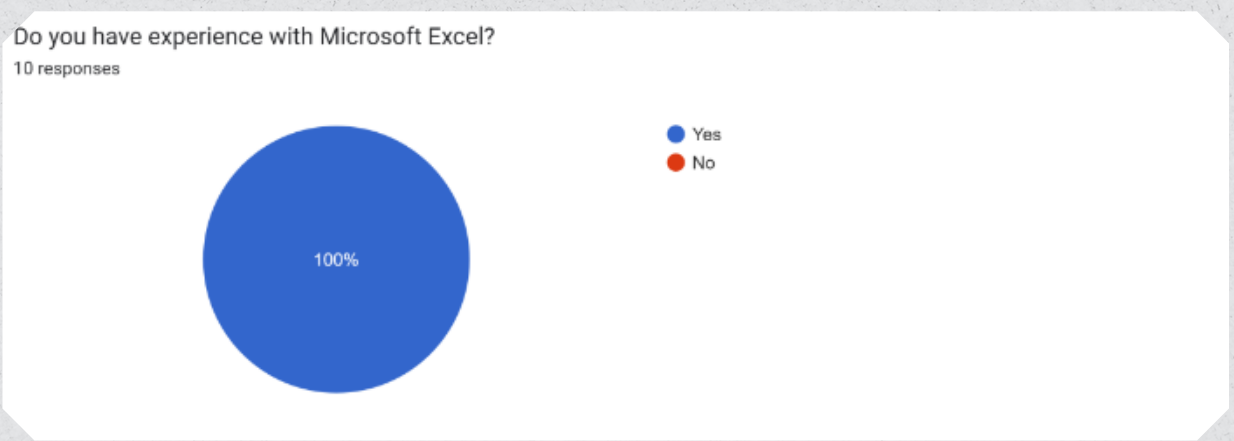
7.2 SURVEY RESPONSES



Graph 1. Even distribution of respondents with expierence and without experience of cost-benefit analysis.



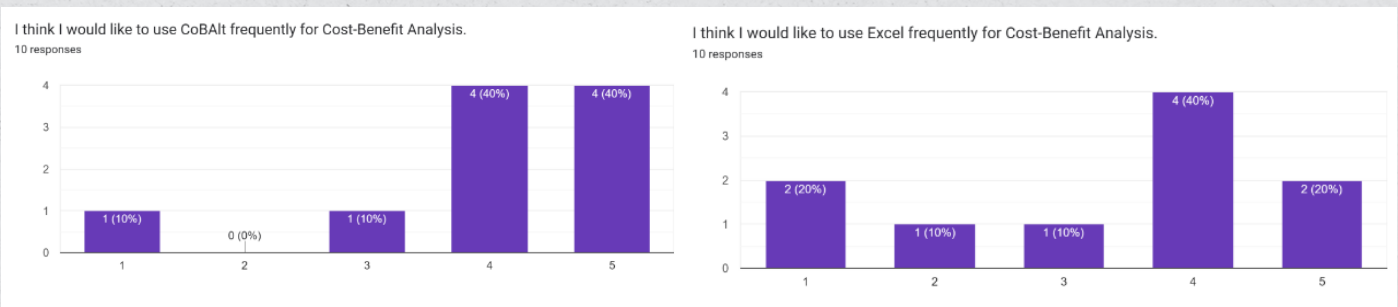
Graph 2. A majority of respondents lack experience with economic models.



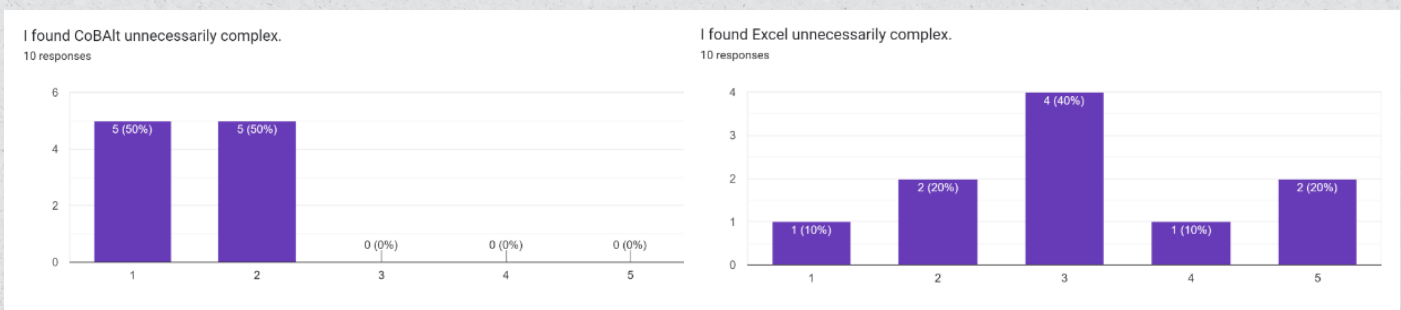
Graph 3. All respondents had experience using Microsoft Excel.

COBALT

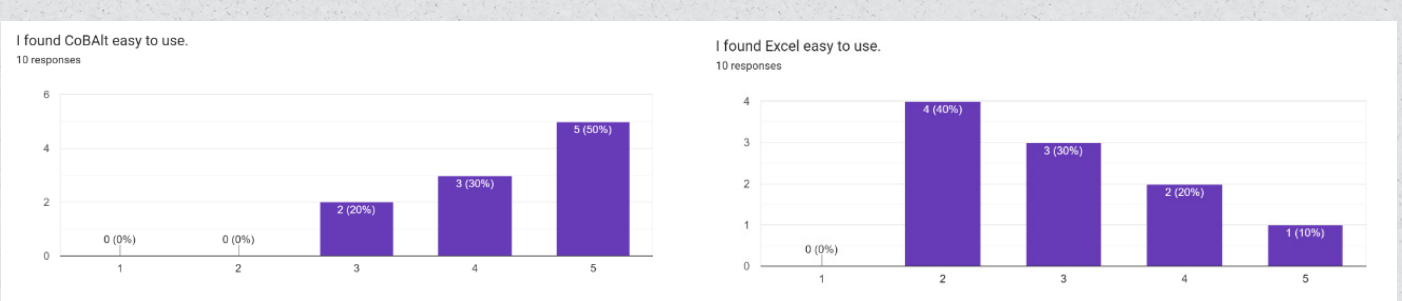
EXCEL



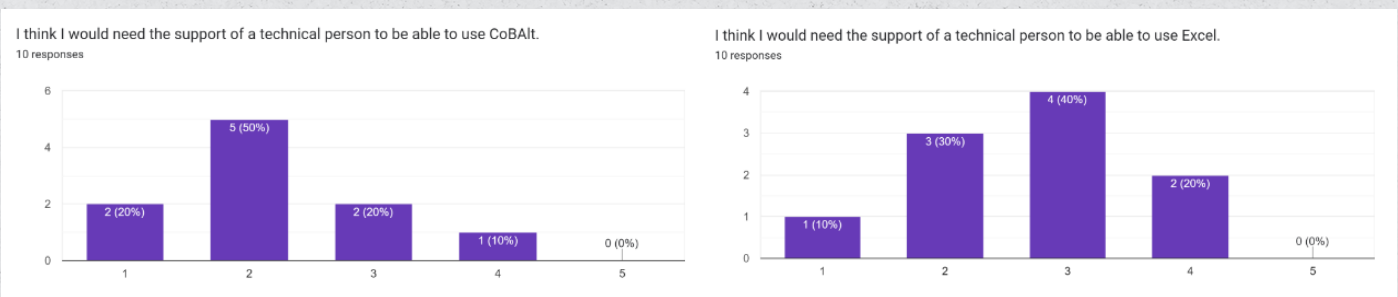
Graphs 4 and 5. Respondents were asked whether they think they would like to use each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).



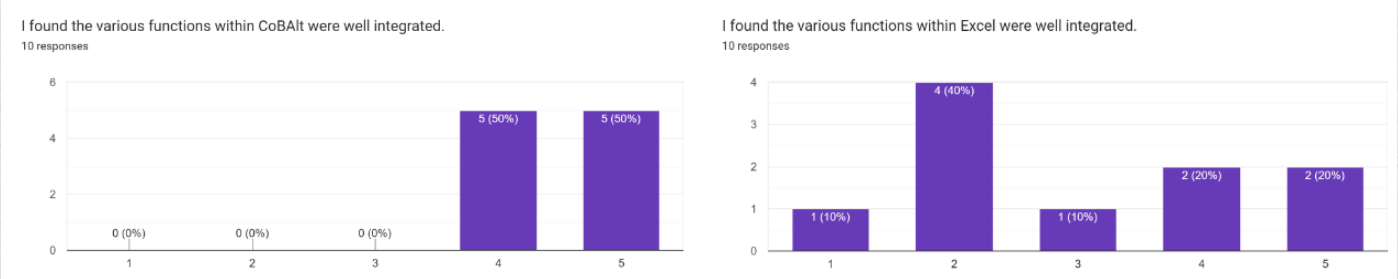
Graphs 6 and 7. Respondents were asked whether they found each respective software unnecessarily complex on a scale from Strongly Disagree (1) to Strongly Agree (5).



Graphs 8 and 9. Respondents were asked whether they found each respective software easy to use on a scale from Strongly Disagree (1) to Strongly Agree (5).



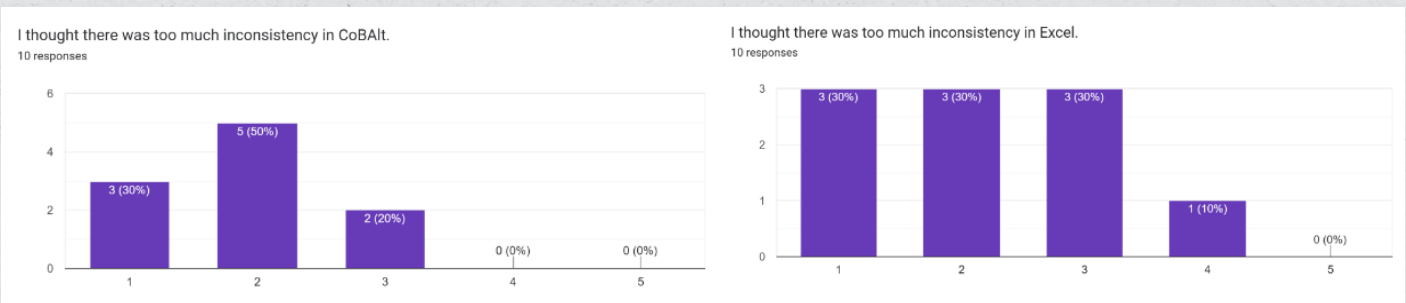
Graphs 10 and 11. Respondents were asked whether they thought they would require technical support to use each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).



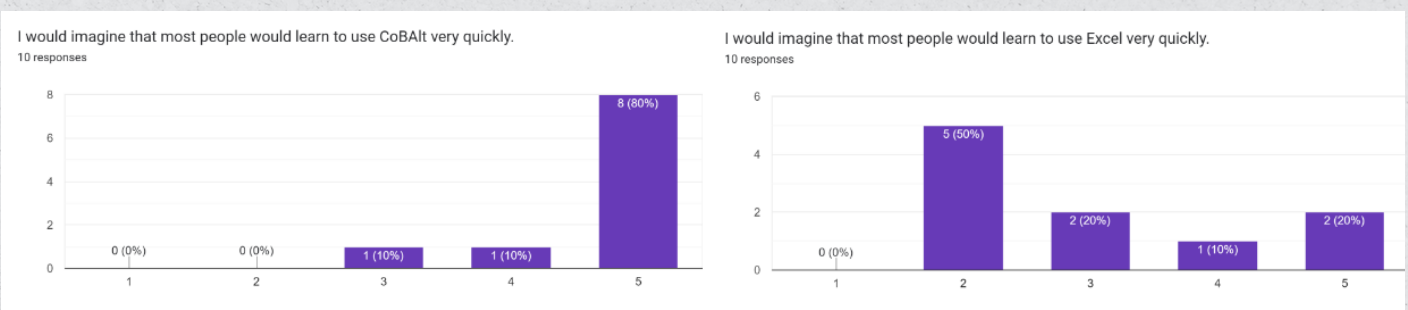
Graphs 12 and 13. Respondents were asked whether they found the features within each respective software well integrated on a scale from Strongly Disagree (1) to Strongly Agree (5).

COBALT

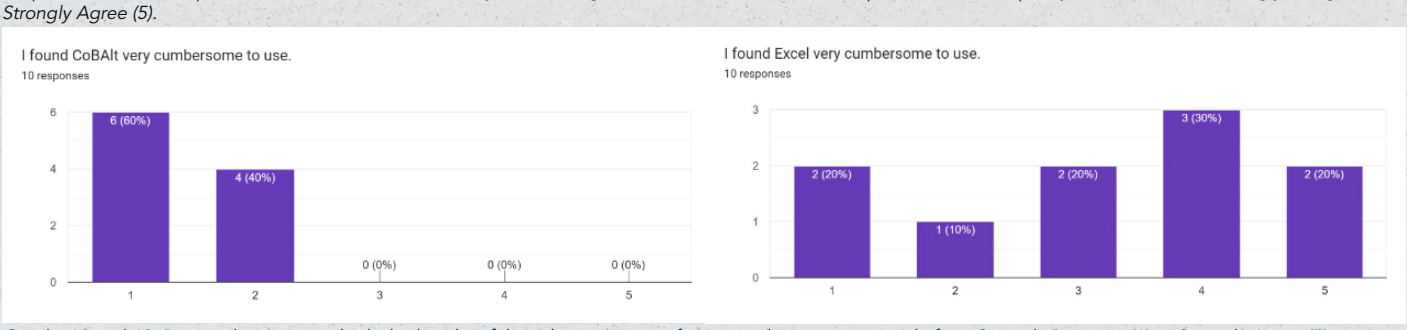
EXCEL



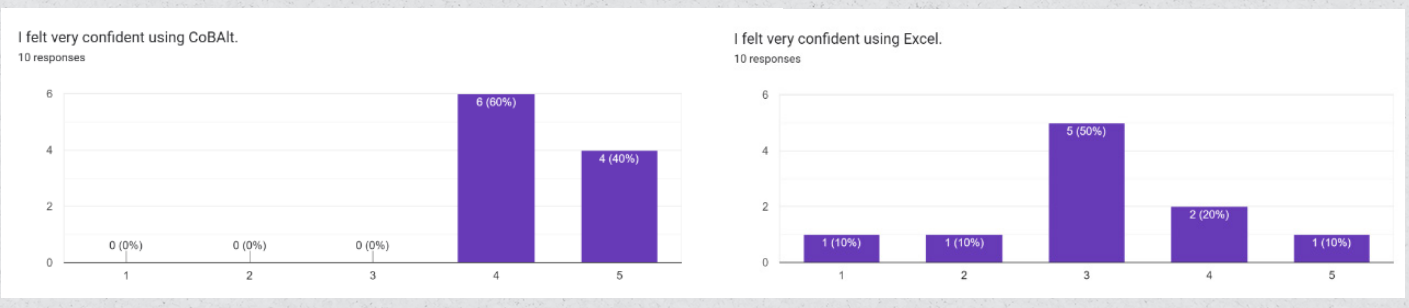
Graphs 14 and 15. Respondents were asked whether they thought there was too much inconsistency within each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).



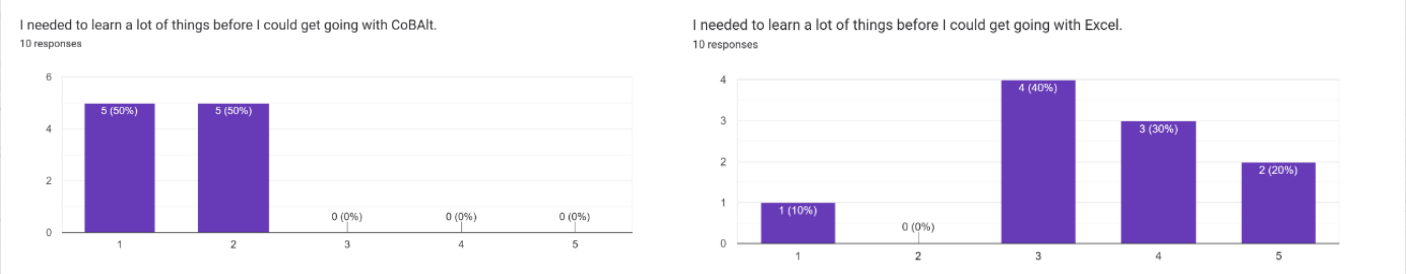
Graphs 16 and 17. Respondents were asked whether they would imagine others would learn each respective software quickly on a scale from Strongly Disagree (1) to Strongly Agree (5).



Graphs 18 and 19. Respondents were asked whether they felt each respective software cumbersome on a scale from Strongly Disagree (1) to Strongly Agree (5).



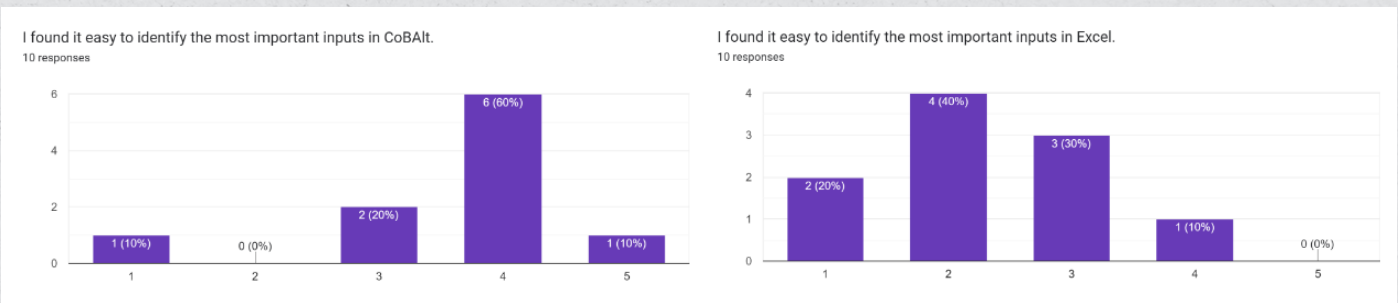
Graphs 20 and 21. Respondents were asked whether they felt confident using each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).



Graphs 22 and 23. Respondents were asked whether they felt like they needed to learn a lot before using each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).

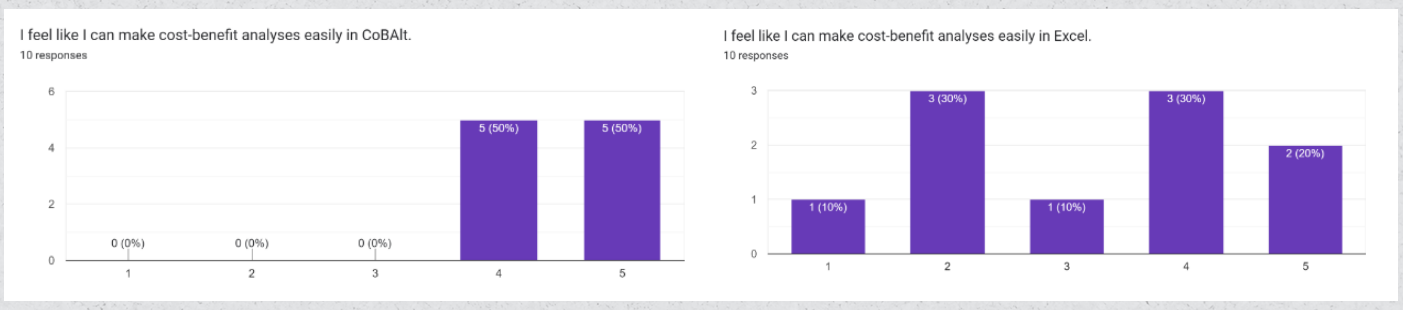
COBALT

EXCEL

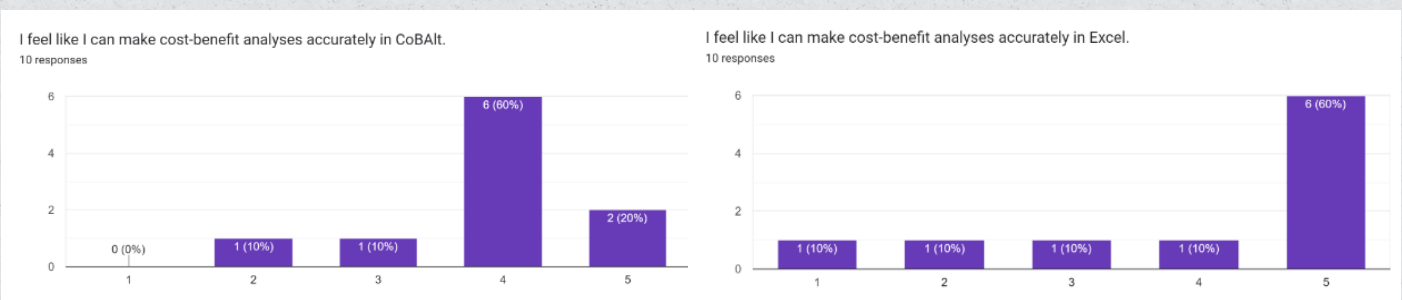


Graphs 24 and 25. Respondents were asked whether they easy to identify important inputs in each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).

Graphs 26 and 27. Respondents were asked whether they felt confident in the accuracy of their CBA in each respective software given the input data on a scale from Strongly Disagree (1) to Strongly Agree (5). There is a spelling mistake in the question, please ignore it for the author his sanity.



Graphs 28 and 29. Respondents were asked whether they felt like they could make CBA easily in each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).



Graphs 30 and 31. Respondents were asked whether they felt like they could make CBA accurately in each respective software on a scale from Strongly Disagree (1) to Strongly Agree (5).

7.3 OBSERVATIONS DURING PILOT SURVEY

Despite the fact that most of the respondents were able to use CoBAlt as intended, and were independently able to create the same CBA result within CoBAlt, only one of the users was able to more clearly identify the projected values as most important purely based on the size of the node. While the majority of the other users were able to identify the most important inputs, when asked for justification as to why they felt they were the most important, the justifications had nothing to do with the features in CoBAlt.

One of the users began adding inputs by clicking on the empty nodes that load into the program on startup instead of clicking the plus button at the bottom left of the program. Which might mean that it is more intuitive to initially interact with the graph than it is to add elements with a large plus button.

Some respondents had difficulty discerning what a cost was and what a benefit was, listing both the "projected impressions" element and "projected revenue per ad viewer" element as benefits before realising their mistake when CoBAlt automatically totalled the benefits.

One of the respondents had such a disdain for Excel that when the time came to use it, they asked if it was ok to use the pen and paper instead, preferring that over the spreadsheet. This user started with CoBAlt, which they were ok with trying. The respondent was asked why they were ok with trying CoBAlt and not Excel, to which they replied that it looked friendlier and they were not as confused with the "+" button as they were with the blank sheet. They preferred not having to decide which column or cell to input things in because that confuses them and makes the analysis "messy."

Users unanimously liked the design of CoBAlt better than Excel and found that it was more satisfying to connect the inputs together. They felt unsatisfied that fixed costs remained separate nodes. One respondent even went so far as to re-label all the fixed costs as neither a cost or a benefit in order to have a "Total Cost" node that connected all of them together. The user did not have to do this, they asked if they had extra time to "fix" the analysis like this so that it looked better to them.

7.3.1 BUGS FOUND IN COBALT BY RESPONDENTS

- Program does not handle dollar ($) sign in the Equation/Value field

- Program does not handle spaces or commas in large values (10 000 or 10,000 vs 10000)

- Backlinking by clicking the dropdown list, does not work. Only using the arrow keys and hitting enter works with the dropdown.

- When manipulating the nodes in the knowledge graph, the size defaults to size of the node title sometimes before returning to the custom sizing. This confuses some users.

7.3.2 SUGGESTIONS FOR IMPROVEMENT BY RESPONDENTS

- Open the program with instructions

- Add folders to the element list

- Add multiple sheets to the program instead of having to open multiple tabs for multiple analyses

- Add the option to manipulate the table in the spreadsheet view of CoBAlt such that you can read the text in the cells better

- Add an additional variable for fixed/recurring costs that automatically adjusts based on timescale changes

- Add additional visulisation options and a button to switch between them

- Integration of standard units (CO2, GBP, EUR) and the option to add new units to the program as well, just to save time having to retype multiple inputs

- The option to link nodes by dragging them into one another in the knowledge graph

- The option to edit multiple inputs at once

- The option to choose the program colours manually

- The option to drag elements to change the order in the elements list

- Add two nodes on startup, one for total cost, and one for total benefit

- Include units in the knowledge graph for better overview

- Highlight the input related to the node when a node is clicked

- Fix the titles such that if they are too long they get cut off. The titles going beyond the edge of the node is annoying

This page was purposefully not left blank.

POST-DEV INTERVIEWS

After the tool was ready for testing, the experts from the initial interviews were invited back to give additional feedback and recommendations.

BERNARD VAN DIJK

As mentioned previously, Bernard van Dijk is an Aviation expert at the Hydrogen Science Coalition and his insights into the benefits of the tools for decision-making make talking with him fruitful for the purposes of this report.

After seeing a demo of the tool, Bernard noted that it looked easy, clean, and balanced. He did warn that there are multiple tools available for comparing costs and comparing CO2 emissions, and that they differ greatly by their ability to dive deeper into life cycle analysis. He noted that he had once tried calculating the CO2 emissions from Amsterdam to Paris in an Embraer and a Tesla Model 3 for an article on LinkedIn. He said that a best case scenario and worst case scenario for the Tesla varied greatly (by about 15x) based on the way you do the analysis.

Overall he was impressed with the demo and excited to try the tool himself, which definitely speaks to the attractiveness of the CoBAlt workspace.

GIGI FLAMAND

As mentioned previously, Gigi is a Master of Ecological Economics and her insights into the viability of CoBAlt as a serious economic tool are invaluable.

After playing with the tool, Gigi found the interface clean and user-friendly. She appreciated the ability to add and manipulate elements easily. The example provided involved calculating CO2 emissions and their associated costs. Gigi could see how elements like CO2 released and the cost of carbon interacted within the tool very quickly. She saw potential in the tool, noting that it could help users visualise the impact of different factors more clearly.

She said that a more polished version could be useful, but wanted to see a better separation between costs and benefits. A separate visualisation on the main screen with costs on one side and benefits on the other, like a traditional cost-benefit analysis, would create clearer distinctions and make it more intuitive for the user. Overall she appreciated that there was a lot of work put into the design and that it came through in how easy it was to input values compared to Excel. She said it was unsurprising, however, considering that CoBAlt was specifically designed for that, while Excel clearly was not.

MARTIN MUIR, IAN MARR, AND ARND SCHIRRMAN

As mentioned previously, Martin Muir has a PhD in Aerospace, Aeronautical, and Astronautical Engineering from the University of Leeds and works as a Senior Modelling and Simulation Scientist at Airbus Central Research and Technology. The inclusion of Ian Marr and Arnd Schirrman in this interview was a welcome surprise. Dr.Marr has a doctorate in Systems Engineering from the University of Bristol and works as the Lead for Future Model Based Systems Engineering projects at Airbus Operations, and Arnd Schirrman, one of the supervisors for this project, works as a Service and Logistics Expert and Research Project Leader at Airbus. All three could provide insights into the potential usefulness of such a surface-level visualisation tool as CoBAlt in their systems engineering work.

Once again, the tool was found to be visually appealing and user-friendly. The interface allows users to add nodes and establish relationships between them, creating a dynamic knowledge graph, which was seen as a novel way of showing the connectivity between different inputs. They also liked that it was based in Excel and used the same syntax as that is a powerful addition to the software. However, they were unsure if the tool could provide as adequate an understanding of the criticality and centrality of different nodes as intended.

If the tool would be able to map parameters at different levels of analysis, from high-level system operations to detailed component-level parameters, it would be incredibly useful for understanding how changes at one level affect other levels.

They suggested applying the tool to existing causal loop diagrams and models from either Airbus or the University of Cranfield to explore its capabilities further, and asked if it was possible to customise the metrics at the bottom of the application for various network science measures, as that would also add functionality.

They compared CoBAlt to Gephi, a generic graph analysis tool, and said that CoBAlt offered a more tailored and user-friendly interface. Gephi would look at the knowledge graph from a more mathematical point of view in terms of network structure. To actually extract information out of Gephi, one would need to spend quite a lot of time really looking at what the different nodes actually mean, whereas CoBAlt provides the definition for those nodes right on screen. They described it as a more practical version of Gephi for this reason, and that it had a lot of potential.

The three of them spoke at length about getting CoBAlt to integrate with existing systems within Airbus. Suggesting different colour-coding schemes to indicate whether the nodes are assumptions, averages, or facts, enhancing the tool's intuitiveness. They suggested being able to drag and drop nodes and connections into the window and having CoBAlt auto-propagate or suggest alternative calculations for things brought into the program. Arrows to show the flow of the edges and perhaps adding another parameter in the thickness of the edge from one node to the other, could also create additional functionality at a glance.

They ended the interview by asking for a copy of the tool to run on an Airbus server instead of on the internet so that they could play with it more easily. They also asked for a copy of the source code to integrate it with AnyLogic, another program they use, because it is also based in Java and had the potential to integrate well. They gave one additional point of feedback, which was to include different visualisation options in the graph, a way to switch between them, and a legend that would describe what the colours and sizes mean in the different visualisation views.

CHAPTER 6: CONCLUSION AND RECOMM

DISCUSSION
ENDATIONS

Given the limitations of the non-representative sample size, the results of the pilot test have quite a large margin of error. Nonetheless, it can be concluded that while CoBAlt has a lower learning curve, more user-friendly interface, and can give a better overview of how data is connected as compared to spreadsheet applications, it fails at its primary purpose: to help users more easily identify the shortcomings within cost-benefit analyses. However, adjusting the parameters for node colour and size may improve overall data perception, and a larger sample size might yield different results.

With the advent of artificial intelligence and the widespread use of large language models capable of interpreting data, the premise of removing interpretation bias by providing decision-makers with an attractive data visualisation environment in this way, seems increasingly untenable. The role of such environments in enhancing transparent decision-making may be less significant than originally thought, as AI can already offer unbiased data interpretation and insights.

Even without this later realisation, CoBAlt had its shortcomings from the beginning. The Break-even Point (BEP) metric, for example, was a boolean value (True/False) instead of an actual value, due to its retrospective nature. It simply calculated whether the costs and benefits intersected within the given timeframe. This was done in case the analysis never reached a break-even point. If instead of calculating backwards from the end of the analysis, CoBAlt were to calculate forward toward a BEP when none existed, it would freeze trying to calculate to infinity. Although there are alternative methods to address this issue, the chosen approach was simpler to implement.

While adhering to most of the ISO guidelines, including the Established Conventions of Development Environments as defined in ISO 25066:2016(E), there are still some guidelines that it does not comply with. Most notably ISO 9241-14 through to 9241-16 and 9241-129 which deal with Menu Dialogues, Command Dialogues, Direct Manipulation Dialogues, and Guidance on Software Individualisation. The program was also never tested for compatibility with screen readers, which also raises accessibility concerns.

When it comes to the usefulness of CoBAlt as a tool, it works well as a cost calculator and as a cost-benefit analysis UI under specific conditions. Whether Airbus will be able to use the tool for their Causal Loop Diagrams remains to be seen.

Taking into account everything found through the research and development of CoBAlt, it would have been potentially more useful to have created a user-friendly Life Cycle Analysis tool for Airbus contractors and suppliers. Instead of a cost-benefit analysis tool, the tool would visualise the interconnected parts of their supply chain for management purposes and offer a unique and low-threshold way for Airbus to get data from their suppliers. It would be a way for both suppliers and Airbus themselves to get a better understanding of their place in the supply chain and their overall environmental impact.

If the decision would be made to continue with the development of CoBAlt as an economic tool, the bugs on page would need to be fully addressed. More stakeholders in the industry would need to be consulted on what features are useful for visualising data. Recommendations include adding a legend and various buttons to change the data visualisation modes. These could include the standard knowledge graph, nodes changing size based on value, a total cost node and total benefit node, and a standard CBA layout with all cost nodes on one side and benefits on the other. The elements should also have switches to be able to turn the inputs on and off at will and the user should be able to drag them to change their order or organise them into folders.

RESOURCES AND APPENDICE

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RESOURCES

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Appendix A. User Survey

CoBAlt User Test Form

This a test of the functionality, usability and comprehensibility of the CoBAlt Cost-Benefit Analysis UI.

* Indicates required question

1. Do you have experience with cost-benefit analysis?

   Mark only one oval.

   - ◯ Yes
   - ◯ No
   - ◯ Maybe
   - ◯ Other: _____

2. Do you have experience with economic models?

   Mark only one oval.

   - ◯ Yes
   - ◯ No
   - ◯ Maybe
   - ◯ Other: _____

3. Do you have experience with Microsoft Excel?

   Mark only one oval.

   - ◯ Yes
   - ◯ No

Test Case

Say you are a local businessperson and want to advertise
your services. You want to advertise because there is a projected average increase in revenue from each person who views your adverts. You have two strategies and want to know how to choose between them.

Strategy A

Newsprint ad space ……. €10,000

Radio show ad space…… €30,000

Highway Billboard……. €10,000

Production cost for graphics …… €10,000

Production costs for radio advert…….. €10,000

Projected Impressions…….. 1000

Projected average revenue per ad viewer €120

Strategy B

Online ad space ……. €30,000

Content production video shorts…….. €10,000

Content production graphics…….. €5000

Paid influencer partnership ……. €5000

Projected impressions …… 1250

Projected average revenue per ad viewer €120

4. Which software are you starting with? *

Mark only one oval.

- ◯ Excel *Skip to question 20*
- ◯ CoBAlt *Skip to question 5*

CoBAlt

Please indicate below whether you agree or disagree with the statements provided.

5. I think I would like to use CoBAlt frequently for Cost-Benefit Analysis. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

6. I found CoBAlt unnecessarily complex. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

7. I found CoBAlt easy to use. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

8. I think I would need the support of a technical person to be able to use CoBAlt. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

9. I found the various functions within CoBAlt were well integrated. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

10. I thought there was too much inconsistency in CoBAlt. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

11. I would imagine that most people would learn to use CoBAlt very quickly. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

12. I found CoBAlt very cumbersome to use. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

13. I felt very confident using CoBAlt. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

14. I needed to learn a lot of things before I could get going with CoBAlt. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

15. I found it easy to identify the most important inputs in CoBAlt. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

16. Given the imputed data in CoBAlt, I feel confident in the accuracy of my cost-benefit analysis. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

17. I feel like I can make cost-benefit analyses easily in CoBAlt. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

18. I feel like I can make cost-benefit analyses accurately in CoBAlt. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

19. Please indicate whether you have used both programs with the test case *

Mark only one oval.

- ◯ I have used both CoBAlt and Excel
- ◯ I have not yet used both CoBAlt and Excel *Skip to question 20*

Excel

20. I think I would like to use Excel frequently for Cost-Benefit Analysis. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

21. I found Excel unnecessarily complex. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

22. I found Excel easy to use. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

23. I think I would need the support of a technical person to be able to use Excel. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

24. I found the various functions within Excel were well integrated. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

25. I thought there was too much inconsistency in Excel. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

26. I would imagine that most people would learn to use Excel very quickly. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

27. I found Excel very cumbersome to use. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

28. I felt very confident using Excel. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

29. I needed to learn a lot of things before I could get going with Excel. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

30. I found it easy to identify the most important inputs in Excel. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

31. Given the imputed data in Excel, I feel confident in the accuracy of my cost-benefit analysis. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

32. I feel like I can make cost-benefit analyses easily in Excel. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

33. I feel like I can make cost-benefit analyses accurately in Excel. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

34. Please indicate whether you have used both programs with the test case *

Mark only one oval.

- ◯ I have used both CoBAlt and Excel
- ◯ I have not yet used both CoBAlt and Excel *Skip to question 5*

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Appendix B. User Survey Results

CoBAlt User Test Form

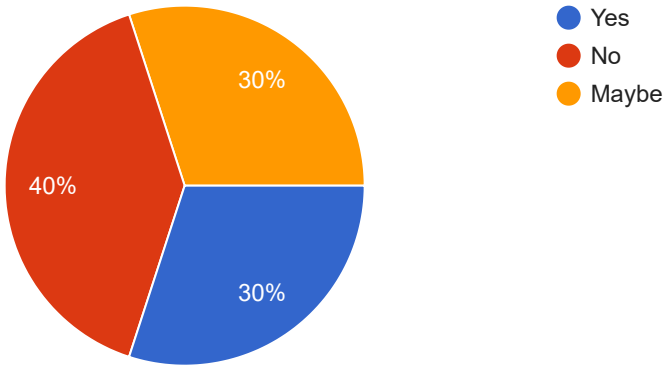
10 responses

Publish analytics

Do you have experience with cost-benefit analysis?

Copy

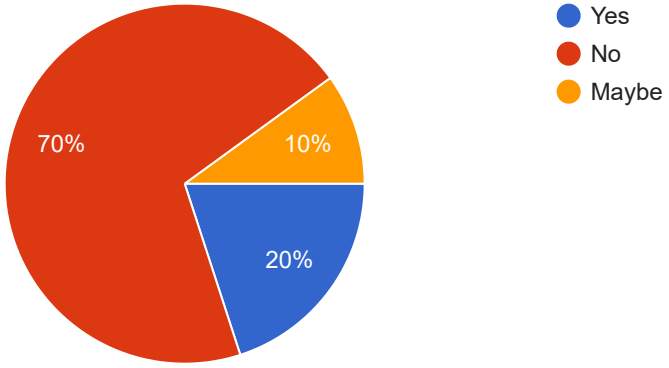
10 responses



Do you have experience with economic models?

Copy

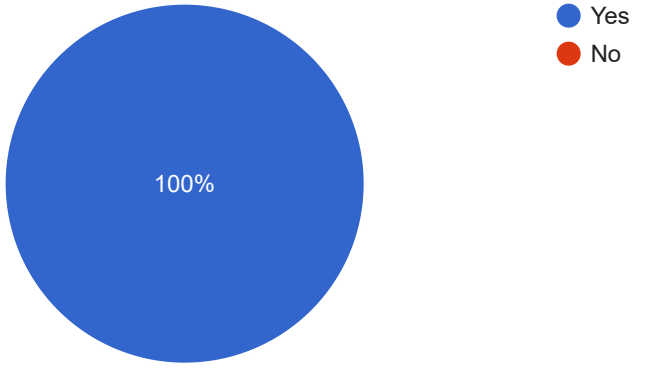
10 responses



Do you have experience with Microsoft Excel?

Copy

10 responses

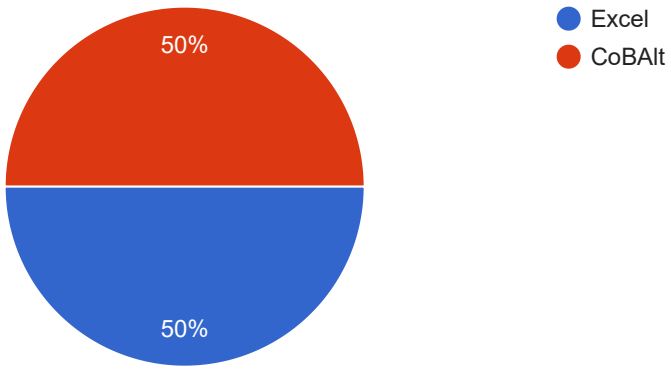


Test Case

Which software are you starting with?

Copy

10 responses

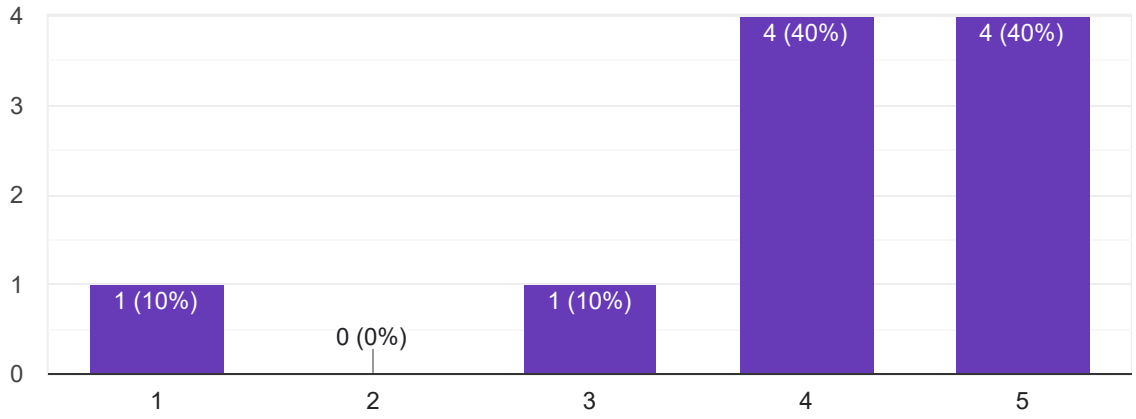


CoBAlt

I think I would like to use CoBAlt frequently for Cost-Benefit Analysis.

Copy

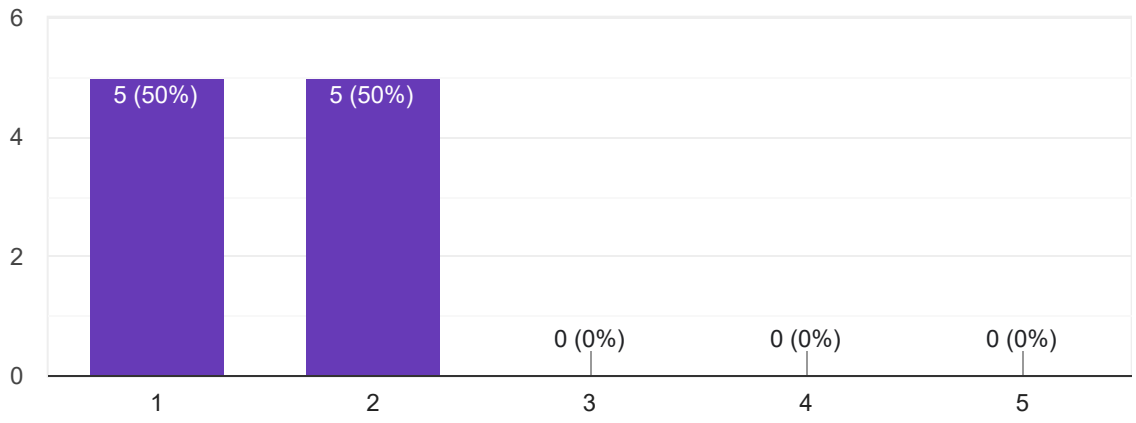
10 responses



I found CoBAlt unnecessarily complex.

Copy

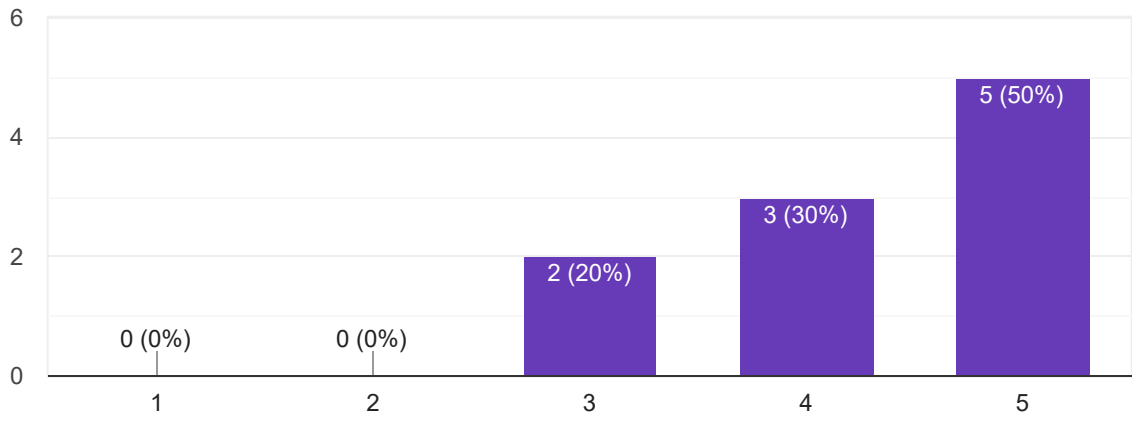
10 responses



I found CoBAlt easy to use.

Copy

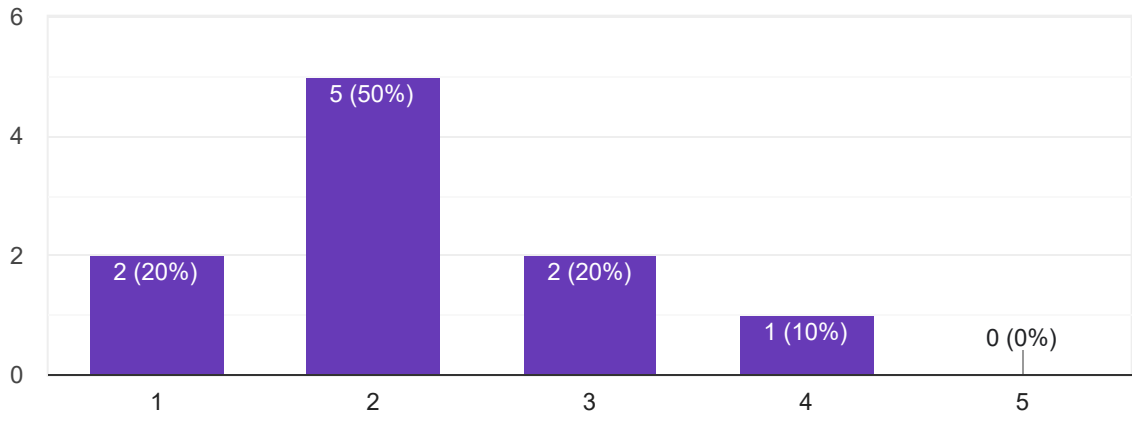
10 responses



I think I would need the support of a technical person to be able to use CoBAlt.

Copy

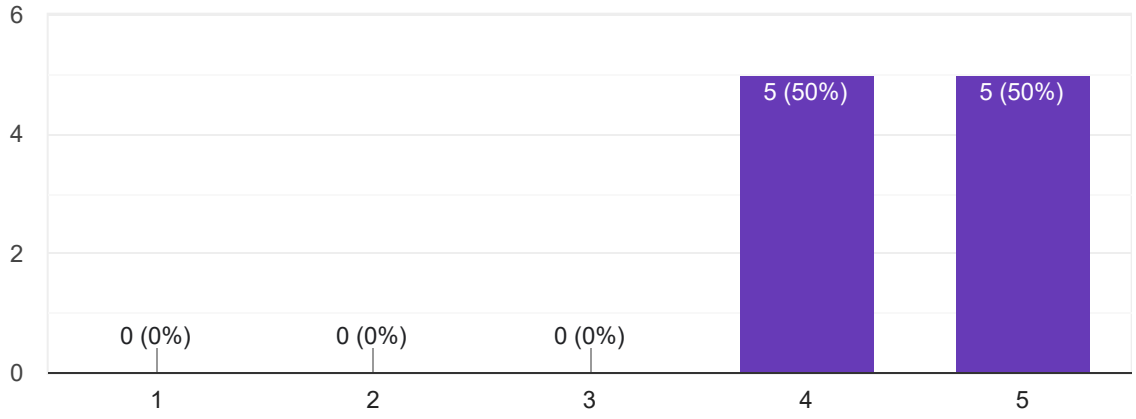
10 responses



I found the various functions within CoBAlt were well integrated.

Copy

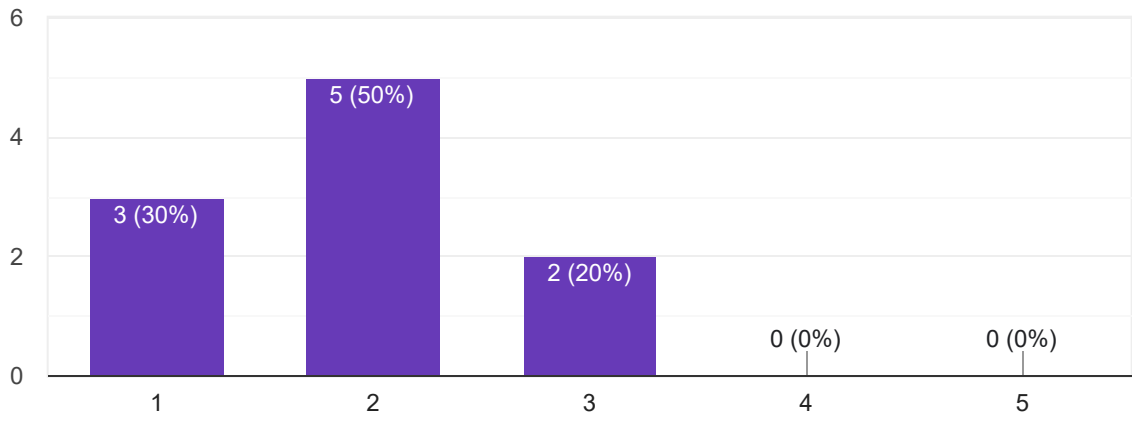
10 responses



I thought there was too much inconsistency in CoBAlt.

Copy

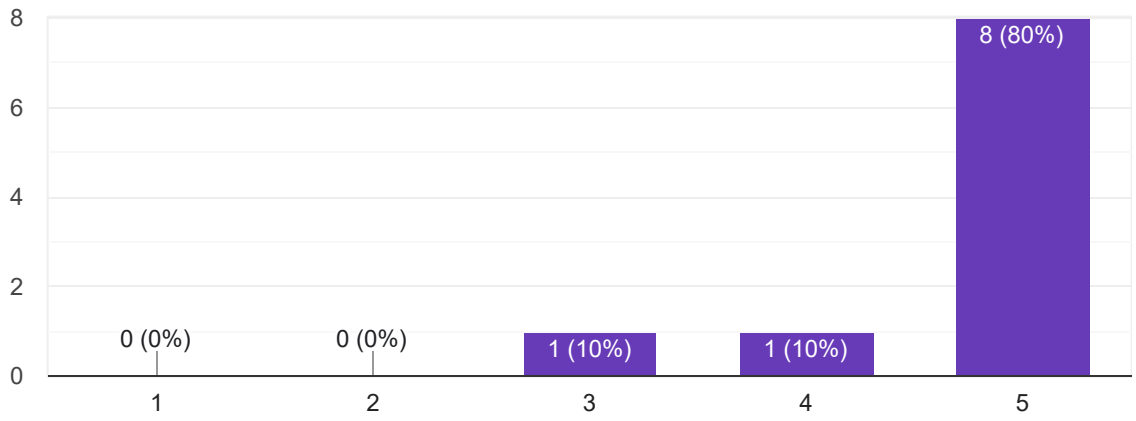
10 responses



I would imagine that most people would learn to use CoBAlt very quickly.

Copy

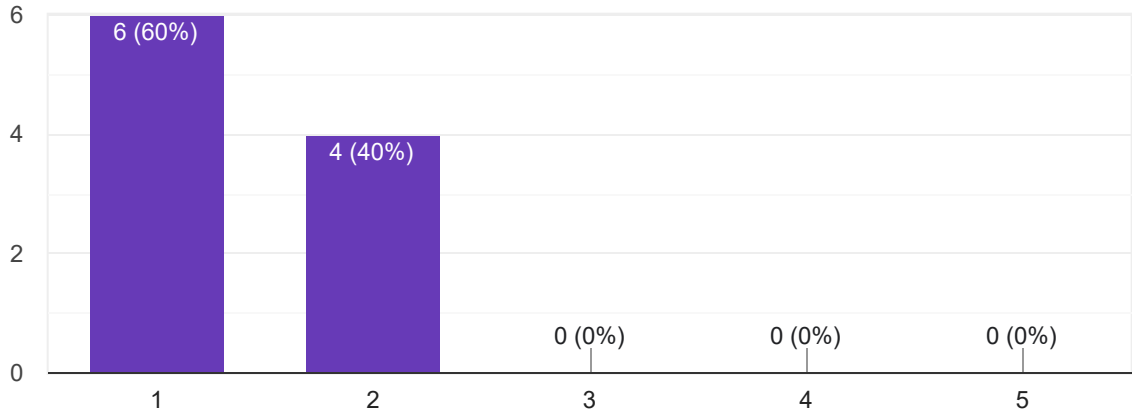
10 responses



I found CoBAlt very cumbersome to use.

Copy

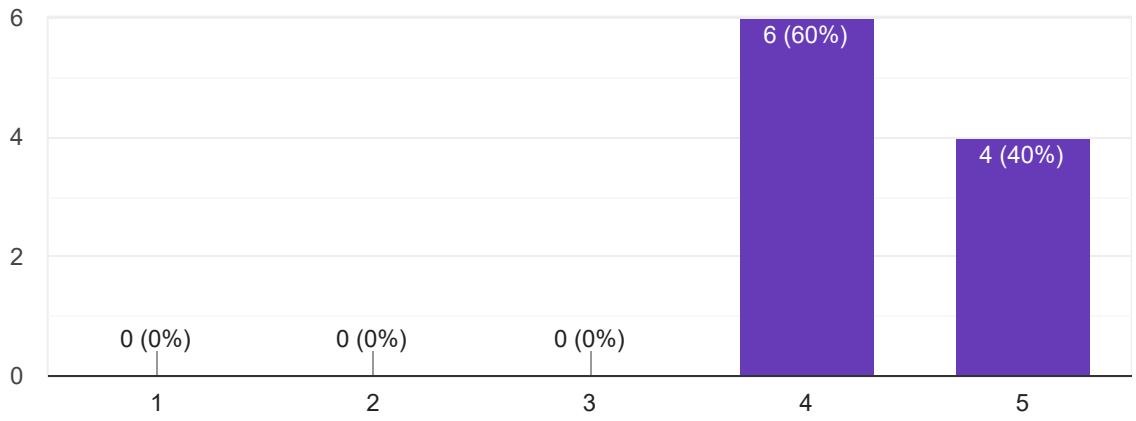
10 responses



I felt very confident using CoBAlt.

Copy

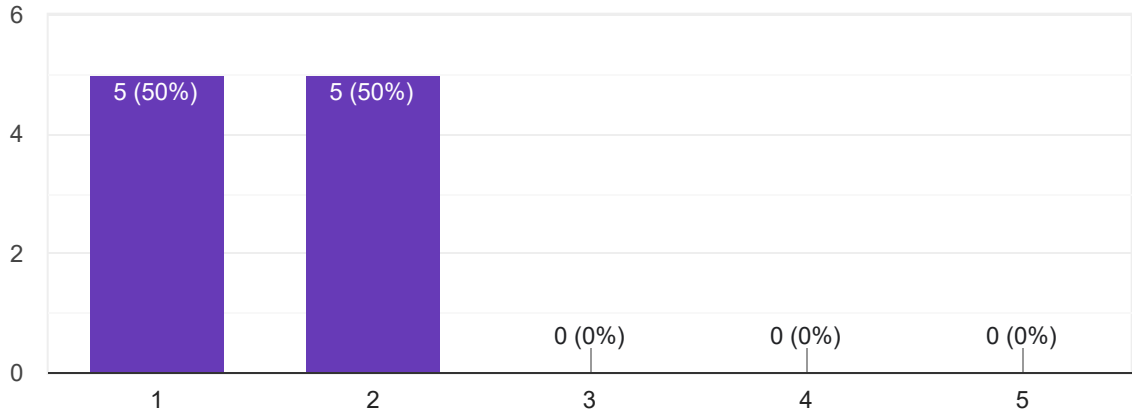
10 responses



I needed to learn a lot of things before I could get going with CoBAlt.

Copy

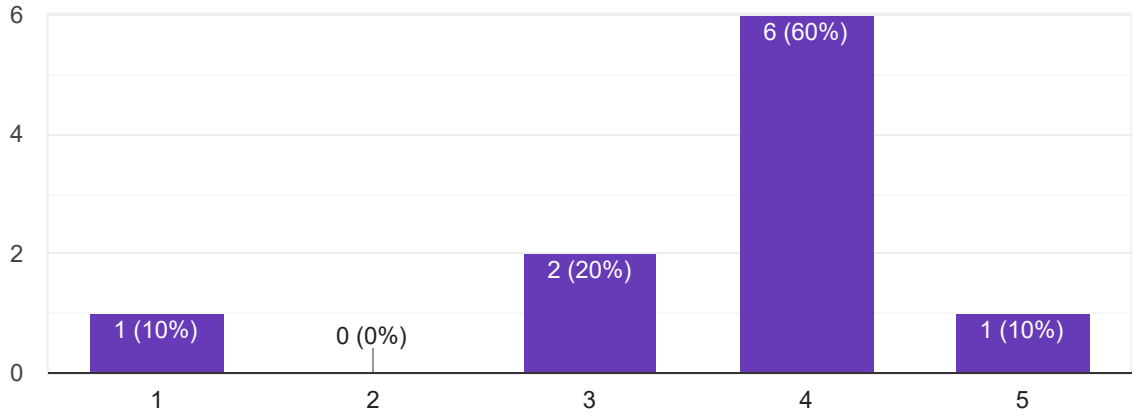
10 responses



I found it easy to identify the most important inputs in CoBAlt.

Copy

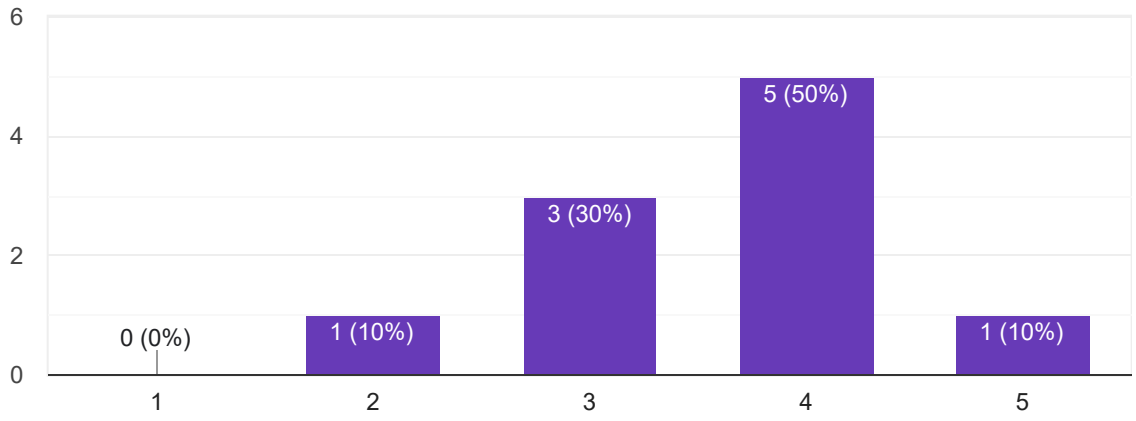
10 responses



Given the imputed data in CoBAlt, I feel confident in the accuracy of my cost-benefit analysis.

Copy

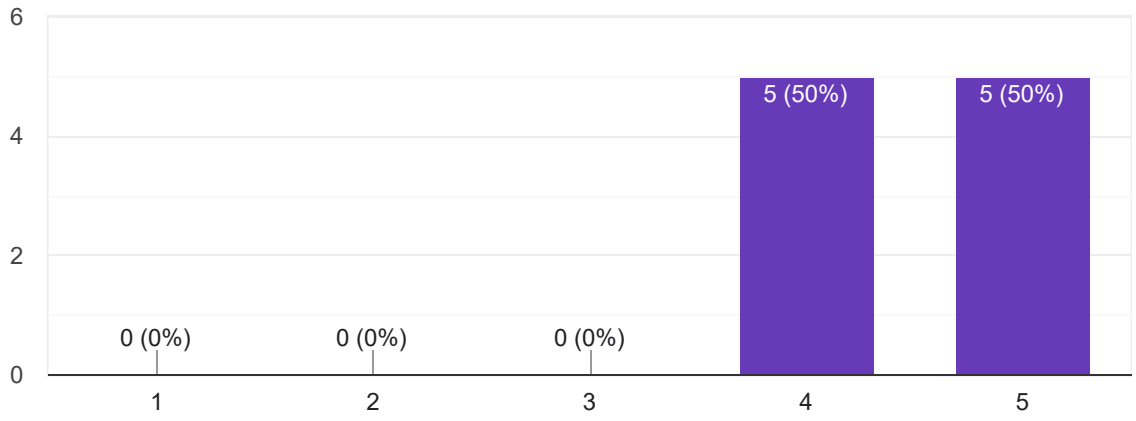
10 responses



I feel like I can make cost-benefit analyses easily in CoBAlt.

Copy

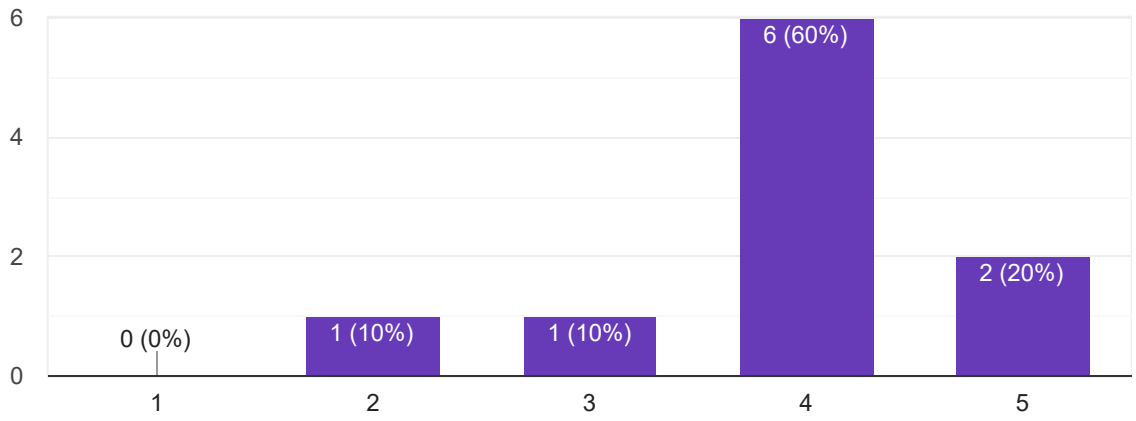
10 responses



I feel like I can make cost-benefit analyses accurately in CoBAlt.

Copy

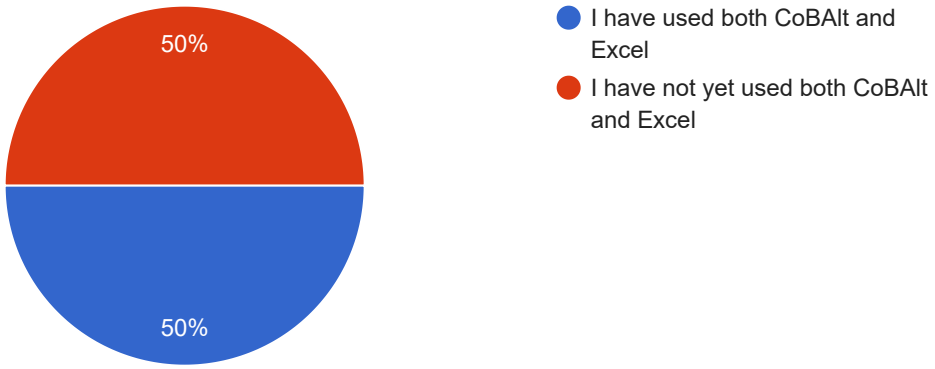
10 responses



Please indicate whether you have used both programs with the test case

Copy

10 responses

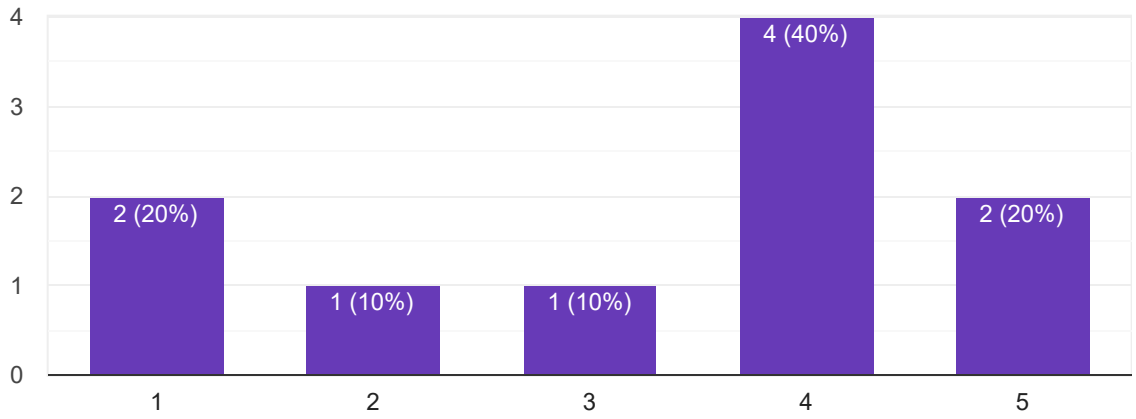


Excel

I think I would like to use Excel frequently for Cost-Benefit Analysis.

Copy

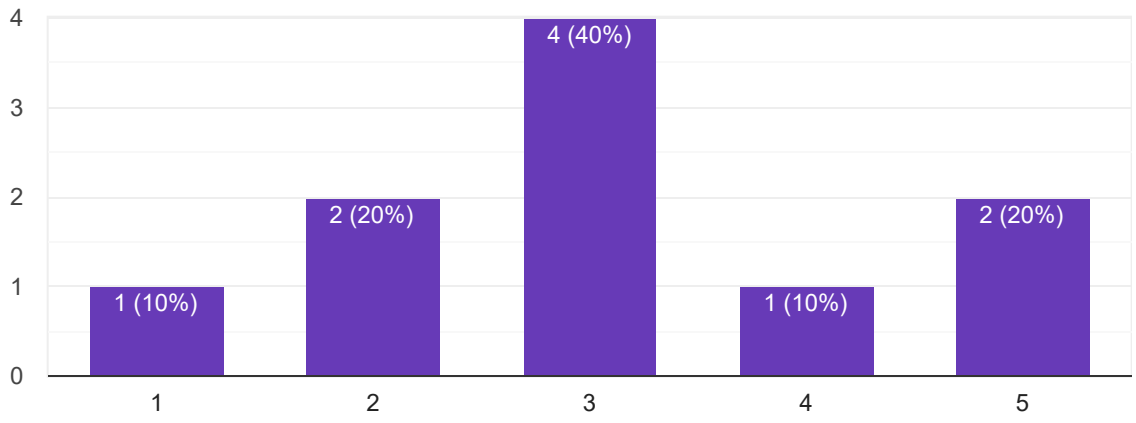
10 responses



I found Excel unnecessarily complex.

Copy

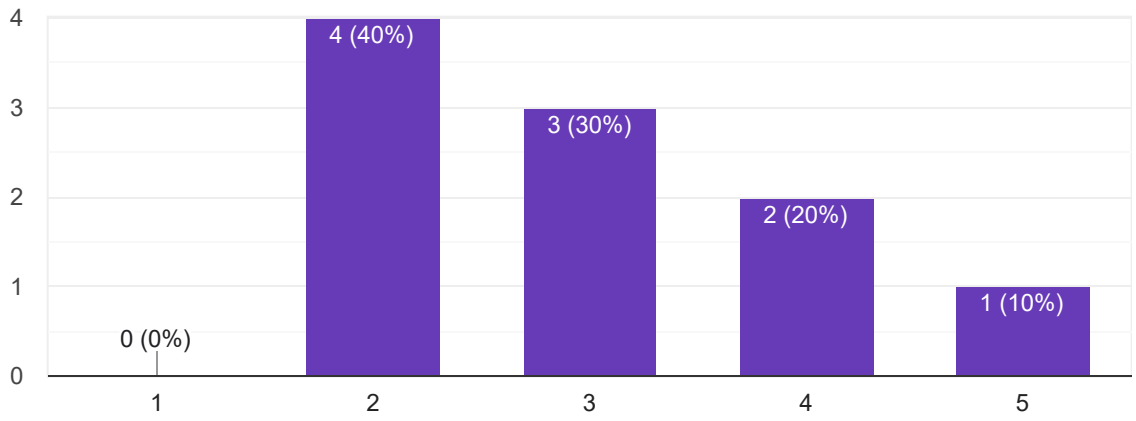
10 responses



I found Excel easy to use.

Copy

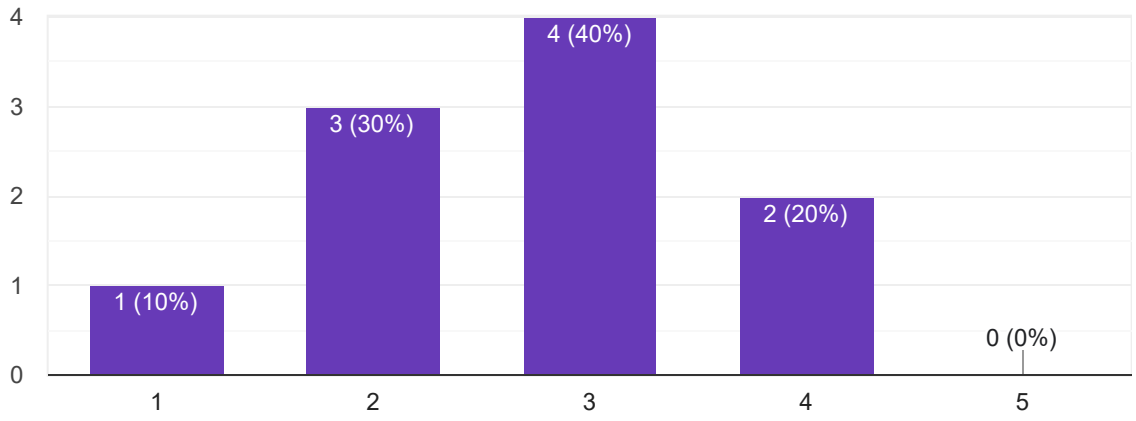
10 responses



I think I would need the support of a technical person to be able to use Excel.

Copy

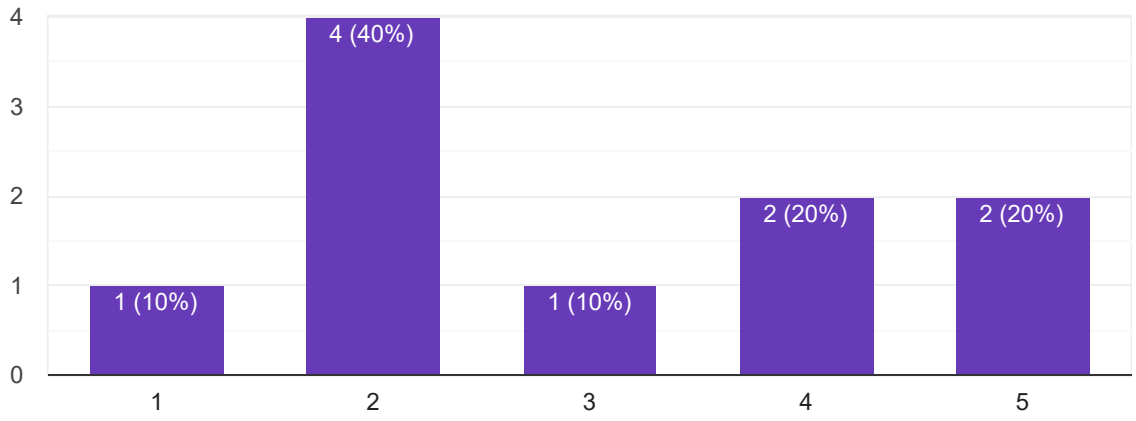
10 responses



I found the various functions within Excel were well integrated.

Copy

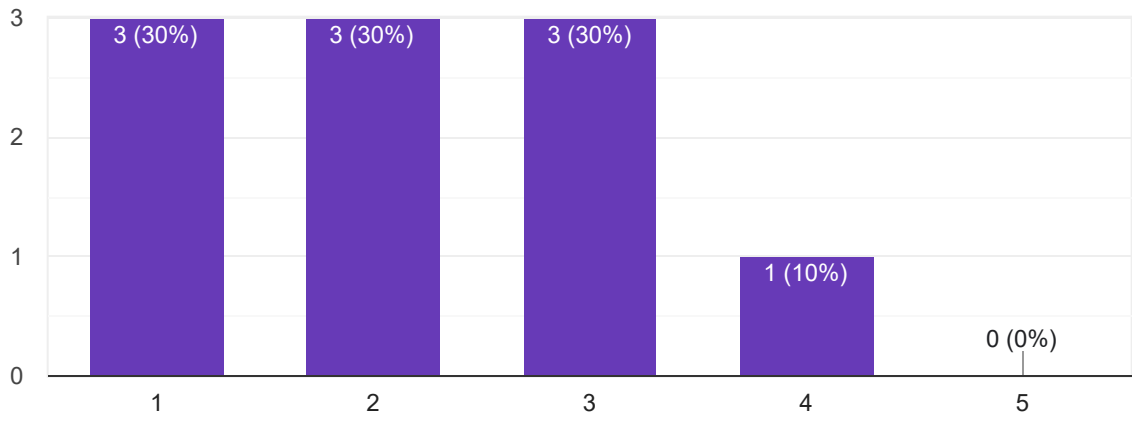
10 responses



I thought there was too much inconsistency in Excel.

Copy

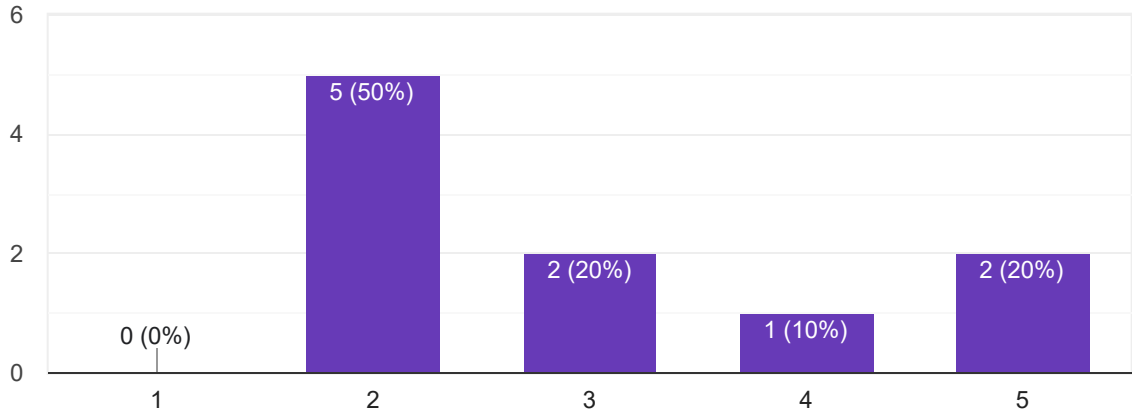
10 responses



I would imagine that most people would learn to use Excel very quickly.

Copy

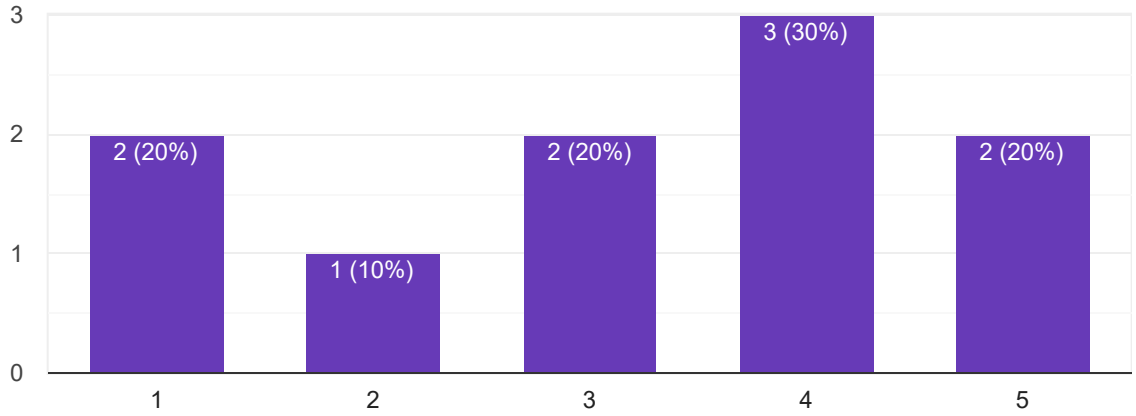
10 responses



I found Excel very cumbersome to use.

Copy

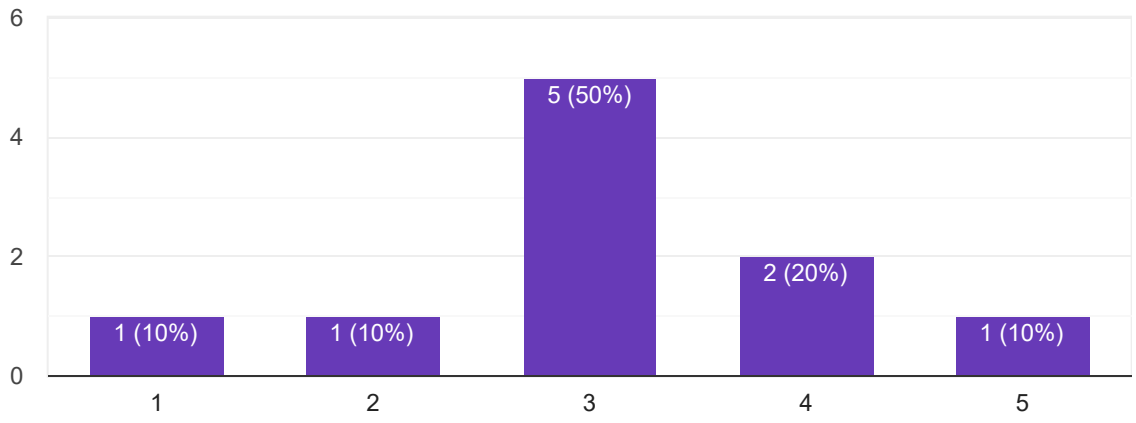
10 responses



I felt very confident using Excel.

Copy

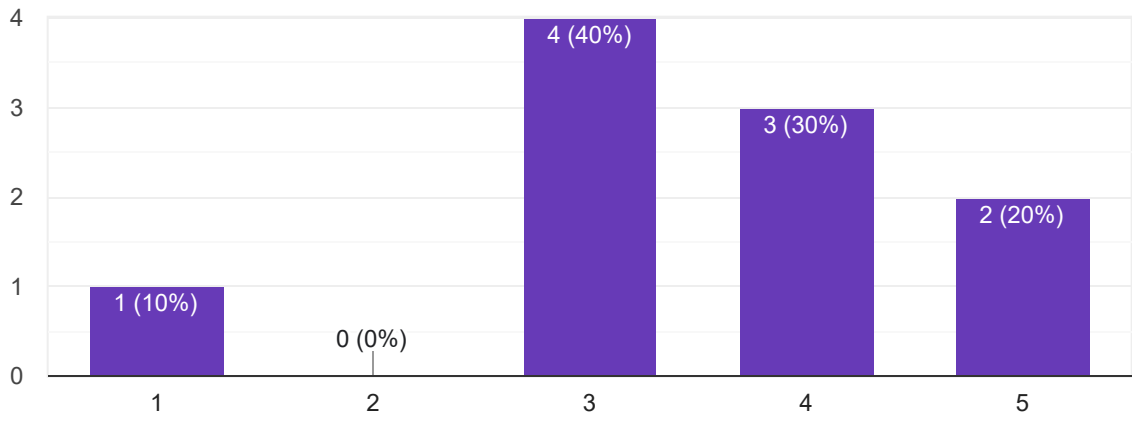
10 responses



I needed to learn a lot of things before I could get going with Excel.

Copy

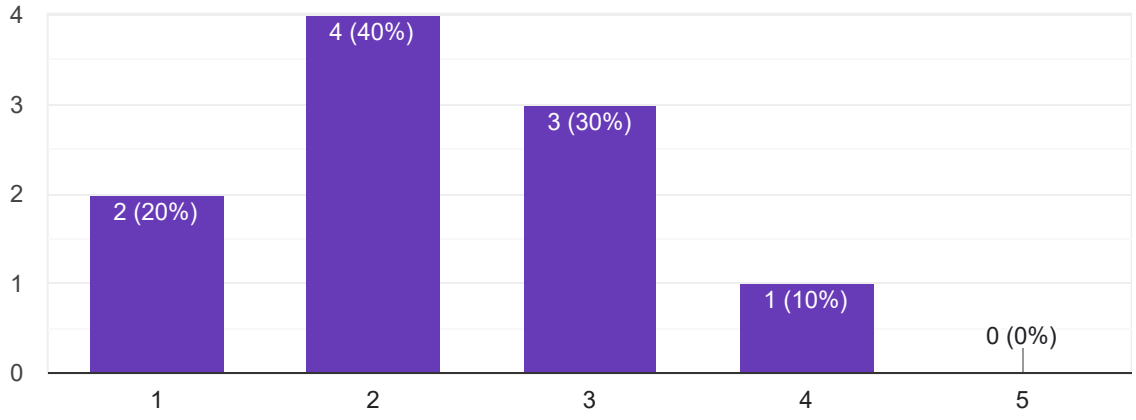
10 responses



I found it easy to identify the most important inputs in Excel.

Copy

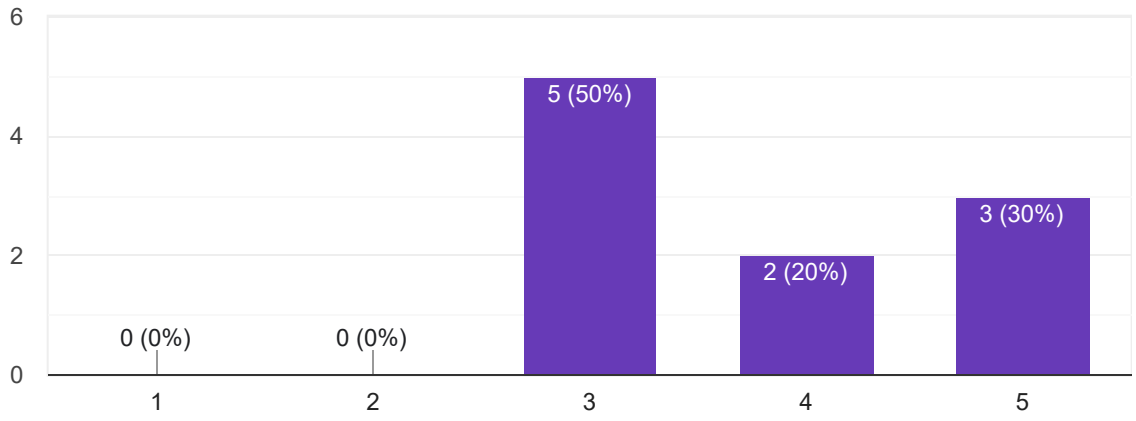
10 responses



Given the imputed data in Excel, I feel confident in the accuracy of my cost-benefit analysis.

Copy

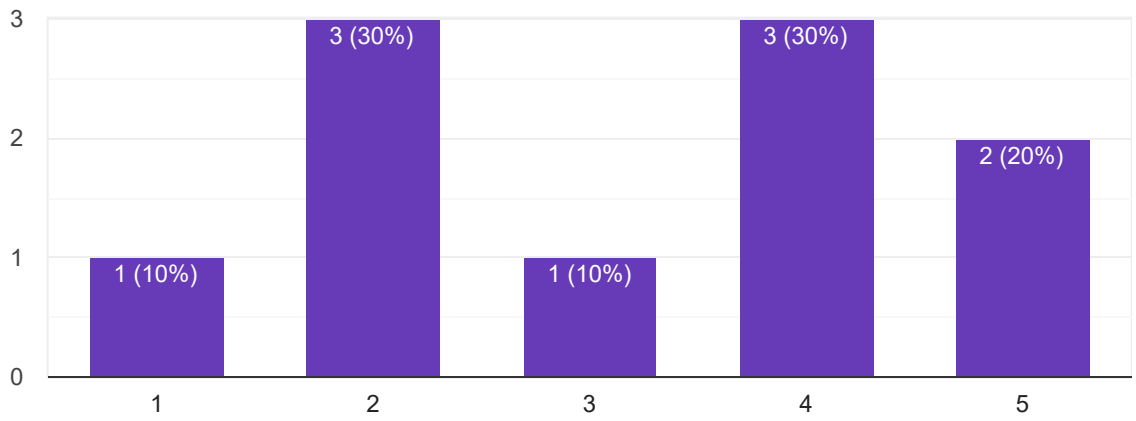
10 responses



I feel like I can make cost-benefit analyses easily in Excel.

Copy

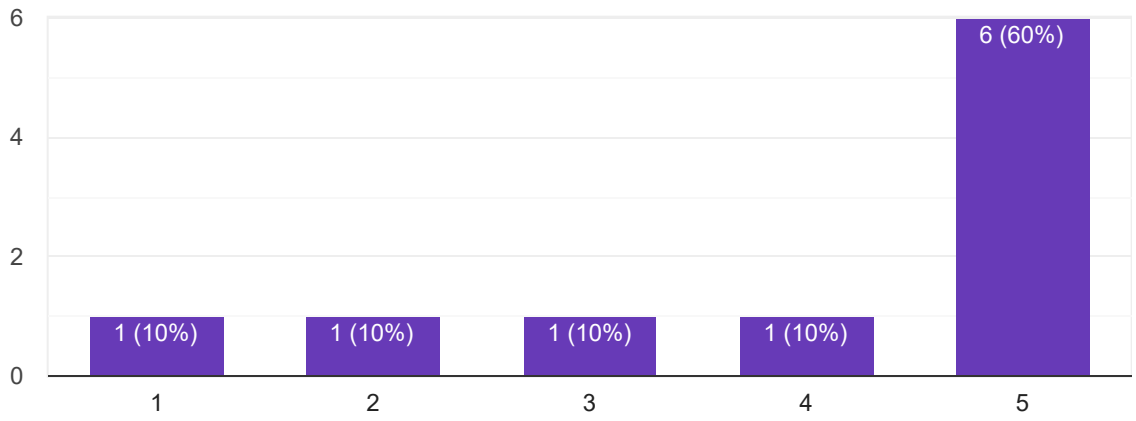
10 responses



I feel like I can make cost-benefit analyses accurately in Excel.

Copy

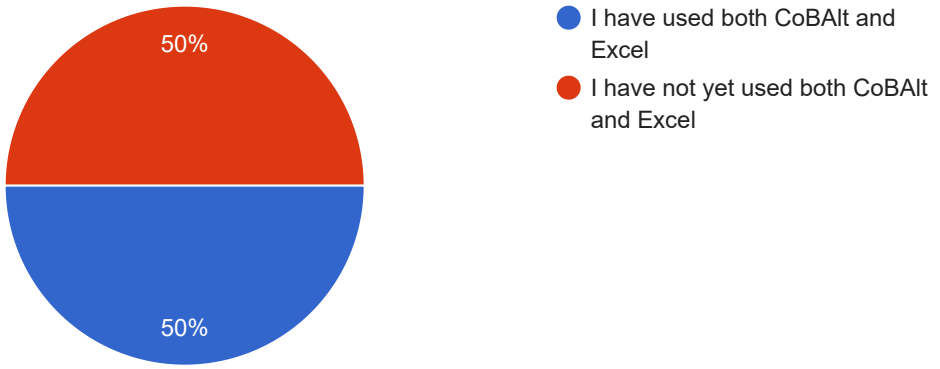
10 responses



Please indicate whether you have used both programs with the test case

Copy

10 responses



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Google Forms

Appendix C. CoBAlt Version History

V1
https://codepen.io/jensofzo/pen/ZEPpoWK
V2
https://codepen.io/jensofzo/pen/qBvGqBx
V3
https://codepen.io/jensofzo/pen/GRLpVdz
V4
https://codepen.io/jensofzo/pen/vYMLNJx
V5 - Working Elements
https://codepen.io/jensofzo/pen/BaEjrMx
V6
https://codepen.io/jensofzo/pen/wvZGBoQ
V7
https://codepen.io/jensofzo/pen/zYXqzoe
V8
https://codepen.io/jensofzo/pen/jORqXOe
V9
https://codepen.io/jensofzo/pen/WNWwWGa
V10
https://codepen.io/jensofzo/pen/ExJyXYR
V11
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V12
https://codepen.io/jensofzo/pen/eYodBGd
V12a
https://codepen.io/jensofzo/pen/ExJNqMq
V12b - Stable
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V13
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V13b - Stable
https://codepen.io/jensofzo/pen/bGJRbza
V14
https://codepen.io/jensofzo/pen/JjVOqWr
V14.1
https://codepen.io/jensofzo/pen/dyLdZoj
V16s
https://codepen.io/jensofzo/pen/MWRGzOa

Appendix D. Interview Transcripts

Bernard van Dijk - Hydrogen coalition interview transcript

Jens: thank you for speaking with me

Bernard: yeah no problem

Jens: as you know I am working about design decisions especially relating to hydrogen infrastructure for airports that was the initial basis of my thesis but as I've gone through I realised that there's is potentially A broader scope for for a tool or something similar so I really want to get to know you know how decisions are being made and things but before we get into that maybe you could describe your role at the Hydrogen science coalition and what it is that you actually do their

Bernard: well I'm not my history is that I want to flight operations engineer at KLM thereafter I was a lecturer in airplane performance and flight control at the university of applied science in amsterdam and I became involved in the hydrogen business actually through a student of mine who asked “sir do you think hydrogen is a good idea in an aircraft and I said well I don't know I have no idea I never thought about it so I investigated it in myself and I came to the conclusion yeah it's not impossible but a lot a lot of other problems and which mostly are related to the chemical and physical problems of hydrogen which not are not going to change that easy so that's also how I came to the hydrpgen science coalition because the founders of the hydrogen science coalition we're looking for navigation experts and I wrote an article linkedIn about hydrogen in aircraft which you probably have seen

Jens: yes

Bernard: yes so that's that's how I came through the hydrogen science coalition so I'm really their aviation expert.

Jens: that’s incredible! could you walk through... you mentioned just now just that hydrogen isn't impossible but it has lots of problems based on the chemical process of chemical properties of hydrogen can you just run through quickly some of the issues with it?

Bernard: yeah the one big issue for aviation is of course that it has a very low energy-volume ratio. That is one of the biggest problems and that eventually is going to cost you passengers, payloads and that will undoubtedly increase price that is no doubt about it so that is that is really the biggest problem any other problems which we have with hydrogen and especially liquid hydrogen is of course the extreme low temperatures we need to store this and that is another problem and then the third problem is how do you get it to the airport ... probably there will be electrolyzer plants on the airfield because now everywhere in the world the hydrogen is consumed at exactly the same place where it is produced. Almost everywhere that hydrogen is, it is transported almost never transported there only an emergency situations but that is another problem which you which you get and of course the hydrogen thanks of aircraft they don't fit into the wing so that is going to reduce your maximum takeoff weight considerably especially on the standard airplane designs to that will probably mean you are going to need aircraft designs like like the flying V from the TU Delft to make it a viable solution. So that I think are the four main problems of hydrogen aircraft and there is of course a safety issue. Because hydrogen is very explosive and its sitting in the same place as the passengers so I can see problems with that also yeah

Jens: yeah absolutely absolutely in your current function when you're I suppose youre advising airports and advising institutions on how to go about building up hydrogen if that's what they are after, is that correct?

Bernard: yeah that's more or less correct, not quite but I'm also saying well maybe you can consider other things but if you are not... I'm more on the side of the aeroplane operators than I'm on the side of the airports

Jens: OK OK and that's because the airport operators are the ones that are going to pay for it in do you believe or is or how does that relate?

Bernard: well if you look at the programmes projects which go ahead right, of all the fan fare which we read on the Internet Michael liebreich did an excellent survey of how much hydrogen projects were which are announced daily and with much much much more fan fare are really going ahead with the firm investments there's only 2% so yeah so I don't think that it's it's ... once the people see the price of hydrogen how expensive it's gonna be and what all kind of equipment you require then they say Oh well is this really something we want to invest in? yeah yeah with all the uncertainties that are around it yeah

Jens: so is that in your opinion the biggest hurdle to hydrogen?

B: yeah on the airport side that is by far the biggest hurdle of hydrogen is who is going to invest in this. And then of course you have the problem there is absolutely no green hydrogen today. less than 1% of the world's hydrogen is produced green so yeah so that means that hydrogen in itself is actually a decarbonisation problem yeah yeah

J: when when what would be your biggest advice to people who are looking at this process are looking at hydrogen as a viable option for like making a decision on hydrogen what would be your your tactic and explaining to them so

B: if I would be a minister or something and I would have to make a decision on this I would say OK it's OK to go ahead with hydrogen but I would first replace the grey hydrogen production and the black hydrogen production which is used today yeah and hydrogen is mainly used today by far the largest part is taken up for fertiliser production, ammonia production that's far by far the greatest amount of hydrogen and the second one is the desulphurisation of fossil fuels that's the other big one which is used a lot of hydrogen today and I would make a decision that we're going firstly going to decarbonize the current grey and black hydrogen production that is a sensible thing to do, I mean there are some other heavy industries that we can decarbonise with hydrogen, steel for instance is also a big one, yeah go to those sectors first and the big advantage is that it saves far more than those plane stuff running around it saves more CO_2 and the more the road traffic that goes to batteries and there are still people talking about that we do hydrogen in cars and trucks and that is not going to happen that's for sure and that means the fossil fuel will get less and we will get less fossil fuel usage and then also the desulphurisation of fossil fuels becomes and maybe you could then use that hydrogen which is then already made green for other purposes that would be my strategy

J: and is that that's a purely economic basis for that or is it

B: yeah that is economic based and is is, yeah sensible. It has no use decarbonize of course it is always good to carbonise aviation but you were going after one of the most difficult to decarbonise sectors and the same is true for intercontinental shipping those two are the really difficult ones, why not start with the easy ones which are far. The whole hydrogen infrastructure

after the electrolyses plant for ammonia production decarbonisation of fuels he's already there so the only thing you have to do is really build electrolysiser plants that's only thing you have to do is build a lot of wind turbines and solar panels and that kind of stuff and then you can solve that problem and that problem saves far more CO2 then aviation

J: I'm 100% with you, no I I've looked at this problem a lot and I have come to the same conclusion but there are still people that are are looking at it the other way around right there's some Glasgow Airport for example is convinced and this these were some questions I still have to book to meeting with them as well because I'm really interested we had a small meeting with Airbus and them together and they're convinced with their their consultants from IKIGAI that's operators won't invest in action on this the infrastructure is available the cheapest way to get the infrastructure available is to build it on our side at Glasgow Airport for small city hoppers and they're using grey hydrogen and they're going to start by making grey hydrogen plants on site and then once the hydrogen is available then operators will invest in it and then once operators have invested and they've got aircraft running on hydrogen then they're going to start investing in new systems that are green hydrogen based

B: yeah that is for me just a scam from the fossil fuel industry hahah

J: right!?? Haha! so how would you go about trying to explain to them in a way that makes sense to them like this is the the abstract part of my thesis right

B: yeah yeah

J: it's how do I get people to be aligned in their decision making process, right, because the further I go down the economic root the more people will say oh but you haven't focused on the environment, right, because economics is just about profits and about return on investment and I say OK but I have taking the environment into account they say yeah but that's not that's not scientific enough it's not there's no scientific basis and I'm trying to come up with a framework for decision making as design thesis that helps people to understand why people are making certain decisions and what the best way forward is

B: well you can explain to them that of course the current production of hydrogen is only grey and black and you can also explain to them what it takes to decarbonize that only, right, the current hydrogen production will require around 4500 terawatt hours of energy to be decarbonised and so that is a huge amount of energy that's twice the amount of green energy that was produced on the whole world in 2020 if you want to know whether that is feasible I can talk amounts but it is absolutely ... it make very little sense that you're going to build with grey hydrogen plants on airfields it only makes the problem worse, it dsoesnt make the problem less and so I would strongly recommend it OK let's fertiliser is by far the greatest user of hydrogen today so why don't we start with that make it that green, that is a sensible solution that requires also the least amount of investments so I can't see an economic case because what you also can tell them is that producing hydrogen with natural gas, grey hydrogen or if you capture the CO2 we call it blue hydrogen, is not so energy intensive, like electrolysis because the chemical bonds between water molecules and natural gas molecules bonds in water are 7 times stronger than the bonds in a gas molecule that means that you will require around 7 times more energy to produce the same amount of hydrogen with natural gas and that's the main reason why we do it with natural gas watch it's far less energy intensive so replacing that will already invest huge amount of energy yes so this is what I would explain to them and when I speak on congress that is also the first slide I show anybody remember that electrolysis uses 7 time more energy than

making it from natural gas and yet will try for the cost gigantically is not somebody but they also say “Oh yeah but Jet fuel is also not very efficient in a gas turbine engine no but oil comes more or less feely out of the ground, you only have to refine it which takes about 12% of the energy of the of the total energy content available from the oil but hydrogen doesn't come freely out of the ground you have to produce it that makes the efficiency very important because every step in the efficiency will take a cost and there the costs of green hydrogen is not yet very known because there are so little projects it's not really an assessment yet but the projections are that we will end up somewhere between 4 and 12 doillars per kilogramme of hydrogen and with four dollars it is on par with Jet fuel but everything higher than that will increase the price more and yeah we talked about it in the hydrogen science coalition we also think that it will be somewhere it will end up between 6 and 8 dollars per kilogram and then it's twice as expensive as Jet fuel so yeah you want 40% payload reduction pf an aircraft specially if you go long range yeah who's going to pay that ticket?

J: the more I've looked at this problem especially for for Airbus the more that I've come to the conclusion that the only way to do it is with heavy government subsidy which

B:Yeah.

which makes sense right but then it's the same thing as the other way around like the Embraer said we don't need government subsidy it will just be passed on to the passenger which I don't think which I mean, I am very sceptical about that because you know so purely economically speaking if you make a model of that right you’re 21 and a 1/2 percent or something like that more likely to have a business deal be done in person right so if you do it in person there 21% 21 or 22% more likely to have the deal be done that's why you go on business trip that's economically feasible for a company. if the price of a ticket goes up by more than 22% no longer worth it you can do it online like this, so if that's the case then half your markets 46% of flights are business so have your market disappears overnight.

B: Yep

J: and then on top of that right it's only luxury travel that's going to survive because it's for vacations and things like that and end your prices already you know above 22% what was before so it was already a luxury product and now it's even more of a luxury product and its only going to get more expensive because your market is dwindling

B: exactly! And the subsidies don’t last. At a certain moment the amounts they are putting in it right will stop some day and then you have to pay really the price of the plant and all the production and everything and yeah what's gonna happen then?

J: exactly I but I don't I don't I don't know how to tackle this problem right and so one of the things that I was thinking of this why don't I make a tool because I've been looking at so I've been talking to economists and I've been talking to people who do these kind of breakdowns and there's the only tool really that economists use is excel and excel is great I love it and use it myself and I understand it but when you make an economic paper and you give that to a policymaker or to business executive or to somebody who's in upper management or whatever basically what they ask you to do is write an executive summary of the excel sheet that you made with your recommendations and whoever reads this does not look at your spreadsheet, does not understand the assumptions that you've made, does not understand what you've done to calculate this, they just go “Ah I have an economist and he says this or she says this” and that to me seems kind of sketchy because they've made so many assumptions to come out these

models that you need to understand in order to make decisions have to understand how this assumptions are being made and in my experience that don't now the people that Airbus seem to think that they do but everyone else in the industry that I have talked to doesn't think so so it's wonderfully wonderfully incoherent but the the idea that I had was to build a tool if you were to imagine a tool like this something that's like it gives you oversight of economic decisions being made how would you imagine tool like that would look at how would you imagine that it would work

B have you talked to Jan polyak? On the internet is the founder of hmm hmm numbers or something and he does all these calculations for hydrogen and he is independent so it's it's quite realistic and I will search it for you

J: yeah if you could send it to me that would be great

B: it's a great site and he has made an excellent programme but you can put it in all these options from this is this and that goes so far and that goes so far and he is also really an expert on hydrogen and he.. Key numbers! That's what its called an he has also made predictions on green hydrogen and stuff.

J: amazing I will look at it thank you so much so you would expect the tool to work something like that OK perfect I'm going to show you a mockup now so I can share my screen with you I'm in the process of coding it at the moment it's very limited in in in the way that it functions which is why this is just a screenshot but essentially you have a plus button here on the bottom left and you can input elements like whatever consumption and market costs or social cost of carbon is of course the market cost of carbon is 50 million ways to calculate it and social carbon there's also 50 right, and then you can put them into little folders right and you can turn them on and off and you can edit the the formulas and then you have your benefit cost ratio your payback time inflationary and timescale on the bottom right here and then in this section here, by the colour and the size of the dots you can see at a glance which ones are the most important of the calculations

B:Ah ok nice yeah

J: so you can see add a glance which one is which element is connected to all the other ones the most so you can see that there are there are linked and then when you save it so you can save it in the programme itself I called it cobalt and if you press the button up here you can save it as an XLS well you can export doesn't excel. do you think that this tool is something that would that would be a benefit or?

B: yeah yeah sure

J: Yeah? Because I I'd like to build something that's generic that people could use but that people could understand the glance and an really yeah perhaps it can only be used as a teaching tool maybe just as a as A to show certain people have assumptions are made even just that would be it would be a useful application for this tool but I'm wondering if you have any any additional insights or think that this is something that would be useful or what is missing

B: yeah I yeah I think basic setup is OK OK sure that is really good, and yeah Im not a marketeer I'm a scientist of course and it's different for me but yeah you have to put in as much constraints and variables as possible. For instance for green hydrogen it is very hard to calculate the price of course there is no experience with it then almost all hydrogen that is used is grey and black and we have numbers on that one but for green its really difficult yeah that's what bloomberg also

says well it's very difficult to make a exact price on green hydrogen because there isn't any there's almost no experience with it so that is difficult I can send you some links where they do these estimates and what they're all about and what their assunptions are so you can have an insight in this

J: I would very much love that that would be very useful. finally do you think that the interface like that would be intuitive to use that somebody would understand how to use it without much instruction

Yeah I think so. it looks very very clean

J: thank you! so with that being said I I'm out of questions for this interview would it be OK if I ask you back once the tool is finished to have a go at it yourself and see how the tool works after this

B:yes absolutely!

J: Perfect thank you so much yes that's the questions are really had at the moment yeah no I I completely agree with you the more I look at this problem more complex it gets

B: what you also could do is we have one person in the hydrogen science coalition which is really the expert hydrogen production hes Paul Martin he worked 35 years in the business so you can also I think he's more or less obliged to help you if you if you give him a ring and he knows exactly yes a lot of knowledge about costs and what it takes to produce hydrogen, how these plants work and what you have to do etc etc so if you want to go into the details of your programme and I always ask Paul also" what you think of this" so that's another tip

J: I have message Paul Martin and he was very reluctant to speak with me he just posted a bunch of articles that he had wrote in the past and he said yes start there read all of those and then if you have more questions to talk to me on LinkedIn I don't really want to call hahah

B:hahaha

J: I was like yeah but I would be really interested in having a phone call! And he was like nonon you have to talk to Bernard so that's how I ended up with you hahaha

B:hahaha yeah ok

J: yeah that's it's I really I think he would be the first to talk to you if I need any like resources on specifically written numbers on how much its going to cost and then I think that's that's actually a feature I need to add to this programme as well something were you can access online resources to choose which model you're going to use for hydrogen cost or something like that and then it automatically loads in that would be something that I think is interesting yeah no it's it's the those kind of things there are things I'm I'm looking at and looking into it although I don't know how complex I'm going to be able to make it by the end of my thesis yeah it's it's the intensity with which this industry is attempting to fix problems without first understanding the problem is crazy to me I at first I was going to do my my thesis at Fokker, fokker next Gen yeah and I had this idea to to calculate how much CO2 would cost to transform schiphol airport and to transform every single fleet aircraft that flies there to hydrogen only. I wanted to see how much CO2 that would cost because then I could see how long you have to fly in terms of years with hydrogen aircraft to offset that carbon and the CEO at Fokker nextgen was like Nope, were not doing that. I was like oh OK... he was just not havin it he he was not of course it was also like company politics so the head of panta holdings he unfortunately passed away just before it was

meant to start and the board at panta didn't really trust this CEO at Fokker to continue on with his mission

28:40

so there he launched a nice and that's why they might didn't accept me in the end and how I love it but but that was just insane to me that was like you'd rather I mean you to have somebody on your side trying to calculate and see how long right but no no no and and same thing with with Glasgow they're they're 100% certain that hydrogen is the way to go they need governments to get it done and my worry is that when you do that you incentivise the market to go into particular direction because that's where the money is that's where they get money from the government gives you free money and the second you've gone down that road even if there were other less polluting options available that's not really shows which was money and yeah should be going away but then what next time that's that's the biggest problem right it's that it works really well or like economically decrease with virtually well if you think that there's a profit model to be made but the second that governments to goes away but that absolutely I'm I'm worried about do you think it will be possible before 20/20/30 did you ever think realistic timeline before most of these people who are starting these companies have no idea they come from the car industry or whatever have no idea what it costs to certify an aircraft whole different thing it takes if you Ave if you're doing existing model OK you can go a little bit faster if you start from scratch and you want to certify and equitix at least 50 years yeah it's crazy you can get all the other end process word 50 years from the start of the design to the end yeah and then also with a very explosive fuel more I'm very interested if there's going to be certified by the government agencies are responding to this what you have to do I no either I I am I've lost faith really in the ability to for governments to remain objective in those kinds of things right because the second the cyber truck for example just came out it has this deal so it's crash like structure it's it's the front has a small compass on behalf A metre but the sides have zero and they don't couple no it's just electrical and so I was like I there's no way it's going to be certified for crash tests and everything it's just stop it has passed what if it's like leniency because it was a green car OK yeah so when we when we go into the FA or to me as I have already said 2030 is the goal which we all know is ******** baby actual from Philadelphia like around magic yeah this one just just got sold so last just the summer passed right you know how many how many 100 hundreds of A3320 that rolled off the line that summer they just sold them right those players can can be flying for at least 40 so by 23rd by 20-30 to have everything flying on net 0 is that such same goal that's impossible isn't it possible exactly we can you know sit here and pretend that yes I'm saying you know all this stuff and it's going to happen but I so the best thing I can do is just find innovation shakeout which fuels in which pass forward are going to be the most stable in the long run and then go for them instead of right we're doing now which is saying oh hydrogen is a way to get 0 let's put all of our eggs in one basket yeah'cause I knew that So what is strikethrough allergy instead of larger yeah and if you see at the spatial property Mauritius or legs due to hydrogen leaks account in the production process it's enormous'cause it's show leaks out of anywhere and it's so much problems of it and then cover stop them because they had used automatically entered into equipment and that was to expand now that if he could not OK then standards companies well I yeah I doubt it very little yeah add there are already 3 hydrogen station serving fuel stations have exploded and it's yeah I don't but she yeah no there's there's a lot of there's a lot of sticks that you can put into bicycle spokes looking at the research that I'm looking at now is just already incredible I mean you mentioned the the energy density of hydrogen that was problem number one that's why I keep us as the first problem the fact that it's in its liquid form which is already more energy dense discussions form it's four times less energy dense than

cares so you need to take four times the size on aircraft that's his first heavier you can't do what we currently do which is put in the wings because the flex would cause significant issues so you have to have it on top of the fuse and you have to have it be the whole length of the fuse Set your finally got here right and that's another problem we want to put forward today first that's why they have this really like on their site that was really like wide playing yeah it's not it's not a circle it's a it's an ovular shape because I want two tanks by the wings inside the fuse but you can't do that because based on FAA regulations you have to have the tank outside the pressure vessel you can't have it inside is last year that's another problem when you're filling up the tank right we thought oh it's just it's just easy you just pour hydrogen and your turn around time isn't affected you have to wait two hours because when you fill the tank with liquid hydrogen what happens is some of their sizes which means the pressure increases inside of the tank which means the top 10% or so you can't feel that's great yeah you have to wait until it cools down enough that it becomes all liquid again and the pressure requests and then you can fill up the rest of us have to wait two hours for that time show way if you know if you were if you live take with you well the favourite just fended off the water yeah yeah more I look at it the more wicked this problem becomes it's at the with the restrictions on carbon emission out of aircraft is also but also nitrogen emission L2 and then X the problem is if you had pure oxygen coming into the engine it wouldn't be an issue because you will lose any out of X but what happens is the more you he up there the more that reacts with the already existing lecture on the air with 70% and you get more analytics hydrogen engines at the moment as they stand they produce more analytics because they burn 500 to 1000° hotter than parents no nobody's talking about how much I next production hydrogen to do so nobody cares I just why don't we care why is nobody asking these questions I don't understand it's not that I I find it an issue I think we can it's perfectly logical to fly on hydrogen I think we can do it it's not it's it's a huge engineering problem that we can solve it that's not a problem I problem isn't going to be any better for the environment than what we currently have and is it going to be worth the investment and I can't come up with a clear answer and that's the Twitter that's why it is hard to is going to play a role if you should she told these problems and we are going to fly out again then there will be row only in the medium range I really like always should be far too much harder for which you can never store in the back office systems it's just impossible and for short range they will switch to batteries and where that exactly I'm struck with batteries does anybody's guess but I think that we had go up to around 50 month you makers with their with batteries and then in between 15 hundreds and say 2500 kilometres dare I solution can I put a block before long range absolutely not for long range you need to have you compare it to A-787-9 new flyer real long range route you have you need about 1/2 swimming pool foolhardy journalistic check out the fly on my own sustainable education fields that is sure yeah OK the simulation feels are you looking at the just just the the simulation tools we know it now or are we looking at some kind of ammonia mix or to be a feeling application this far to talking show all the questions you're starting off the fire because there for the moment show party toxic that it's never going that people say that's also going to play a role in shaping forget it's far apart Avengers so I think we will make a short of my own kareshi which is more or less the same map Ortiz yeah yeah if you only all regeneration only lower shipping there will be enough life in this table that is like you need about 21 X issue 44 model figures for every action and the potential without hello checking takeaway in the fuel at the food supplies is about 50 so that's enough to do a long range alright and answered so that's that would be the future scenario you predict where they have multiple difference solutions how this can become an because it will that really catch it can be the same as cheaper for you that batteries will bring always 'cause you have far less conversions in the process that will be two to three times cheaper so the moment that happens if he goes if you cannot go up to three kilowatt hours per

metres for battery status it won't be any plans like marketing do you think that will get there before just they shape otential around yeah it's it is possible only if they're going to be rechargeable that is political they have to introduce batteries often better density level but they're not rechargeable special people OK unfortunately I think we can make it if you look through the battery density increase over time yeah I think that we have a long way to go yet so I think it's possible that only short to medium range will go to batteries but yeah that is shared ownership projection of mine and that is not face one chemistry ahead how would you recommend we go about figuring out whether that's actually going to be possible or not right now what we've done is we've said this is a crisis that we need to act now and we've decided that it doesn't matter what like we shouldn't even have debates about this it should just be any action to reduce carbon is the best action which I am firmly against it on how you use it on that topic but that's my personal belief the thing which I would do especially if I wanted politics is first tax kerosene if I go with my car to to certain Spain or something I have to pay everywhere text you my car but if I go by plane next play nothing could explain this again right so I will text you about the same as I as we text off you will that will be my first decision then it's getting a lot more expensive and where you can use that money to financial cultural initiative store and I will start in the end eagle battery electric planes that's the place where I would start see how far we can go with that one thank you so much for staying out and talking with me this is really educational and I will also give you a cheque next step once the tool is ready and then and then we can we can sit down again you can go through that or tell me what you think is wrong with yeah OK yeah thank you so much for that I'm lovely day OK yes you too bye bye

Gigi Interview Audio

Wed, May 15, 2024 6:39PM 1:03:49

SUMMARY KEYWORDS

economics, ecological economics, stakeholders, orthodox, cost benefit analysis, electric cars, assumptions, economist, analysis, monetary value, involving, work, tool, meeting, problem, values, fossil fuel industry, executive summary, framework, stake

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00:00

See the contact details of the person that I complain to,

00:03

you can complain to this person here, they're the general researcher. You can complain to the head retreat researcher as well. But it's James and James doesn't care. And then you can even contact the guy that I was supposed to have a meeting with. Okay, I was supposed to have a meeting with this guy. I'm recording it, it's fine. Let's put on me with this guy called. And he was my data steward. And he is responsible for the data that I create from these interviews, and I had to have a meeting with him because the data steward Yes, exactly. And the reason I had to have a meeting with him. His name is Jeff love, but he's a doctor. That's Dr.

00:45

Dr. Love. Okay, okay.

00:48

I suppose I'm meeting with him, because then he could talk me through ways of being handling data better. Yeah. And I wrote down in my data management plan that I was that I had sent him an email, but that he hadn't hadn't answered me in a week. Yeah. week and a half. After I sent him an email, he answers me. He says, Hi, yeah, I'm sorry that I was, you know, late. Yeah. Not sure if a meeting is necessary. Given that you're just going to do interviews, just right, in the data management plan, that you had a meeting with me. And all as well, Oh, lovely. stuff. But in the data management plan, it says I have to have a meeting with my data steward. And in my faculty, Dr. Love is my data stewards. So I just wrote, I sent him an email, and then they approved it, even before I had a meeting with him, even though the DNP says I have to have a meeting with and it has like it specifies like a philan box of the date that I had the meeting with this person, so that I make the make sure that I have a meeting.

01:54

So it wouldn't be a bit condescending towards qualitative interviews. There are certain things that you need to actually watch out for. No, of course,

02:01

no, but I think I think the whole process is ridiculous. I have I have a I have a thing. Right. I was gonna use this to record all my interviews. And then it's stored offline. Yeah, nobody can hack it. Because it doesn't connect to the internet. Yeah, it's just a recorder. Yeah. And it would have been perfect, or would have made transcripts using an offline programme on my PC. And they said, no, no, you're not allowed to use personal devices to record. I was like, so joked about it with James. I was like, hey, if I give this to you, right, this is now your property, and you lend it to me for the duration of the project, then it's not a personal device. To okay. Please, state your name and your occupation.

02:56

My name is Shuji Flamel. My occupation you mean like my job right now? Or what? Yeah,

03:02

well, in this case, it'll be your capacity as a as an environmental economist, okay. Well, I

03:09

have a master's in ecological economics.

03:13

I just graduated, currently working part time as a receptionist, but looking to get into the field of ecological economics or something adjacent to that I might go more into the ecological direction. Well, we will have to see what happens. What

03:33

is the difference between Ecological Economics and environmental economics?

03:39

So environmental economics is economics rooted in Orthodox economics. So kind of the traditional ways in which we look at the economy, whereas Ecological Economics tries to steer away from orthodox economics and tries to build a new economic framework in which to view sustainability problems. So there's a lot of problems with sort of traditional economics in the way that the

environment is viewed and that, you know, when like, the economic models first came out, for example, they kind of assumed that resources were infinite basically. And they didn't really take into account, you know, that. Just a lot of things that we now seem more important. And there's just like a lot of friction between economics, like orthodox economics, and heterodox, yeah, and heterodox economics are just like, sustainability practices. So

04:38

how do you view these sustainability practices within the framework of, of existing orthodox economics? Are they a step in the right direction? Are they not good enough? Are they?

04:54

I think it's a difficult one because of course, It's like, something is better than nothing. Right. But I think in a lot of cases, placing sustainability issues within orthodox economics kind of takes power away from it. Okay? To give an example, because I think it's maybe good to keep it a little concrete, you've got ecosystem valuation, for example, right? Within orthodox economics, you would say that, okay, like, this is the ecosystem, and we can assign a monetary value to this ecosystem based on a full evaluation of everything that the ecosystem provides us as a society. Right? So you look at like,

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is that only like the, the value of the physical material present within the ecosystem? Or is this also taking into account like, other benefits,

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it can also take into account other benefits, and they're already sort of the views can diverge. But like, the primary principle, in Orthodox economics is you can place a value on these things. And then you can you can go, you know, very, like superficial on that and say, like, it's purely just the services that the ecosystem provides, right? Or purely like the materials, right? Like, if you have a forest, like just like the timber and stuff. Yeah, usually what they do is they will go a step further and be like, Okay, well, it does protect us against floods, for example, or it helps I guess, soil erosion. Okay, right. And of course, there's also like cultural and social dimensions to it and like, even spiritual value. So, from an orthodox economics, five fantage vantage points, a few points, you would try to place value on that and then add it all up. And then you just get a sum of money that represents Right, yeah, heterodox economics. So ecological economics would say, well, actually, it has intrinsic value, and you cannot put a price tag on it. Right. Okay. Right. So so that's a very different kind of core assumption that you're stemming from then. Because you're saying like, you cannot really put a value on it. So you know, you have to

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it just depends very differently when you're making policies, for example, right? Because if you can put a value on this, that you can compare two different things, right? And say, like, Okay, well, if we chop up this forest, but we compensate in like, other financial ways, then it evens out. Right? Right

chop on this forest, but we compensate in like, other financial ways, then it evens out. Right? Right. Whereas, you know, Ecological Economics kind of comes in and says, Well, you can't you can't ever really, truly replace things. The big concept in Ecological Economics is this concept of like, there being limits to how interchangeable things are, okay? Right. Just because you can even say you put a monetary value on something doesn't necessarily always mean that if you have something with the same monetary value, it's equally interchangeable. Okay. So that's something you run into there.

07:58

Right? So in Ecological Economics, you would then say that intrinsic values, you could never you could never take truly take something and equate it to something of equal value, you can't create a variable. Like, it doesn't have to be money, but we can use money as an example. You could never equate something to a value of money, or a value. Yeah, yeah. A variable. You could never equate something to a variable that you could equate something else to as well, you can never

08:35

create a Yeah, yeah, it just recognises that there's just hard limits to stuff, you know. And of course, I mean, in practice, you know, like, in academics, there's a very strong distinction between the two, and it seems more black and white, I think, in practice, you have a lot more areas of grey, where if you if you're coming from, like orthodox economics, you will be like, you know, at some point, like, what's the difference between someone from the orthodox economic side coming in and making like 20 categories that they all like, put values on somebody from Ecological Economics coming in and saying, like, well, you know, there's limits to it, but the limits are not so hard, you know, what I mean? Okay, they they, in practice, everything is like in many I think, disciplines, you know, it's kind of all over the place sometimes and can be hard to differentiate. But yeah, in theory, that's the that's the distinction. Is

09:22

there a, I would imagine it's not the case, but you could elaborate on it perhaps. Is there a fundamental framework for Ecological Economics where you could like, if you're not taking money as a as a value? How do you solve the same problems? I mean, let me put the question a little bit differently. If if somebody comes up to you with a problem, how do we best solve this and they're asking this to, to sort of economists I would imagine it would be very easy for a an orthodox Economists to come up with a value or like the directions to solve the problem and then say, Okay, this one will give you so much value this will give so much. Yeah. How would an ecological economist solve solve the same problem? Solving? Yeah, air quotes? Yeah. How would they go about solving that same problem?

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I think then

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you're probably leaning more into simply trying to sit down with every one that has a stake in a certain, like you're talking about, like one ecological system, right. So sitting down with everyone that has a stake in it and trying to come to sort of some form of agreement based on like, how they value things.

10:49
Okay, so it's like a social contract, essentially.

10:53
Yeah, I think that's one way to approach it. But to be honest, in my degree, we didn't talk too much about how to go about these things. In the day to day, I will say, Okay, this. So I don't know, if that's what you're right. That's what you need information on. Yeah.

11:13
So Well, essentially, what I'm doing is I'm trying to, I can reveal more of my cards now that I've, that I've talked to you about. I want to make a tool. Yeah, this tool makes economics work more accessible to decision makers. Yeah. So my assumption is on all of this, this isn't always the case. But in some cases, it is the case that piece of economics work is requested. So they have what was the best way to solve problem x. And they give this to an economist and this economist comes up with or does their work and comes up with a document that is way too long for words, and says, Okay, well, in this document, there are three different scenarios. These scenarios are the best case scenario, worst case scenario and a middle of road scenario. Yeah, they write an executive summary, based on this work. Yeah. And they have this executive summary to our decision maker, whether that's somebody at a corporation, whether it's somebody in a government, whether it's somebody, wherever, and they read this executive summary, and on the basis of that executive summary, they make a decision. And they use that executive summary as their as the basis upon which they can say for sure that this is the right decision, right. And what I'm trying to get at is, how do I do that? How do I make a tool that helps show people what, what the actual process was behind?

12:48
So make it more transparent? Yes,

12:49
yeah. Okay. Obviously, it'll be quite surface level, or at least have to balance between. What my goal essentially is that in the time it takes you to read an executive summary of a particular work, you could also just open up this software. And within that time, get a better understanding and more thorough understanding of what has been done. And I want to get that as in as broad a broader scope as possible. Especially because a lot of people are focusing on environmental economics. Yeah. Not necessarily ecological economics, but environmental at the very least. Yeah. So I was wondering how to do that best. That's also one of the ways that like, so as part of my thesis, I've been looking a lot at

carbon costing. And there's multiple different ways to calculate the cost of carbon. Yeah. And all of them rely very heavily on assumptions. And that was basically the starting point for this thesis, because it was like, I can already see that depending on who you asked to do the calculation work? Yeah, they will choose a different framework, choose a different model. And then based on that, they'll say, oh, yeah, the cost will be this, and then the value will be much lower, or much higher, depending on their what, what school, they went to what, what they believe in themselves. Sure. And if you simply just read the report, right, and take that as, oh, well, this person did the work. They did the calculations. Yeah, that must be correct. Then you ignore how the things are being calculated how things are going. And I would, I would really like to make the tool in such a way that that I can incorporate things like Ecological Economics, as well as Orthodox economics. Yeah, so the question now is, how do I do that? How do I, is there a general framework that I can use? Is there a way that I can put this into a tool that if you were an economist, either orthodox or heterodox economists, that you could use this tool, put your work in the tool, hand this tool off to somebody who's going to make a decision and have them understand? Right? Right. Okay.

15:01

Do you think that's an interesting idea? And I mean, I agree with you that economics just has this overarching problem where a lot of the assumptions just are quite implicit once you don't realise that these are assumptions that are being made, like onto the base has to be like an economics expert. And even then I think you have to be a pretty critical economics experts to be able to get to the point where like, wait a minute, like, you know, we're assuming lost a lot of things. I think my degree was interesting, because coming at it from this different vantage point of ecological economics kind of puts the Orthodox economics in stark contrast, right. So you have something with which to compare it to. And I think it's more obvious to see like these assumptions that are being made, you know what I mean? Yeah, I think, yeah, in terms of a framework. Basically, just like, as the economist you would be just inputting a bunch of things. Right.

16:09

Okay.

16:10

I would, actually, I guess I'm more asking you like, yeah, envision it. Yeah. And then the Moto would sort of process that and make it. So that's the person like the policy or decision maker looking at it. So that it's like, legible for them? Right? Yeah.

16:29

Yeah.

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How would you envision a tool like that to function?

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Well, I think I think you could do something like that. I mean,

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are you focusing on a specific, like, kind of economic reports? Or I

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am, but I'd like to keep it broad for the minute and then I'll go, I'll go deeper into it in a minute. Yeah, I'm talking more about it,

17:09
because my mind automatically kind of jumps to something we've talked about before, you know, the difference between a cost benefit analysis and an multicriteria analysis? I think, in a way, that's kind of a good way to also kind of look at how orthodox economics would do it versus sort of like Ecological Economics, right? Orthodox economists would probably just run a cost benefit

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analysis, okay. And what is the difference, the fundamental difference between cost benefit versus multicriteria? So

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multicriteria analysis I think the difference lies in how value is assigned to things cost benefit analysis looks purely at the monetary value. And, and the process itself is, is very like, like one person is assigning these monetary values and performing the analysis, right, like the economic expert, let's say, whereas in multicriteria analysis, it's a, it's supposed to be a democratic process. So everyone that has a stake in the economic issue is involved. Together, they come up with the values, right? That, okay, economic think is supposed to have, right. And then together, they reach a conclusion. And they, they sketch out different scenarios. And then in the end, in the end, you are assigning value to things right, but but the value has more dimensions, because you've got the monetary value, but you've also got usually value for something like, well, depending what it is, but like a social value or a health value, something like that. Then in the end, everything gets weighted also based on whatever one thinks is most important. Right? And then you can come to a conclusion about what scenario might be best. Yeah. Okay. So it's much more inclusive and already more transparent in that sense. Yeah. Because you're involving, because you're involving everyone in the process involving

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all the stakeholders. And then you also and then they also weigh it at the end. They Yeah, so the weights are also

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weights are also determined by by the stakeholders. So basically, every step of the way, the stakeholders are involved. Also, at the very beginning with a definition of, you know, you get to define the values and actually define the problem to find the scenarios like that's all Yeah, everyone's evolved

19:43
at a cost benefit analysis Sure.

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cost benefit analysis simply looks at at at cost. Yes. So

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yes, and as As far as I know, because of course, every time you assign values to anything, you're making assumptions. Yes, of course, as far as I know, in the cost benefit analysis, that that is left up to the economic expert, meaning the cost benefit analysis, and they make their best estimates on based on, you know, the data that is available to them.

20:19
That's really interesting. Because I would, I would suggest that there's that there's not an entirely infeasible overlap between the two. Because you're, you're labelling something as a cost or a benefit in terms of money at the end of the multicriteria analysis anyway. You could, you could simply slide a cost or benefit up or down, depending on what stakeholders feel.

20:53
Yeah. Okay. Yeah.

20:58
I was gonna go through some of the questions that I have. Yeah, sure. And then I'll give you more information, and then we can keep talking about it.

21:11
Yes, that's actually a question that I want to get. Oh.

21:22
Okay, so there's two questions that I want to do. As an extension to this one, how often does public opinion play in a multivariate analysis? Is it just a stakeholder? Or is it does it also affect this public opinion affect the way you would perform a materials?

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What do you mean by public opinion, just literally like, the viewpoints of?

21:51
Yeah, so one of the things that that I'm looking at is changing public opinion, would change the way a government incentives are placed. So if you were to somehow predict social behaviour, behavioural economics, that you would then say, well, in the future, people would be more open to or less open to or be more susceptible to or more interested in this direction. And so this should be weighed more. Does that play a role at all? Yeah,

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that can play a role. I know. So for

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my degree, I had to do an assignment in making a multi criteria analysis. And I looked at it different sources of protein that the Dutch government basically imports quite a lot of their soy right now. And they want to import less soy, basically, and source it more from within the EU. And there's a lot of different options available to like, where do you get that protein from? Right? If not soy because soy doesn't? Well, we can grow in here on Dutch soil, but it's not as efficient as like importing it, let's say. So the work that I did was kind of an extension of work the government itself was already doing, and the government had done focus groups. I'm not sure if they, if they involve civilians, but yeah, I guess it depends a little bit how you again, like to find supplements, because it definitely, for example, just included consumers, right, like people will eat the products, which are like, general people, right? They're not experts or anything like that. And, I mean, a big factor there, when you're trying to make a decision is like, how socially viable is this new source of protein? Right? If you look at insects, for example, like it's a great source of protein, but it's not so socially accessible, at least not right now. Right? Like can change in the future. But right now, it's definitely a factor as to why it's not being so you know, so sold on the markets, why it's so popular. So yeah, those things are definitely taken into account.

24:17

Then the other question I wanted to have is how do you balance environmental impact with economic viability? So again, that the idea that you can't, how did you put it, you're putting a value on something that's that is a social value, and then you you treat it like you've talked to stakeholders, and you create a new value for Yeah, for that that will be then transformed into an economic value? Yeah. Say you're working with. I'm gonna give you a concrete example because this doesn't make much sense. So you're working with the fossil fuel industry. The stakeholders involved within the fossil fuel industry are tended towards one side of an argument, I would say, yeah. So how would you balance that? So how would you balance the economic viability, something with the environmental impact of something, especially if your stakeholders are all a bit one sided? Yeah.

25:13

So if you were running a multicriteria analysis, a really important aspect of that is including all the important stakeholders. So with an issue like fossil fuels, yes, of course, you've got the fossil fuel fuel industry in there. But you've also got, I think, a lot of other stakeholders who probably have different values, like the government and the people consuming fossil fuels, and even also, like, environmental organisations and stuff, because everyone, it can be very, very complicated process, right? Because you have to include a lot of people. So the philosophy of the multicriteria analysis is basically like, as long as you include everyone, or, you know, to the degree that is practically possible that has a stake in this issue, because we're including everyone's values, that amalgamation of values is going to lead you to the best decision. So if the fossil fuel industry is more heavily, you know, they value profitability a lot, you're probably in this situation, you're gonna have other stakeholders that value other things a lot. Yeah. And because it's sort of like a democratic process, everyone's opinion matters. How

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do you, sorry to cut you off? But how do you find which outside organisations are the best to have in a situation like that? As far as stakeholders within your multicriteria analysis? And if you feel uncomfortable, the question you do have to let me know, no, that's fine. It's fine. Because I can imagine that like, if you were to, and I suppose this has, this has to do a lot with with how incompetent a of an economist somebody is, yeah, let's say you're working on an electric car. As a concrete example, yeah. And you don't take in to account the, the lithium runoff or something like that, because the car that you're working on is inherently a better car than what we used to have. And so you potentially run the risk of overvaluing. Something ecologically. This is just a surface level example. Because I want to I want to know how to choose external organisations that would give you the best balance, right of opinions. Right? Well,

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I think choosing stakeholders is guided very much by the context of the decision itself. No, no, it's very grounded in like, the project that you're doing and the decision that you're making. So I think, I think the process really is as simple as literally just involving everyone that has a stake in the project. Okay. You know, so far with electric cars, the Netherlands? Yeah. Yeah, it's very, it's context specific.

So the Netherlands, let's say, let's say the government wanted this project electric cars, they would include, like, the electric car manufacturers who have a stake in the, in the Dutch electric car markets, right? Yeah. The Dutch consumers? Yeah, any sort of agencies

28:16

can ask for a question to that one. How do you prevent it from going too far into macro? Scaling? If you're going to be doing this kind of research? So for example, I can imagine it with electric cars, because it's the topic we've got now. If you're in the Dutch market, how? Because the Dutch don't produce electric cars. Yeah. But the French do. Yeah. You're providing input? They're providing money to a foreign government. Yes. Right. You're increasing the GDP there. So this very quickly becomes a Yeah, I see what you mean.

28:58

It's not like a chain. Right. Where's the cutoff point? Yeah. I think so I don't have any practical experience in like how this actually works, right? In the everyday so maybe my answers that keep that in mind when I'm answering these questions, but I think it probably just works very like case by case and people just you just draw the line somewhere according to your best schedule. I don't think there's there's a specific protocol for it, or at least we didn't learn a specific protocol for it. But I think it's a it's a problem. It's a real problem that is basically a recurring feature and a lot of complex sustainability questions. You know, also with like, a lot of the new stuff that ecological economics is doing like they're developing new tools and techniques for analysing economic issues. One of them being this idea of input output analysis, okay? So are more formally environmentally extended input output analysis. So what you do is basically like a huge matrix of like, industries within different countries. And sort of like, what each industry sells to other industries and what each industry buys from other industries. Okay. And the trick is because you can assign a, you can, you know, basically like, okay, let's say we're talking about the agricultural industry rights, and we'll keep it simple. We'll just talk about the the US right, like very broad. Okay, you can do it for like, between countries, but let's say the agriculture industry within the Netherlands, you're talking about, like Apple or something, right? Like, you know, I mean, within limits, of course, but like, you know, how much co2 it takes to produce one kilogramme of apples, right? Yeah. So you can then the trick is, then that you trace that through the different supply chains of different companies.

Marin Muir – first interview transcript

Jens: That social political social and political aspects I completely agree and that's part of what I'm finding in my research there's one study in particular that studied to 2400 hundreds convos from different areas in the world and they found that the more that people were invested in either heterodox or orthodox economics the more their bias was shown So what they do is they took they took certain quotes from different well known historical figures and historical economists and they purposely misattributed them and then they ranked how the respondents would agree or disagree with the statement it turns out the ones that are the farthest side so the ones that are either completely rooted in orthodox or mainstream economics or those that were completely against the mainstream so as far from that as you could possibly be those were the ones that showed the most the most at the most bias and the interesting thing is those are those are the ones that have the strongest political opinions social political aspect of that is extremely important but it's something that I did not expect coming into this I just thought that there was like certain theoretical frameworks that everyone would have and that was dictate the end result of economics reports but it's a it's a much more complicated than much more socially relevant than that and but I'm noticing from your story there is also it's there's a mirror here in the heavens and owning airport is going to do these acts and things so they are investing heavily in hydrogen not just because of hydrogen nation but because of infrastructure for all purposes

Martin: infrastructure point of view in terms of the cost benefit analysis sequel to understand how big a pull aviation might have on the sector as to whether or not we are going to be significant factor in its development and that will influence your cost benefit analysis and whether or not the parties have significant weight on that costing because we know from previous events but substantial government subsidies could go a long way towards accelerating the acceptance of novel technologies or novel methods and we've seen this with Tesla for example

Jens: yeah that's exactly I mean that's what I expected but I didn't expect it to this extent I expected there to be a business decision being made on the basis that governments would subsidise any type of green energy or green transition but I didn't expect the government to have such a big hand at actually forcing a market towards something like this

Martin: well They’ve got cards parts to play don't they can either incentivize or they can punish by regulation we were seeing certainly aspects of the former but there will come a point where you'll start again you are starting to see it in some respects you see aspects regarding the latter as well so you've seen regulation in Germany the prohibits nuclear you see regulation now occurring in France that prevents flights under certain distance with in certain airports once you see again that you can other countries regarding the face of the fossil fuel powered cars so this is where the heavy hand comes in in order to crush habits and the other hand comes in to offer incentive yeah

Arnd: yeah a good example and also for for penalties is noise hours of aircrafts and costs for landing fees typical to pick add I'm not sure it's also affected landing fees by by pollution for noise so you have limited time for for landing so overnight it's difficult all you have to pay more significant more for lending fees typical approach and we will see this if you have a choice for

different types of aircraft in terms of pollution or fuel finally I think we will see the same 'cause you cannot more and more add incentives, incentives are limited. At the moment in Germany overnights this weekend on Saturday they stopped the payment for all electrical vehicles for Sunday it was within 24 hours they stopped complete incentive for electrical cars it was incredible that's only last weekend because the money is gone yeah so it's quite simple so next step will be you cannot drive into the cities within an electrical car otherwise test in Germany so you can incentivise until the money is gone or you have to restrict or taxes or whatever

Jens: Yeah I completely understands that, it also it also depends on I think aviation regulatory committees I know that here in Europe you pay the fee in terms of take off weights but in north North America you pay the fee in terms of landing weight which is like it steers the aviation industry away from something like electric planes because batteries weigh the same as they do when they land as when they when they take off so after here in Europe it doesn't make much of a difference but for North America it certainly huge amount of difference if you're landing at the same weight as you're taking off in terms of landing fees you wanted to something Martin sorry

Martin: Yeah I was going to say that landing fees are going to be the major economic lever by which money is exchanged between the different parties and dance right at the moment the landing fees are levied based upon the sea or engine database which says noise footprints their emissions synthesis etc and then that is multiplied by the number of passengers on board so I'm not sure whether landing wait actually I thought my recent research I thought that the landing weight was related to the number of passengers not necessarily related to the weight of the aircraft so I don't feel that the fuel weight is accounted for so it might be equivalent as long as you're not throwing passengers out mid flight which is probably the next low cost carrier business model

Jens: There have been designs where they were the whole fuse the back of the fuse comes off and then like in case of urgency has like the things that you maybe maybe have to separately and I I do know the ICO database I I have I've looked at that and as wide as that matrix is I found it difficult because there are different engine configurations for the same aircraft and so you'd never know or at least this review I found it difficult to know exactly how much for example nitrogen is being produced from particular engine source because one engine runs hotter than the other produces more nitrogen

Martin: This message is reference to the tail number of the aircraft so that's referenced each time that it goes in so it has that metrics that's put in place and indeed the engines change on the aircraft over time so

Jens: yeah that's also interesting

Arnd: normally becauses airport aircraft businesses are very long term business as fast you had a quite easy to calculator problem in terms of time dependencies but nowadays we have a lot of uncertainties in terms of houses incentives or penalties will develop or the regulations on the other hand how is the technology will evolve nobody knows how quickly you you can change different fuels or maybe different aircraft and how the society behaves so an investment now it's much more complicated in the past to simply said OK we can calculate this interest rate every year three percentage and maybe after 10 or 15 years we will have a change in in some maybe technical parameters maybe but in the end it's very static static investment calculation but nowadays you don't know if the airlines start to go for SAF as an example so they generate emissions and then we have a maybe a new aircraft sets maybe can use hydrogen as an

example and this will be calculated also in the emissions and then see the airlines will move to your airport becauses infrastructure or not this is so a lottery game at the moment because it's so difficult to to understand the dynamics yeah yeah so therefore it's really helpful to have this this a model where you can play around what what happens if you assume that we will see hard penalty regulations or society society driven customer behaviour airlines or .. in the SAF conference in June we saw some airlines KLM and and they were totally enthusiastic in over fulfilling the promises in reducing their emissions and lufthansa who was very conservative and said OK we we can do what we want nobody will pay this extra premium, or yeah only 5% in maximum and so on so this is very difficult to to take into consideration this uncertainty in terms of financial but also our cost and non-monetary aspects of your calculation

Jens: but what my eventually what the cost of analysis aims to do is basically just it's just a test for the tool itself I want to put it through the paces by by giving by making something like this and it would only be a very local kind of thing would be much smaller scale than this I just wanted to for example look at if we take Schiphol as an example because its just the closest airport to me what we could do in terms of hydrogen infrastructure to replace the existing fleets and how much that would cost in terms of monetary cost and how much would also cost in terms of carbon equivalency so how long would you to fly with hydrogen at technically 0 emissions in order to offset the carbon cost of it take to transition the entire system of of Amsterdam airports into something that runs only on hydrogen

Martin: like carbon cost? Are you talking about the cost to manufacture and implement?

Jens: yes so I'm talking about the cost of ripping out current infrastructure and replacing it with hydrogen infrastructure

Martin: OK

Jens: because we want so that's that's at least what's what's the European flights was it

Martin: that’s a really difficult one ultimately because in terms of volumemetric equivalent that you actually need for hydrogen you're talking about huge pipes

Jens: yeah

Martin: so that means the ripping up of the entire apron

Jens: yes yes

Martin: your storage capabilities are incredibly limited you probably need on site liquification so because moving liquid hydrogen to the airport is a no go and I don't know how much spare space Schiphol has at the moment I think it's quite packed at the moment?

Jens Yeah it's it's terrible I think that that's that's largely the reason why I want to do it with Schiphol and largely the reason why I want to do it with hydrogen my belief is that SAF is the best that we could possibly do in terms of and then you could argue whether the power to liquid is better or feedstock is better but essentially what you could do is just transition your entire fleets to sustainable aviation fuel because chemically we want to make it identical to jet A1 so the the idea being you could keep existing fleets and save on infrastructure costs because right now we have like so I was going to do this research at Fokker to begin with to start and they pulled the rug out from underneath me because well a bunch of reasons but business politics had to do with it but also because I proposed this research and they said that they didn't want

the answer to this research because I assume for the same reason that I that I hypothesise now that when I finish with this that it would be much greener to not make hydrogen transition

Martin: it's a difficult one though because if you're looking about the only way you can scale SAF is power to liquid

Jens: yes

Martin: indeed so even if you look at all the best replacements and other things they have eventually you still end up having to do this transition and if you do power to liquid then you need direct air carbon capture and if you've got direct air carbon capture then why do you need SAF?

Jens: yeah so that's what that's that's a good question based on “based on what is it better to do the transition for hydrogen instead of SAF?”

Martin: so hydrogen has a lower overall energy cost than SAF so when you look at end to end production from electrolysis all the way through to storage pumping because you can move hydrogen around as a gas it essentially self-flows from one point to another point following the pressure gradient so as long as it's in polymer pipes it can move the problem is that you with liquid hydrogen around and we can only fly with liquid hydrogen so the burden there becomes on us to try and find a means of getting that liquefied hydrogen into the aircraft and onto the aircraft side, now at the moment if you look at places like Schiphol and Heathrow etc none of their fuel (well not none but a day/day and halfs use) is stored on site and that’s it the rest of it comes through massive pipelines along the river network and the coastal networks that supply the airport with the fuel necessary to operate so you're talking 22 and a half million litres of fuel per day for these bigger airports so you're talking about 90 million litres of hydrogen as a direct replacement and that's in a liquid so you’ve got to have some means of getting it site. One argument I've heard is that with liquification you don't necessarily need as much onsite storage 'cause you can store it in the aircraft which is good because you can fuel them and then were engineering into 0E the idea that the hydrogen can be stored in the tanks without power for significant amounts of time without warming or expanding etc or cryogenics and the thermal solution in the tax is designed to support this so there is that

Jens: I understand how complex this is because like storing it on the plane would mean that you have to power the plane the entire time right because of the cryogenics...

Matin: no not necessarily so the thermal solution that theyre proposing in places it is designed to be an active solution for when the aircraft is in operation but it can go for significant periods of time without power and still maintain its capability the difficulty is when you're using hydrogen fuel cells is that you've got hydrogen going out to the fuel cells and not all of its used you need to recuperate it and bring it back and when you do that it comes back warmer so you need go cryogenically cool that before you put it back in the tank so yeah

Jens: that was one of the things that I've read about that you couldn't figure refuelling time it because you want to refuel with liquid so when you're refuelling the tank you have to wait a significant amount of time you can't fill it all the way up to 100% because there's significant pressure difference

Martin: so there is but there are methods that you can use in order to try and get that volumetric expansion aspect down so you can pump slower which is one of the aspects that we're looking

at at the moment but of course that has a knock on effect on turn around time and for the aircraft

Jens: yes

Martin: so for larger aircraft for example that probably won't matter 'cause you gotta get the passengers off and it takes a bit of time to get luggage off and turn them around anywhere But the smaller aircraft yes that will have an impact there's also the aspect related to safety exclusion zones for refuelling which are currently in place for hydrogen but whether those will be in place in the future we don't know so again you've got several aspects regarding ground handling that come into the economics that determine whether or not it could be a success or not and for which airlines at which times which airports

Jens: I am learning so much, so when I was at Fokker for the brief time that I was there I had only been with people who were on the engineering side and trying to manufacture the planes that run on hydrogen and right now they're talking with Rolls Royce for the engine system as a supplier but the problem is Rolls Royce had promised liquid hydrogen engines and what they what they've currently worked on is gaseous hydrogen powered

Martin: So theyre working on gaseous?

Jens: that's what I got from an engineer that works at Fokker they were getting screwed over because essentially they had built an entire system.. 'cause their taking an old Fokker 100 and there trying to have remove one of the engines and replace it with one that runs on hydrogen as a test bay for future aircraft designs and theyve redesigned the system to run on liquid hydrogen and now they're getting told by Rolls Royce that it won't be liquid itll be gaseous so they have to add a system in place to turn it from liquid to gas or store it on the plane as a gas which they're already looking at volume problems because they need four times

Martin: yeah you would never store it as a gas on the plane you wouldn’t be able to go more than to the end of the runway

Jens: exactly

Martin: That would be as far as you could get with it it would be interesting so if you haven't already look at the fly zero reports that were published by the UK so this was an experimental hydrogen study that was a partnership between airbus UK, Rolls Royce and a few universities and they looked at various comparisons between fuel cells solid oxide fuel cells direct burn hydrogen etc and the various configurations of aircraft necessary to support different architectures. Rolls Royce were very much on the direct burn hydrogen and whilst it is gaseous is the interest the combustion chamber it's liquid through the rest of the aircraft so they they use a heat exchanger in order to warm up the hydrogen so that it becomes highly gaseous at the point where it enters the combustion chamber so that it mixes properly and burns I think you need a one to four ratio which is quite different to what you'd get with Jet A1 but Rolls were very happy with the way hydrogen burned once they got the mixing ratio the ended up with very very uniform burn but you can't use traditional injectors in order to inject it 'cause it doesn't mix properly so you have to do something that looks like a shower head

Jens: yeah and also something to inject that more ceramic as well because they they looked at efficiency curves and they saw that it was burning 400 to 500 Celsius so hotter than than what they were used to

Martin: yup

Jens just for me Martin, what is your capacity at Airbus so I can write it down

Martin: I am a senior modelling and simulation scientist

Jens: OK and just quick question in the current function outline how you go about making decisions like this, what models are using and how you're doing that if it's not a trade secret obviously

Martin: I wouldn't say it's massively secret but so at the moment these types of problems are too big to be studied using traditional approaches so anything that would involve optimization based methods you're looking at too many design variables in too many connected systems to be able to make informed decisions you would have to either reduce each systems dimensionality so substantially that it wouldn't make sense or you have to hold different systems static while you optimised another system and in reality that's not the way the world works all of these systems work together so we're trying to use systems engineering techniques in order to study connected systems so how one system behaves in accordance with another and then as each system starts to change the attached system moves with it and so you get real sort of emergent behaviour like you would see in how people responded to the pandemic for example yeah the difficulty with this is that the usual methods by which you support these type of techniques either rely on really simplified problems within the environment so that's the decisions that are made quite easy to track and follow or it's used in a very systems engineering type process where you understand the behaviour of each bit of your system and you actively programme it and then you allow the system to operate around that programming to find the best means of operating through those various components we can't do either of those because the system is too big and it's too complex so we need to do a hybrid so that's the type of approach that we're taking now we have a series of layers that we want to study within this you've got the outer sort of social political layer you've got the next level down which is almost your governmental layer if you will then you've got the next layer down which would be something like your overall energy infrastructure that supports your country or regional network and then from that you've got transport networks that lives within that and then within that you've got the specific aviation sector and then even within that you've got the airports and aircraft themselves so you can see seven different layers of modelling and all of them connected all of them subject to decisions in each of the layer we need to find a way of reducing that model to a point where we can study it with realism but while managing the complexity and that is the project that we're currently embarked upon

Jens: when you do this kind of work who do you give it to and in what format do you give it to them to make decisions?

Martin: it depends, within the projects that we work on together just outlined these are very sort of prototype level methods it's not something that has been done at this level as far as I'm aware anywhere in the world.. what we're doing at the moment is we're exploring that environment to determine what the limits of it are how close we can get to realism without making it so computationally difficult to solve that it's practically impossible and also that it's not so difficult to programme that it's practicably difficult to implement so some people can't change it and fiddle with it and we need to give it enough.... we need to get enough simplicity that people come mess about with this a little bit but with enough complexity that it doesn't immediately break when people do mess about with it and we need to be able to hand over at the end of the

project not just the model and the methods because even at that point it won't be accurate it will just be capable. what we need to be able to explain to people is where the limits of this technology lie, where it can be applied successfully, where it needs development, where additional work needs to be done, and what the ideal use cases are so for us for this project it would be a prototype series of methods and the treatise on the best applications of these on where development should occur.

Jens: so where the limits of the system lie what the use cases are .. so it's... because it's a prototype system and you're using your just exploring the limits and youre handing over right limits are and how to fiddle around with it... so where I can I can draw parallels because what I am trying to do is make this kind of stuff accessible to people who are from a top level going to make decisions based on this work and I'm running into the same problems you were running into with OK “how do I make sure that people who fiddle with it understand what they're doing when they fiddle with it? how the things have been calculated before?”... like you said when you hand it over it might not be as accurate as you want it to be but it will be capable so the idea is to say based on if somebody would use that system to calculate something and then write a report based on that and then give it to somebody else to make the decision and they read it and I say “well based on this report I have to make this decision” but they haven't seen the initial... like they haven’t seen the tool, like they haven't seen the model they don't know how to look at it how are you...

Martin: sorry I don't think people necessarily need to see the model , they need to understand what the inputs to the model are but theres a significant amount going on in the backend of the model that’s not really explainable.

Jens: no I definitely I definitely understand that aspect of it my point was more that the model goes about calculating things in a certain way and there are reasons for why each of those nodes if you will are calculated in the way they are and at the end if the person making the decision doesn't know why those nodes are calculated the way they are they can't be expected to make a full decision or an informed enough decision...

Martin: oh no so this is where we would go through validation and verification of the model before we actually ruled it out for any future prediction scenarios So what we do is treat.. we would calibrate the model based on our future treatise of what we want to do so we will build the model based on their future treatise but we would actually test the model using an archival data set so that the aspects related to that model still then fit data related to something that happened 10 years ago and then what we do is run that model and see if the model behaves in a very similar way, so we would then tune the model in order to make it behave in that way, in some respects were cheating because we know the outcome but the difficulty is that you don't know the future outcome so overshooting the model for the wrong thing

Jens: yeah that's what I was going to ask

Martin: Yeah ultimately you don't know and this is something that I've said to everybody we talked about this project this isn’t a tool for predicting the future, it’s a tool for predicting a possible future based on a certain series of input characteristics and a certain series of relationships you can never map everything all you can do is make better informed decisions and that's what this is intended to do.

Jens: In your experience do people understand that aspect of it?

Martin: Yes because you can draw a direct parallel to the pandemic. this type of modelling approach has been applied quite well in terms of mapping epidemiology. So it works well for epidemiology in that it treats everyone the same and you've got large numbers of similar components within your system and they all behave in similar way but in reality that's not true because all those components are representing people and those people all behave differently depending on what's happening around them but Even so it gives you the right... no... it gives you the right direction it maybe just doesn't give you the right vector

Jens: yeah yeah no that's what I'm trying to get done in my thesis now because it it it how do I say I had the idea that people weren't aware that this this kind of model was yeah largely just a predictor it wasn't it's not going to accurately predict something that's going to happen in the future because we have no idea it just it just designed to make better informed decisions and from that aspect I wasn't sure if everybody knew that

Martin: I don't think everybody is every time you talk about predicting the future they really think that you're going to be able to share price in four half years but in reality that there's so many things that go into it and will never be able to map the whole thing and let's face it you know were airbus, so we're looking at a tiny sub sector of the world that's not necessarily the most important. If this were a really important and capable tool then the economics community would've actually solved this because it would be far more valuable to them to solve than it would be to us

Jens: so in your experience explaining this to people you you don't find that difficult?

Martin: I think that everyone's aware that the tools they have at the moment are not suitable for the purpose of predicting a future that is subject to a substantial paradigm shift all of the tools that we use at the moment are regression based, they look at what happened in the past and predict the future based upon a certain number of markets and that's not sufficient for predicting something where not one thing is going to change but several things are going to change and stocastics doesn't work like that you're ending up with two or three or four different things contributing towards the shift of a single data point then just doesn't work and so you need something else something that can take into account that change and this is what this is intended to do whether it works? Well, we'll find out.

Jens: yeah you and me both, ummm, I wanted to ask this, because we were talking about how to make it sufficiently simple enough for people to understand how to play with the values within within it how do you balance that, what is your current workflow for balancing the simplicity of the of the tool and making it easily understood for people who have to make decisions

Martin: theres actually 3rd axis on that as well so you've got the simplicity of access and you've got the results at the end of it but you've also got another aspect which is related to this, the complexity of the model in terms of solution as well so you've got three sides of the triangle here and ultimately at the moment I'm not biassing my work towards the implementation aspect. if it has to be complex to begin with, then that's fine and we'll find a way to make it easier in the same way that finite element analysis and computational dynamics has become easier overtime it doesn't need to be a hammer for every situation right

Jens: yeah no that's amazing

Martin: the other thing that you can do as well, the easiest way to represent a lot of these interactions is just the floor processes. people respond diagrams if you can show the item in a flow process, ie how information is moving between them how different sections of the model connect to each other even if you can't show exactly what's being exchanged and why especially over time, at least you can explain how it was architected.

Jens: that's actually really nice I'm gonna write that down. I am going to go through my document real quick just to make sure Im not missing any questions I had and want to get through. Actually the rest I have is not very useful because I have a small mock up of a really basic tool just as this is the first of the interviews that I'm going to give so I have no requirements so this tool is essentially useless as of now but I can show it to you if you like it's a very very simplistic system let me just start screen share

On the left pane elements with the plus button in the bottom left corner to add elements there's different folders within each and then on the bottom right you've got the very simple payback time inflationary timescale and the benefits cost ratio and in the pain on the right side there you see sort of mind mapper connected connection matrix and the size and the colour of the dots depicts how many connections there are within each other mental left hand side so you could connect different elements together so that you have a the timescale based on that timescale everyone elements of four years you put that in as a as an element and then you add to that so would be like inflation over those four years would be a separate elements of inflation and you multiply that by the separate elements of timescale it's a very very simple thing that I've just built and so I was wondering if you questions based on that what is your initial reaction to this and is it something that would be at all useful in your opinion

Martin: What's your intended market for it? Who is it intended to inform? Who is it intended to help?

Jens: this was just a really simple representation of something that I could build it in order to test the hypothesis that forcing people to interact with the with the model itself with a calculation instead of reading something and based on reading something taking or making a decision

Martin: the ultimate result of this is to see if people change their behaviour based upon what they see in the calculation?

Jens: yeah to see if people understand that this assumption based right because my hypothesis was that people didn't understand that The thing is that we were that we were doing with member modelling stuff like this was not an accurate predictor of the future but was it was based on large amounts of assumption. Does that make sense?

Martin: yeah it does, I'm just trying to think about whether or not it would be useful and to whom it would be useful... and what kind type of decision are you hoping to change in the people to see this? what's the the marker of success in this?

Jens: Good question but what I'm what I'm looking for was essentially just I'm hoping that OK.... I was hoping that my work now would be I would be a piece of a puzzle that would show people that this this type of science this type of modelling this type of prediction isn't accurate it is meant as a sort of better... like it's meant to inform people but it's not meant as a sort of crux to base your decision on. it's meant as a as a sort of additional stream of information to help to better inform you for a decision and it's not meant as the be all and end

Martin: Whats the context for the model though? Whats the target market? Is it for a CEO making a decision on investment? is it for an individual making a power purchase? Is it someone choosing a flight or bus or? what's the..

Jens: So my my point was basically you have Schiphol airport and the CEO over there or decision maker or somebody who's in the conversation of whether we should go in a certain direction the current decisions being made especially by talking to the people within the industry that I I know in within the aviation industry (albeit a very limited amount of people that I know) but the CEO of Fokker was one of them, where he was all in on hydrogen because hydrogen is where the investment is and then the question was “why is the investment there? and is this the best way forward? and what would be the best case scenario? and why is no one talking about the insane infrastructure costs associated with this?” and then when I did some some research into this topic I found out that it was just because it's incredibly complex and nobody realises that these things are assumptions so “how can we better show that these are assumptions without taking away too much time from somebody who has to make these decisions?” “how can I, like in one glance, in the same amount of time as it would take to read an executive summary, give you a piece of economics work in such a way that you understand that it's assumption, that you understand where the assumptions are being made and then you can better make better informed decisions”

Martin: I think if you wanted to pitch that model to the high level that you're talking about then you would need to add significantly more complexity to it that allows you to capture the state of that industry with its downward pressure and its upward opportunities

Jens: OK

Martin: so in my opinion, and this is just my opinion, I think everybody is pressing for hydrogen for two reasons one is that it is hard it is technologically challenging but there's an awful lot of knowledge to be gained in that: cryogenics, high power electrification, new materials, new technologies those are advantageous whether hydrogen powered aircraft work or not. you could use them for almost anything. Technological cost is high but there is also an awful lot of subsidy available for that type of research. Secondly, I think most people are probably aware that SAF faces sustainability scaling challenges yeah and it relies heavily upon the development of other technologies which could also potentially derail SAFs use case and if hydrogen did become a thing, then SAF wouldn’t be a thing. So it's balancing where you see the problems so you said that you could directly swap to SAF right now but that's not actually true either you can run SAF for a limited point of time without changing the aircraft but you do need to change the aircraft to run SAF

Jens: so then my understanding of SAF is incorrect because I thought that sustainable of aviation fuel the way that it is made now, they attempted to make it chemically the same as Jet A1

Martin: it's similar to Jet A1, it burns the same so its chemical burning ratio is the same but the additives to make it stable are not the same so it tends to dry out stuff like fuel and engine seals. So you would need different seals in the aircraft in order to keep the tanks and everything the same so the aircraft and would need a retrofit at the moment with a small percentage it's OK and if you just run a tank of it or two tanks of it again it's probably OK but over time it will degrade the seakling aspects so there still needs to be aspects related to the airport infrastructure and the aircraft that needs to alter similarly you can't do it all at once so if you start introducing SAF

by regulation they would need to be stored separately, you would need to be tanked separately, it would need to be monitored so youd still need more space at the airport more trucks more infrastructure at the airport but you would only need them for a limited time, so you've got to invest in something that you then demolish

Jens: yes OK yeah understood

Martin: so there's that aspect of it as well and then I think so those are your sort of opportunistic things that are available that sort of going into the industry but I think you've always got downward pressure as well from people or you will shortly anywhere in that if direct air carbon capture isn't successful at a decent energy price point because we know that that kind of work now but it needs megawatts of power to recuperate some kgs of carbon then how much is that.. its not greenwashing but it's masking its environmental credentials when that energy could be better used for other things

Jens: yeah absolutely

Martin: so hydrogen in terms of fuel cells it works it works now and you can tell everybody electrolysis now for far less cost than you can SAF when you look at the energy generation cost and the emissions mix for SAF... um have you looked at how was it called Cambridge sustainable aviation centre? is it? so they've got a comparison matrix that allows you to compare SAF to batteries to ammonia to hydrogen powered aircraft in their various configs whether direct burn fuel cells etc and it shows you the current capability and the margin of error on development for that and there is a far bigger bounding box on sustainably aviation fuel then there is an hydrogen

Jens: that's so cool

Martin: so one of the things that your tool might be good to do is to actually link to a number of these available online tools to draw information into it so this is supported by sustainable aviation trust, this is supported by flyzero, this is supported by the European Commission and these are all coming into my model and you can see here that the error bound on investment in this technology if you look at 10 year time scale is this, if you look at 25 years time scale its this, and these are based on assumptions of people doing XY investment doing XY and so on

Jens: OK

Martin The difficult one to predict it is about research investment because ultimately we don't know where it's going to go and research investment accounts for a lot.

Jens: yeah

Martin: but it doesn't necessarily need to be even direct investment it can be just in the form of research tax credits they provided by governments almost invisible

Jens: or completely invisible social like societal change... that change of view within the general public. Whats happening now at the TU Delft is we're having these open discussions about whether to continue collaboration with the fossil fuel industry and so you already see that people especially on campus at university are already shifting opinion towards more sustainable stuff so theres no need to invest in something that there is already genuine hunger for.... Yeah that's really interesting thank you so much this has been incredible and Ive learned so much. I don't actually have directly any more questions but I'm I'm really still just interested in so where did you get the where do I find more information about the stability additives within

sustainable aviation fuel because everything I found so far was just saying that it's chemically the same

Martin: well firstly its important to know that there's there's several different types of SAF there is no unique blend of stuff but the blend that's been supported by people like lufthansa in terms of their the introduction of it into the aircraft in their ten percentage of their fleet fuel that they've put in I would look at that as your primary source but source of truth for SAF I would then have a look at... oh what can I say because I am aware that this is being recorded

Jens: Oh sorry sorry yeah

Martin: so look at Airbus' supply network and speak to the supplier network regarding the fuel system and they'll be able to tell you potentially a little bit more about SAFs interaction with fuel seals with global compounds etc also speak to department's like at the University of Leeds you mentioned you had contact with their combustion department heavily studied hydrogen and SAF and Ammonia and they'll be able to tell you what they had to do in order to try and stop the things leaking half the time

Jens: OK perfect yeah also if there's something you say that you don't want to be recorded just just tell me and I will

Martin: yeah Ive been quite careful in what I have said haha

Jens: yeah 'cause it was something that's in the form as well so the recording is is currently being stored offline and I'm only using it for transcription purposes and if at the end you say well I can't I can't .. I shouldn't have said that then we will just strike it yes so that's good

Martin: I think all future fuels for aviation have a challenge, I think theres just some fuels that potentially have more opportunity than they do a challenge

Jens yeah in my head, with my limited knowledge, hydrogen had more of a challenge that's why I was

Martin: its got an opportunity though as well

Jens: yeah yeah

Martin: much more

Jens: in Europe do you think electric flight is going to take off?

Martin: for short range I think it works I think if you look at things that are less than 100 miles then it's fine it's the only way you can do short range hops or maybe in the regional market in the US you can work perfectly, island hopping it works perfectly, you've got low maintenance costs lower repair costs etc so I think it works for that big long range commercial aircraft you need to have a step change in energy density for it to work 'cause at the moment energy density versus kerosene makes the about 2% as efficient as using kerosene. 2%!

Jens: that's not a lot of percent haha

Marting: cause if you think, as you have stated earlier, the weight of the aircraft is common for takeoff and landing so you have to land with all that weight which currently the aircraft don't do they land with a percentage of the weight even if they have to do an emergency go around they ditch fuel and that's because the wing structures aren't strong enough to support the fully

loaded weight of the aircraft on landing and so the wing structures have to be heavier so the aircraft overall is heavier and then you've got the heavyweight to the battery so just compounding problem all the time so until we see a big change I really don't see that as a potential even for sort of 500 to 700 nautical miles it would be a difficult sell

Jens: there is also the compounding problems of having the the battery in the fuse, like, all of it instead of also being stored semi in the wing 'cause that would be where the fuel normally goes

Martin: I mean we're talking about putting hydrogen fuel in the fuselage anyway so I don't think...

Jens: is that allowed 'cause I thought that you had to put it outside of the pressure vessel?

Martin: it can still be outside the pressure vessel, just more the bulkhead forward

Jens: ah OK OK so you're just putting the tank all the way at the back of the aircraft

Martin: or separating them or having multiple tanks or cetera but yes there are multiple studies to look at how it could work

Jens: the Cambridge sustainable aviation comparison matrix are their other sources like that you mentioned the civil aviation trust..

Martin: there is one from MIT stability aspects related to aviation and to its connection to the extended energy sector... oh what was the other one... Brigham Young University have sustainability impact department... I think most UK and European universities are touching on it to some degree it's just the Cambridge have gotten further in terms of publishing something quickly

Jens:OK

Martin: also probably look at TU Munich as well so TU Munich usually has a strong connection to multidisciplinary optimization I'd be surprised if they're not looking at sustainability as part of that mix... Ill have to get going in a few seconds I have another meeting

Jens: thank you so much for your time really this is this is incredible and if I do end up finishing the tool which right now seems to be significantly more more complex

Martin: Only through more linking

Jens: then I will I'll potentially give you a callback, through Arnd of course, but yes so I'll give you a call back to get your review of that one as well

Martin OK thank you so much

Jens: OK bye

Martin: bye

Jens's Meeting Notes

Mon, Jun 03, 2024 9:54AM 23:25

SUMMARY KEYWORDS

cost, app, compare, tool, co2, tracks, plane, co2 emissions, inputs, analysis, point, calculations, based, fuel, difference, metrics, difficult, concrete, train, lifecycle

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05:06
Good morning credit. How are you?

05:08
Good morning. How are you?

05:10
I'm doing all right. I'm doing all right.

05:12
Okay. Yeah, I'm doing fine.

05:16
Oh, good, good. So, I was just going to show you the final tool. And I'm trying a new note taking transcription app. I hope that's okay. Yeah. So I'll share I'll share with you the final version. The screen. There we go. So this is Cobalts version 16 Because we're on version 16. Now. Down at the bottom here, you've got a bunch of metrics for discount rate timescale cost benefit, benefit to cost ratio, Net Present Value inflation. Breakeven point how the system works as you can push a plus button at the bottom, you can enter an element and you can enter a value for that. So I'm just going to call it 500 units. Cost or a benefit, so I'm just going to add it as is and it shows up here on the right side and I can then what I can do is I can enter the second element, which will be the cost of that and I can hit equals now that's based on Excel. So instead of having a cell reference, which isn't possible here anymore, because there's no cells, you use the square bracket, and you can I called this feature back linking, but it really just it's a cell reference, but then instead of a cell reference, it's referencing the title of the input that you did before. And let's say that each one of those is worth a euro 20 And we give that a Euro cost that I can add that and then they become linked.

06:57

Okay, yeah. Yeah.

06:58

So what they end up doing is it's you can use it as a calculator. So to calculate total cost, you can also use it as a comparing tool so you can compare between between different things. And you can also then use it as a proper cost benefit analysis tool because you can do a cost and benefit. I can show you that it's also based on Excel. So I think I grabbed this table button here, you can see that the table is here on the right. Yeah. So everything everything works exactly like it would an Excel Actually, I'll open up some similar stuff I've made before. So this is yes. So this is the cost of fuel from a from Amsterdam to or from Paris to London, sorry. And so you can do that if you if you see here you can see that the nodes grow in size based on the number of dependent variables they have. So the amount of care isn't required here has a lot of it's actually just two but there's two things that it's connected to cost of carbon as well as a lot of things that that are dependent upon it for calculation, right. And so they ended up growing the largest, but in a cost benefit analysis. The problem or at least the problem that I noticed with cost benefit analysis is that the analysis itself can be empirically sound, but the inputs that go into the analysis may not be calculated in such a way that they are empirically sound. So the cost of carbon for instance, doesn't actually have a concrete value. This is just based on the ETS credit system, which is a market value that changes per day. Right. And the amount of kerosene required here is based on the average weight of the plane, which is also a projected value. You need the layout of the plane to do it and then the average weight of the plane is also based on just a number that's, you know, found on the Internet somewhere. So based on that, you can see the most the two most important inputs in this analysis are just, you know, guesses at what it could possibly be. And so, it should tell you as the viewer of this analysis that the the accuracy of this analysis is is rather low. I can open up a different one. This is so normally what what you have is you have comparative metrics in monetary units, so in money, but here I've used I've used co2 instead because this tool can allow you to do whatever you want. It's a comparable metric. So I have the co2 per passenger for a train trip from Amsterdam to Hamburg, and a co2 per passenger for a plane trip to Amsterdam to Hamburg. And you can see that they're the only differences but nine kilos. Yeah. Yeah. And you can for every one of these nodes here, obviously it's kind of hard to go find them in the in the chart here on the left, so you can just double click on them and then they they show up so you can you can see. And then you can also save to Excel. You can there's a CSV file that you can download. And then you can open it in Excel or you could open open an Excel file of course in in this in this program, so yeah. And then there's an Information button with some some information display on how to use the program and things like that. If you want to play with it yourself, I can actually send you this because it's alive on the internet

11:13

Okay, well in first glance, it looks nice.

11:20

There are some bugs with it. It's it's not completely smooth sailing, but it's at least to the point where I'm happy that it's that you can do calculations in it and that you can you can play around with it. Yeah

Yeah.

11:35

How did you find the aircraft data?

11:39

You can actually I can I can send you the CSV file as well. Can I attach files here? I'm not sure if I can't or shouldn't be able to share more apps No I'll send it to you via we transfer length that's readily available on the internet most of it's

12:08

okay. Because it's for plane just vary depending on the payload factor you you can the weight of the airplane the distance you fly the height you fly. There are a lot of variables Yeah.

12:21

Why? Because it was working with Airbus. I chose an A 320 Okay

12:34

there's the retransfer think I have there's two files in there. One is, is the first one I showed you with the fuel burn cost. And then the other one was the co2 for the trip. Okay.

12:55

Well, thanks for your time, too.

12:59

No, of course, of course. But I was I was just wondering if To what extent do you think that this app would be useful for decision making in the sphere of governance are in the hydrogen coalition?

13:17

Yeah, it's difficult to say there are a lot of those apps available where you can compare co2 emissions if you go by plane train car or whatever. The way they they show up some once in a while really large differences and yeah, that is the trick is there from how far do you take the lifecycle analysis and how deep do you go in there? You can compare just the co2 emissions from the flight and that's quite easy. Yeah, that is, there is not that kind of problem. But if you are going deeper into stuff with all the

if you will have to make construct a high speed railway network and that kind of stuff, then then it's starting to get difficult. There are reports out there where shall really well but if you have debts if you want to program that all in a in a in a program which depicts your Shilo to emissions. That is not an easy task. Now Yeah. I wrote also on our top goal, but if you go by plane to perish or by, by electric car to Paris, and maybe you saw my article on that one, I did not actually but I will. Yeah, it's on LinkedIn and I made a comparison between going with an M bra e 195. And or going with a Tesla Model three to two bearish and then you can compare the co2 emissions but as always hear yourself yeah, well the results are depending on what you what you take everything I did. My conclusion is a Tesla is better on all fronts, even lifecycle emissions in it. But if there's a great difference between 25 more fuel efficient, up to 10 times more fuel efficient so you'll see there a large difference in those in those bands. Yeah. So yeah, but that is a difficult with every program you make how much stuff as soon as you go to lifecycle analysis is starting to get difficult. Yeah, yeah, no, but that's

16:02

that's exactly that's exactly one of the things that I wanted to do for fulcrum before they they decided that it wasn't a good good enough thesis but the fact that the second you start looking at the co2 cost for infrastructure to switch from one kind of fuel to another. All bets are off, you're gonna start looking at 50 years 60 years down the line to get carbon neutral. You know, because there's, there's no there's no way to offset the carbon that it will cost to pour the concrete for the new foundations because the tanks that you fill with hydrogen need to be in there and and so on and so forth. Yeah. And that's one of the things that my my father as well said when he was looking at new routes to fly in Africa. So he was he is a consultant and he works. One of the one of his clients was Djibouti airlines. And he said, Well, you know, the the second you start looking at costs of B wants to have people go from one place to another, what would be the best in terms of co2 emissions in the next 100 years? It turns out it's not to train because to get a train you need a station and a parking lot and terminal and all of that other stuff that you would normally need for an airport as well. Yeah, but then you also need to track 500 kilometers, right?

17:36

Yeah, but it's greatly depending on other new tracks or do you call for new direction that is getting already better? Yeah. So there's a lot of variables in there. Yeah,

17:48

yeah. Yeah. That's exactly right.

17:51

You're in Europe, for instance, we have already one of the most dense railway networks in the world. Yeah, the tracks are already there. And if you want to make them into high speed tracks, that's not a just dead big efforts. You have to remove them and make a little more ground concrete work, but that's not a lot. A whole lot of difficulties. Were and if you go to America, there is almost no trade network there. And if you make everything new, then it's going to look different. Yeah, exactly.

18:26

That's exactly what's happening in China right now. Any new high speed rail development that's being built as being built in China? One reason is because it's easy to put a new train there. Right, then you have to be laying there. But it's also you're starting from scratch. So you have to there is no track there. So you have Yeah, the point of the of the application was basically just to say, well, you know, this should be an easier way for people to view data, rather than giving them a spreadsheet. You give them this instead, and that hopefully they can see for themselves. I mean, I can I can let the cat out of the bag because I've already done the user testing for it. It fails at doing that. Yeah.

19:16

So I think Well, the problem is people have to do it easy. If you want to compare my well if you for instance, go to Singapore. Yeah, there is no other option number Floyd, legend clear and the same thing to America. But the tool should be in that respect shown thing, which is easy to understand a little simple inputs. And then there's something out for now. Okay. This is a comparison between your co2 emissions. Yeah, yeah. So but it is, but it is difficult. Yeah. Yeah, but what I see from your program, it's seems seems okay, so I'm going to have a little play around with it.

20:10

Yeah, no, that's the point. That's the point obviously.

20:13

Yeah. I have I'm really busy the coming two days but then on the end of the week overall, where she and I do a little bit of calculations myself because I don't know if there are fuel consumption figures of the A 320 But it has them surely 4737 800 So I can compare it with that one because they're almost the same. It's not that different. No.

20:45

Okay. There is. Absolutely I'd love to see what you came up with. Even just for my own curiosity, perhaps I could use it in the presentation or something. Do you remember the app itself doesn't save anything? So if you want to save it you have to save it as a CSV file before you close the web app, because for safety reasons, but GDPR has really strict guidelines. And I knew that I was going to be making this thing for Airbus. And I wasn't allowed to save anything in app. So the second year tab refreshes or you close your browser, any work that you've done. It deletes it. Okay, so you have to save it to your PC before. You can reopen it and you can edit it and then you have to save it again. But you know, that's you know. Yeah. Yeah, and then I have to I have to unfortunately hand in my thesis tomorrow afternoon. So your test won't show up in the thesis but I could, I could use I could use it in the in the presentation and I obviously I love the input on the tool even regardless of whether it's gonna show up in the report or not. My the whole purpose of this interview was just to get your initial thoughts of the tool after seeing it and and what you liked about it and what what what you could potentially or how it was different from your expectation. I'll put it

22:15

that way. No, no, no, no, I think for my first rule, what you're showing me it looks while balance. And it's easier that it's important that people should do it are really easy. If you have numbers in it. Okay, what's the difference in co2 emissions? Yeah,

22:32

yeah. Yeah, no, good. Excellent. Well, that's, that's fantastic to hear. Thank you so much.

22:37

Oh, yeah. You're welcome. And then if, at

22:41

some point, if you've if you've got something that's interesting, I'd love to hear it. Then we can either set up another meeting or you can just send it to me Yeah. via email. Okay. Thank you so much for your time, and I really appreciate it. I really appreciate you looking at it. Okay,

22:54

thank you. Bye

Gigi Post-dev interview

Tue, May 28, 2024 2:15PM 21:05

SUMMARY KEYWORDS

cost benefit analysis, programme, benefit, cost, co2, calculated, carbon, node, square bracket, add, released, metric, more polished version, projected, megaton, works, click, kerosene, number, intuitive

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00:00
looking professional

00:08
what programme is this?

00:11
This is an arc

00:25
so let me just get your initial reactions and talk through it as you as you go through the programme

00:35
just got loud Yeah, okay. Um I like the interface looks clean. I suppose these are like are you drop drop things into me as well. Hello um so this is a tool to analyse cost benefit analyses, right? Yeah.

01:06
So do you then drop like costs or benefits into the little?

01:15
Yeah. So when you can, what you can do is if you go to the bottom left, there's a plus button. And you can add an element. You can just type whatever you like and there

01:28
you go. You can click whether it's a cost or benefit and you can type in equation or you can click add, like

01:37
what is the was the clear? Well, you can give this was like,

01:41
yes if this was you can create a value in there. You can say 500 okay to do that

02:01
oh, and then they like

02:04
Okay, okay. So now I feel like what you can do is you can hit the plus button again. You can type in your name,

02:13
you know, maybe I should change this to something that actually is like to get in the spirit of these Okay, let's say I don't know

02:32
well, just I guess car carbon emissions. co2 released co2 released. I heard like it sounds Yeah,

02:45
but that's maybe not right the empty there but you can write like a description

02:56
okay, where to go?

03:00

And that's, that's, that's still there. You have to specify the school sometimes properly, but don't worry. Okay. And what you can do is you can type Okay, so co2 released and you can megatons you can add like a cost to that. So like the cost of carbon code, the total cost of learning how to hear Yeah, just right. Cost if

03:29

somebody doesn't like it

03:42

yeah, Castle carbon

03:44

equals. Learn if you use the square bracket tool, so open the square bracket. Now you can select your co2 released and close the square bracket. You've now referenced that cell Okay, now you can multiply that by a number if you wanted to. If you say purse per megaton now you got okay wait

04:16

you kind of get the idea of how it works now. Um,

04:23

I can open up an example for you and this is just for you to get used to the programme. Do you like the way it works? Basically

04:30

I do like the way it works. The only thing that now I'm wondering is like what is the exact relation between these two things? Because is it like one of them is like how you it's not one of them's not how you measure the other right?

04:43

No? No, the link that's that the programme shows here is just that they're connected. And in this case, the relationship is wonderful. Okay, because you've just said the co2 release is equal to

05:02

Okay, okay. Sure. Okay, maybe throw me as an example. Yeah. Well

05:14
that was will do.

05:21
Okay, so the hope is that you will see now if I asked you the question, what are the two most important elements in this breakdown? If you could tell me those two

05:34
seem most important element? Yes.

05:42
Well, the amount of kerosene required seems pretty important. And then maybe the cost of carbon Yeah,

05:50
that's exactly correct. And so this programme calculates the size of the node and carcass the importance of each the node based on how many dependent variables

06:03
are created with it. Okay. So, the distance, right is a is a node that

06:12
the kerosene required relies on and so it then becomes a larger notes and so on and so forth.

06:21
Okay, okay.

06:24
And then if you see in the left pane, scroll down, you can see all elements, but obviously you can also click and edit them via the Yeah

click and edit them via the Yeah,

06:34
and this is completely interchangeable with Excel, tab here. You can see that this is the school down here.

06:43
Okay, well, it's a graph and just you can see the total it's just used using using it as a calculator. Essentially, because it's only got a little customer benefit.

06:56
Yeah, I was gonna say so this is just, this is just costs

06:59
just cost. Okay.

07:03
And what would happen if you were at benefits?

07:05
What you could do is you could then say well, okay, the the so you have a value, so the kerosene that you're using, and you're trying to find out the benefit, benefit per litre of kerosene, then you would connect it. So it'd be a social benefit, probably. Yeah. Or it would be ticket pricing would be a benefit. And then ticket pricing would be the number of people, right, the number of people is a very variable in the amount of charisma required, or at least this variable in the average weight of the plane. Right. And so like that, that's how the whole system would start to become connected. And then you will see that the the green nodes in there as well as red now we have two hostages carbon costs which are the Paris in the cost

08:01
Okay, okay. I think this is good that you see everything in the metrics summary here. Okay, it's just all the costs now.

08:14

You can edit only the discount rate timescale and inflation and everything else gets calculated for you.

08:37
Okay, one of the biggest limitations that Strugar has is it can't cut it to breakeven point. Okay, so I have a breakeven points metric and all it does is it calculates based on the timescale whether the benefits will outweigh the costs. And so the timescales now once it's one year, I suppose, are one month living and what do you what do you want and it calculates whether the breakeven happens within that time period. Okay.

09:11
But it's all it does. It adds up the costs and benefits the other Yeah,

09:16
basically, it just compares the two. And then it'll tell you whether it happens within that time scale or not. And the reason why I didn't want to give

09:26
a break up like it Well, the reason why I didn't have a character is if it doesn't happen at all. It will continue to iterate

09:36
and never be able to calculate it and so it won't show you the final result of the entire programme. If there's no break even point which I didn't want to happen okay.

09:58
So this is a cost benefit analysis for

10:03
this is just a cost of carbon for a trip

10:08
Okay, so it's a trip for our students parents.

10:21
Okay, yeah, so you basically have to two costs right? The cost of the trip, carbon costs and the like monetary costs, I

10:31
guess. The carbon cost is a monetary cost. It's based on the ETS system. If you double click on it. It's called the cost of carbon inside of it. And the cost of carbon is based on ETS versus 63. Okay. So you can even double click on the cost of carbon you can see where it comes from.

10:54
Okay

11:03
okay, okay, okay.

11:04
The hope is that people will say okay, the to the two most important in this analysis are required on the cost of carbon. If you double click on the cost of carbonate sneakers credit system, which is shaky because the

11:18
market cost Yeah, but it's a pretty standard metric.

11:22
But there's no solid you can say, well, this is empirically the best. Like this is how this is how much you know, societal or environmental damage carbon does on society. We know that because it's in the easiest corporate present, but that's and then carries amount of charism required if you double click on that, you can see that it's a projection to the average weight of the plane, right? It's not the wait for this plane before this. It's average. Right? So the accuracy of that is also low. Sure. So the accuracy of the entire analysis is potentially also relatively low. It's nuanced. There's there's probably not it's probably not the best calculation because the two most important notes are

12:04
right, right. Right, right. Yeah, I see what you mean. But it is a good overview, like at least you know,

sort of what the two most important factors are. And if you wanted to, you could always like,

12:17
pull up the numbers for yourself, right.

12:22
Like, I think in university when we had to do our own cost benefit analyses, we also we also ran into the same problems, right? Like if you want the most accurate numbers for something you have to go through, down such a long rabbit hole that at some point, it's just, you just don't have the time or resources? Yeah,

12:40
I think that's very fair as well. Because that's, that's one of the biggest release one of the basis for

12:48
like, I'll give you I'll give you an example. So with if we load this free we're gonna give you this paper

13:07
obviously, you don't have to fill it all in but that's what I'll have. People who are you know, who don't know the software yet. I'll have them do this. Now they're the how they'll do it once in Excel and once in cobalt.

13:20
To compare the two and Oh, cobalt. I like it.

13:26
cost benefit analysis and so what they'll do is they'll say okay, strategy a for a small business is to do newsprint as base 10,000 For newsprint as base radio show. Artspace is 30,000 highway billboards. 10,000. Production costs for graphics is 10,000 radio advert is 10,000 And then you have projected impressions over the years been 1000s and have been projected average revenue for our viewers 120. It's very simple cost benefit analysis, you've multiply 1000 by 120. Right as your benefit, and then the restaurant fixed costs and those are

14:03

doing all these things. Yeah. Okay. Yeah. She's,

14:08

it's online versus in print. And you can look at what the VCR is for this strategy versus the VCR this way. And then hopefully what they'll see when they type it in. I can open that for you. So strategy A, it looks like this. He had a VCR at 1.7. And we get to see how everything is and then strategy B is a VCR three. So it's obviously way better. And the hope is that when they open this and they say well, you know impressions and average ad revenue, those are the two most important nodes. Let's see how they're calculated. This is a projected value. This is a projected value. You have no idea how those are calculated. Right? Right. Okay. Right. Those are not real. They're masquerading as concrete values in the empirical analysis, but you have no idea whether this is actually going to happen. Yeah. Yeah. So the hope is that when they do it in Excel, that they don't see a difference between the concrete and the projected values that here that they do right. Okay. That's the hope. Yeah. Do you think that will happen?

15:33

Yeah, well, I think so. But you, you probably have to like nudge maybe. That's, that's my worry. I don't know. If that's like ethical. But yeah.

15:59

Let me ask you this. Do you like the programme What do you like about it? What do you dislike about it? And would it be useful in any way, shape or form?

16:09

I like I like the look of it. I like that. It's very, like super user friendly because you can like add these things like change these things. It's quite intuitive. This um, in terms of like, getting an overview of the actual cost benefits. Because I'm in my head, I'm comparing it to what I know of how cost benefit analysis are usually presented, which is just like a table, right? You have the cost on one side and the analysis on the other. And I think visually that for me is a little bit more intuitive than this. Okay? Because it has weighed with the costs on one side and the in that and the benefits on the other. It's very clear, right? Like, like, what is what and then yeah, like I think it works and this also works but you need a little bit more like thinking to go into this to be able to say like, oh, okay, like I kind of get where you're coming from. I'm also because every like the costs and the benefits are like mix throughout each other right? Yeah. I don't know if you can do this at all, but like if you had if you sort of like separated it's you know, yeah. Maybe that will be more intuitive. Because then you can also sort of the other costs on one side than the other. And then it's, I think it's also more intuitive that these things are then like, factors that are going into Yeah, and then I think, actually, for me, like this makes more sense. And then I'm also like, more quickly, really being like, oh, okay, this is my benefit, but there's these two things attached with are those things let me check them out. Right and then you

18:13

you can I can show you one that is a cost benefit. But in carbon. This one, you can see it's two different ones. So you can see this is the cost or the cost one Yeah, that's just a comparison. So they're both actually just cost actually, their total co2 For one mode of transport total co2 for another. But you can use the softer the switch as well, just to compare two different sides

18:42

of one to two different Okay, yeah,

18:44

so the plane is 30 kilogrammes. of co2 in the trenches.

18:54

Yeah, I do like this. I like having it attached as like little bubbles, because then it is clear that like, these are all the factors that are going into it. And then, like you say, you can click on the factor and then kind of in your head is very clear and compartmentalised and like like, it's easy to wonder like okay, what is actually going into this factor, right and like, how, what kind of assumptions are we making and like, how, how reliable are those assumptions? Just kind of what you us to get it right. Yeah. Yeah, I think if you did that visually, for me, that would work really well. Okay. If you like then, if you have a very clear distinction between what are costs and what are benefits and then yeah, I think that it works. Okay.

19:57

Yeah, is it going to be useful? Do you see this you know, if there was a more polished version of this, would you see it?

20:15

I think it definitely could be useful. Yeah. I just feel like we both kind of

20:23

want to live in idea where people who really care about large assumptions I don't know if like, like I don't know if like companies tomorrow but like on board because generally don't really know much about thinking things. Critically, they think they did.

20:41

And this will be a good thank you. Yeah. Yeah, that was it. You can you can I can give you a form to fill it if you want. It's a Google form about your experience with this. But yeah, if it helps you Yeah. Yeah, it wasn't added on much more information. Cool.

Interview_Martin Muir_Ian Marr_Post dev interview

Mon, May 13, 2024 10:43AM 48:39

SUMMARY KEYWORDS

parameters, node, interesting, aircraft, centrality, organise, dependency, guess, causal loop diagram, level, martin, influences, visit, network, causal loop diagrams, building, functions, user interface, booking, apply

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00:16
Good Good et Cie see final meeting before four days of weekend

00:32
so and everything completed on your thesis or how many pages

00:50
one more topic before the other turn for your visit here in Hamburg on 31st You want to also coat on the surface to this exhibition I think it's a good idea I have talked with Shichi that she should join because he can meet some suppliers and most probably it would be good if you process also to the other students to visit but then of course you need to manage some stay overnight and so on and I mean we have a little bit more time but we if we want to organise a factory visit the s one option to book a pass for 25 people but if your only reason it's a little bit too costly then of course you can also have single bookings for for per person but then I think you'll join a kind of public group of most of in most cases retired people walking around, but I think we need many more than a week a time for the booking I haven't tried it up to now but normally we have a catalogue item that we can go for a guided tour but I think it takes some time because it's organised by an external travel agency and so on and yes that's that's important okay, I think Martin is also invited to we will see if you will join us and then we will see you thank you

03:15
didn't answer

03:17
didn't answer Yeah, that's right. He has not on set

03:31
mighty light for him. I think it starts early Martin

03:40
but now it's a it's a noon and UK I think it's afternoon already

03:56
Wow, let's see he's still online.

04:40
Let's see if he answers

05:44
We think we simply start and join in later if Martin has seen my mail he doesn't lie and when he's occupied you can hear us I guess but yeah okay but not talk

06:34
I guess so no sunshine in the park

06:40
I get through this mason appreciate them?

08:12
Sounds good

08:36
yeah see for bubbles and

10:10

Sorry, it's me just playing around my sound sorry apologies apologies?

12:07

Put it back up on screen, it's quite just so you can have a bit more look. So yeah, those are playing around in my old gear this time it was slightly slightly out of phase. But so the idea is basically to have a knowledge graph the dependencies and basically the interactions between those so is, so for this example you've got here, then it is a space? Or is this just this is effectively a demonstration problem rather than basically just something that's actually based on some some actual causal diagrams or system dynamics? Or is it?

13:04

Yeah, it's just like sensitive, you know, I mean, in terms of yeah, in terms of identifying where the uncertainties are, and identifying where the kind of critical points are, is it I mean, I'm guessing this is using kind of like, the typical network measures like, between the centrality and you know, I can, can you basically look at this from different perspectives to see basically the criticality of different nodes. So, if you look at the kind of between the centrality or the node degree or something like that can can be this peace.

14:01

Yeah, I mean, I mean, so potentially, I mean, this is the potential interest here, it could be something like parameter mapping with something like cameo, I don't even know, they're counting. Well, I'm all model based systems engineering. So in particularly when there's multiple levels, and very complex dependencies between parameters. So we have simulation process models, which were starting to assemble or building up gradually over time, which basically show the dependency between parameters at different levels of analysis. So what I mean by that is we might be doing analysis that kind of the system of systems level, which is you know, we're talking about going between like fleets of aircraft and airport operations and industrial simulations and maintenance and provisioning requirements and those kinds of really, really high level sort of analysis. just tickle trades and things. So the kind of things we'll be doing with aren't. And then you basically got things that the kind of aircraft level which are much, much more detailed decompositions, we get down to individual aircraft sizing parameters, the kind of geometrical consideration physical properties of the aircraft, and so on and so forth. And so where it gets interesting is when you're trying to basically at a detailed design point of view, trying to understand where a, what is influencing or shaping a particular parameter, and where that, where that comes from. So it may be that you're working at kind of component level, or, or what we might call CFCs, central competence level where you're basically on a kind of structures or flight physics level. And at that level, you may be dealing with some very, very detailed parameters. So you know, things like load alleviation functions on a wing or various other things. And you may be interested to know, well, how does you know changing, changing the takeoff field length capabilities of this aircraft? How does this impact this parameter? Or how does you know? How does changing the fuel type in a really high level parameter? How does that cascade through and and impact those really detailed level parameters further down. So the kind of thing where this could be interesting is if you can sort of use the some of this kind of thing to signify the dependency between if

it's possible, I mean, I don't know if that's possible, but if it's possible to kind of signify the dependency between parameters are different levels and that can be quite interesting as a kind of a more flat a flat view of the parameters if you like that makes sense.

17:05
It's more about extending the capability so yeah.

17:57
An interesting case study here would be so with the University of Cranfield at the moment, we're basically building causal loop diagrams and system dynamics models of aviation infrastructure. And so they're basically building these causal loop diagrams are supposed to say this factor influences this factor, which influences this fashion influences this factor. Now, that kind of causal loop Diagram View is is interesting to kind of see the loops and to see how these kind of feedback dynamics happen between all these different parameters influences, but it doesn't on its own from just looking at causal loop diagram, it doesn't necessarily give you the criticality. So doesn't necessarily tell you that, you know, this parameter is fundamental to all, sometimes you can see that fairly, obviously, because you can see just the number of inputs going into something, usually, they're fairly obvious. But sometimes, you know, in terms of the sensitivity in that, you might find that basically, because something's got a large scaling factor are in our influence on other things that basically it may only have a few connections, but those those connections may be disproportionately powerful in terms of what it does. So one interesting application could be trying to basically take some of the the kind of causal diagrams and models which have been built by the Cranfield team and seeing how that might translate into this and what that teaches you could be interesting.

19:56
Is, is the flexibility in there too? To programme in your own metrics for things, so, yeah, so I'm just thinking so you have kind of a range of different network science metrics such as between the centrality, no degree trumping all the other ones now that they build different KPIs you get from network science. So what could be quite interesting would be, I mean, I guess if you're, I guess if you know, kind of giffy and those other kinds of tools and you can you can basically look down the list of the KPIs and basically do and effectively arrange layouts based on kind of gravity algorithms and other things to to form the layout for structure. So that's, that's sometimes quite useful. Yeah, Gaffey, it's a graph analysis tool. But it's so that has a it has a range of different network science metrics. But she uses an it's worth a look, it's useful thing, but this is quite nice because Gaffey is very general purpose very generic, if you like, whereas, what you have here is actually something which is basically a user interface, which basically shows you the graph shows you the interface between these things, but then also gives you the, the parameters, the details, the sources and equations in this kind of upfront user interface way. So that's kind of a bit easier to interpret and Gaffey because Gaffey doesn't really tell you it looks kind of very mathematical point of view in terms of the network structure. But it's you have to actually extract information out of that you've got to spend quite a bit of time kind of looking at what those what the different nodes actually mean. was a nice thing what you've got here is basically then the definition of those nodes is right on screen.

22:25

Exactly connection information which is really valuable because that's the kind of thing you that's kind of unity and getting because guess you wouldn't tell you just by clicking on a node, how that node node was derived, you just basically have a generic mathematical application which is basically saying apply between the centrality or between Oh edge vector I can remember I can't remember what they all are but but you know, apply apply these different mathematic formula and that will be what's applied to that and it'll be applied generically across the board. Whereas here you have some things which are specific to each individual node

22:59

new colour code your nodes in order to make sure that you've you can immediately highlight to the user that something is an assumption something is an average something is a fact etc Yeah.

23:54

What's the relation for the benefit? What's the calculation for the benefit? So this is to varying routes is it

24:03

okay

24:05

okay

24:16

and does this if you select a journey for example, by plane will it automatically propagate an alternative journey via a different type if it's available or will it not Do you have to build that from scratch? Okay

24:41

um, many of these little these blobs available these these little nodes available to just drag into the window and connect or do you drag a note in the auto connects or brings in a subsidiary number of nodes?

25:13

Okay, and is there any form of sort of class inheritance in the background so that for example, when you bring in an aviation audit knows it's gonna bring in a kerosene nobody knows it's going to bring in

you bring in an aviation audit knows it's gonna bring in a kerosene nobody knows it's going to bring in a certain aircraft node etcetera

25:27
okay

25:43
no but if you're wanting it sort of travel if you were doing it sort of not travel specific button you know carbon cost effectively it's associated with travel then having those inheritance classes for each type of travel that you've doing would make the instantiation an awful lot quicker

26:38
I think it's useful my guess is it's been able to visualise the cost benefits in that way and this is a more practical useful version of kind of getting that sense I think is what's called a potential

26:58
Okay, that's it's more of a generic network modelling tools so but this is actually this is actually more tailored and specific to to our needs. So this is more useful well.

28:10
In that sense does it use all the existing Excel functions is that portal

28:16
okay

28:20
okay with that there's a lot of power at your fingertips and because you've already got all that functionality already built in Yeah

28:35
Oh, I see okay

28:52

28:52

so, if you wanted so you have to do this by hand. So is it quite complex if you wanted to add in a new function if you wanted to bring something else across as quite a Do you have to actually literally get into the code of the the sort of VBA from?

29:44

Think he's still showing them