Refurbishment
implementing MCDA and BIM based LCA

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"First comes thought; then organization of that thought, into ideas and plans; then transformation of those plans into reality. The beginning, as you will observe, is in your imagination."

— Napoleon Hill

Preface

This master thesis is the result of the graduation research carried out in collaboration with Eindhoven University of Technology and Strukton Worksphere. The thesis represents the final work for the masters Construction Management and Engineering (CME) and Urban Systems and Real Estate (USRE) and thus marks the end of my career as a student. My career started in September 2018 with the switching program for CME and during the course of several years I took on the challenge to combine the CME master track with the track of USRE. The achievements I have accomplished during this period would not have been possible without the friendly and stimulating environment created by all the people that are present at Eindhoven University of Technology.

The thesis is a representation of my personal interests, it covers a broad topic and is focused on the development of practical tools that are directly linked to real-world implementation. The two applications developed in this thesis also represent the challenges that I like to set myself. As well as, the urge to gain new knowledge and skills.

During the research for my thesis, it has been great to have the support of my supervisors at the TU/e that helped me guide through the process its ups and downs. Their support motivated me to go further in-depth and lift the thesis to a higher level. I would therefore like to thank Qi Han, Theo Arentze and Pieter Pauwels.
The case study conducted in this thesis is a refurbishment project of an ABN-Amro office conducted by Strukton. At Strukton I have had a supervisor and partner to brainstorm with in Gijs van Heijster. The meetings with him helped to keep the research focused on real-world applications and the possibility to work with an actual case has given great results and new insights that otherwise would not have been identified. I would like to thank everyone at Strukton for their support, trust and feedback.
I am grateful for all the experts that have helped me out in their field of view. Julia Kaltenegger on integrating LCA and BIM, Rick van Fessem for all the Angular programming issues and Remco van Groesen who helped me with fully understanding all the equations.

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Finally, I would like to thank my friends, family and especially my girlfriend who have all supported and motivated me the last nine months.

I hope you enjoy reading this report and gain new insight into the refurbishment process.

Rick van den Biggelaar
Eindhoven, May 2022

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only one pilot study and a limited group of experts.

Summary

Introduction

The building sector has a big contribution on the emission of greenhouse gasses. In total, the building sector is found responsible for over 40% of the energy usage and 30% of all greenhouse gasses emitted worldwide (Brejnrod et al., 2017).

Many sustainability policies and initiatives are focused on new-build developments. However, comparing the impact generated by new development is only minimal, since most emissions are generated by the already existing real estate. The replacement rate of existing real estate is minimal. Therefore, a shift of focus is required to look at existing real estate. (Mansfield, 2009).

In a refurbishment processes, design choices are made before their environmental impact is known. The choices of decision makers are based on their personal feels and needs. For designers the reasoning behind design choices, and thus the feels and needs of the decision makers, remain unknown. The environmental impact is calculated using Life Cycle Assessment (LCA) methods but these studies can only be conducted when the material choices have been finalized and when there is a definitive design. Studies are conducted using applications and tools but implementation with Building Information Models (BIM) is still lacking.

Problem statement

From the literature, a two-sided research problem is identified: On the one side, the lack of insight into the actual needs and feels of the decision makers that support sustainable renovation decisions. On the other side, the quantification of the actual environmental impact, is generated by design choices that are made by the decision makers.

The following research question is posed: *How can designers implement MCDA to help clients decide on sustainable refurbishment measures and implement BIM with LCA to verify and quantify the environmental impact of refurbishment works?*

The goal of the research is to identify the key aspects that drive decision-makers in circular and sustainable refurbishment measures, through multi-criteria decision-making analysis (MCDA). This will help designers understand the needs and feels of the client better and allow for an improved refurbishment plan. To gain insight into the impact of refurbishment works on the level of sustainability and provide quantitative feedback to the client, this research focuses on the development of an application that allows for automated LCA analysis of IFC-Building models. Furthermore, this research will help to gain insight into the methods of re-utilizing existing building components in a refurbishment design as well as impact calculation.

The research is limited to the availability of data taken from the existing case study building, the environmental data in material databases, and to the existing calculation methods that have been implemented. Furthermore, the research is limited since it focuses on

Methodology

A building design is a result of a set of choices, but the reasoning behind these choices is not always clear. Within sustainable refurbishment, it is required to tailor materials and energy consumption during the design process by making choices on refurbishment measures. These decisions are made based on the visions of the experts that are working on the refurbishment project (Gohardani & Bjork, 2012). The choices experts are facing require extensive analysis of multiple criteria and these criteria are often hard to quantify.

The Causal Network Elicitation Technique Decision Assistant (CNET-DA) is a semi-structured interview method to measure the components of mental representation of choice tasks. CNET-DA can be used to analyze and identify the preferences of decision makers. The interview method reveals the Decision Network (DN) and is an extension of the Bayesian Belief Network (which is a causal network). CNET-DA is considered a multi criteria decision making assistant (Arentze, 2016). The CNET-DA method assigns a utility to the different choice options (alternatives), which is a combination of the expected gain and expected costs (Dellaert et al., 2017). The higher the utility, the better the alternative suits the interviewee.

CNET-DA is an extension of a method earlier used in consumer preference research namely, the Causal Network Elicitation Technique (CNET). It is based on the multi-attribute utility theory, which is a trajectory within the methods of MCDM. CNET-DA is suggested as an alternative to the AHP method. The framework in which CNET-DA operates uses the multi-attribute utility framework and extends on this, considering the addition of the attribute-benefit link that is added.

The CNET-DA interview process consists of multiple steps to identify the attributes and benefits that eventually influence the overall utility of a set of different choice alternatives. To mitigate the time intensity of the CNET-DA the method is converted into a web-application which allows interviewees to conduct the steps of the CNET-DA tool and receive a direct result of utility,the relative strengths, and the importance of the attribute and benefits.

To calculate the environmental impact of the design choices, a method is proposed and developed to calculate the environmental impact of a building using BIM data and an environmental database. In addition, an algorithm is developed to calculate the environmental impact of materials that are reused in the refurbishment process but for which no LCA data is available. The result of this development is a BIM based Environmental Evaluation (BEE) tool. The tool extracts quantity information from an IFC file that is uploaded by the user and uses the NL-SfB code of the material to search the environmental impact from a material database. The environmental database used is manually filled with LCA environmental impact data from product sheets and the NMD. The tool allows the user to navigate the building in 3D and select a building component to edit the specific material of a building component or its lifespan. Furthermore, the user decides whether a building component should be considered in the environmental impact calculation via a checkbox.

After every alteration that the user makes, the environmental impact calculation is updated and gives the user real-time feedback. After a user has finished with alterations and the calculation, the user can export the results of the calculation as a PDF file and save the changes of building components to IFC. The whole application is developed as a Web-Application which means any device with a compatible web browser can connect and use the BEE tool. Overall BEE is capable of automatically calculating the environmental impact using LCA environmental impact data. The tool relies on the user to upload an IFC that contains the set of properties needed, therefore requiring the expertise of a user to ensure the calculations are correct.

Case Study

This research proposes two methods to improve the environmental ambition and assessment in the office renovation process. To evaluate performance in a real-world situation and gain user feedback, this research conducts a case study, in which the proposed methods are implemented. This case study was conducted for an ABN AMRO office refurbishment project in Diemen, The Netherlands.

Results

Firstly, the case study has given insight in the implementation of the tools CNET-DA and BEE in the refurbishment process. Secondly, the case study gave insight in the decisions made during the refurbishment and their respective environmental impact. Thirdly, it has given the opportunity to test the tools and find out their limitations.

The CNET-DA tool has shown to give insight into the incentives of the decisions during the refurbishment process. The results of the CNET-DA tool show that the alternative with the highest utility is not always implemented in the final design of the case. This does indicate that there are variables which are important to the decision makers, but not taken into account during the design process. This confirms the gap indicated in the literature and shows that there is an opportunity for designers to improve their design for the clients' needs.

The decision makers have been interviewed on their experience in using CNET-DA. The overall response is positive and the decision makers believe the results represent their feels and beliefs. Decision makers indicated they would like to see further implementation of CNET-DA in future projects to gain more experience in the added value.

To assess the environmental impact of the design choices the application BEE has been implemented to calculate the impact of different components of the BIM model. Insight is given for the components of floor carpet tiles and the reuse of wall tiles which shows the choices made during the design process. For the before mentioned components the optimal design choice, considering the environmental costs, is made by the decision makers.

The implementation of BEE identified limitations of the tool when using real-life large scale IFC models. The tool is unable to handle IFC file formats over 100 MB, this limitation is accountable to the handling of the IFC file with the IFC.JS framework. This thesis adopted the IFC.JS framework which is still in the early development stages and has not (yet) been designed for larger file sizes. Besides the limitations, the case study did show the usability of BEE and its ability to calculate environmental impact based on an IFC model.

Conclusion & Discussion

This research proposes methods to gain more insight into the early design process and the verification of refurbishment projects. Specifically, the research proposes a method to measure the preference of clients/decision makers regarding their feels and needs for sustainable design choices in the refurbishment process. This allows the designers to tailor their design to the incentives of the client and understand why they prefer certain measures. On the other hand, the research was focused on creating a tool (BEE) for calculating the environmental costs index in a refurbishment process which also allows the implementation of reused materials. Including a method to easily calculate the environmental impact of reused materials without conducting a full LCA study but utilizing life cycle information from the NMD. The following research question has been answered: *How can designers implement MCDA to help clients decide on sustainable refurbishment measures and implement BIM with LCA to verify and quantify the environmental impact of refurbishment works?*

To implement MCDA and assess the preferences of decision makers the CNET-DA method has been used. A methodology has been constructed and the building was divided into the shearing layers using the 6S model. The labor intensity issues of the CNET-DA method are minimized by designing and constructing a web application allowing to walk through the CNET-DA steps digitally and resulting in the automated calculation. This has been implemented in a case study refurbishment project of ABN Amro and has been reviewed by experts.

Implementation of LCA and BIM is achieved with the proposed tool BEE. Allowing users to calculate the environmental cost index based on existing LCA environmental impact data and using BIM files, in the form of IFC, as the data input. The tool is web-based and provides the user with a navigatable 3D representation of the building and real-time environmental impact calculations.

While both CNET-DA and BEE have been implemented in the case study, no direct connection has been realized between the two tools. The proposed user for CNET-DA will differ from the user of BEE and therefore there is no need for a combination of the two elements in one model or tool. However, a feedback loop could be established to improve the decision making process and integrate the information on the environmental impact generated with BEE for the decision making in CNET-DA. By conducting the environmental impact analysis earlier in the process, the accuracy may be limited, but it does give an indication that can be used as an attribute in CNET-DA. By creating the feedback loop and integrating BEE with CNET-DA an ultimate scenario arises, allowing for improved decision making in the refurbishment process. This is beneficial for the decision makers who will get a better representation of their needs and feels, but also for the designer since they can better understand the requirements of their clients. Furthermore, by integrating the environmental impact cost index, the decision makers are directly confronted with the environmental impact of their decisions which forces them to take this into consideration when determining their preferences. ■

Samenvatting

Introductie

De bouwsector levert een grote bijdrage aan de uitstoot van broeikasgassen. In totaal is de bouwsector verantwoordelijk voor meer dan 40% van het totale energie verbruik en voor 30% van de totale uitstoot van broeikasgassen in de wereld (Brejnrod e.a., 2017).

Veel verduurzamings initiatieven en beleidstukken zijn gefocust op nieuwe vastgoedontwikkelingen. De totale impact van de nieuwe ontwikkelingen is echter maar marginaal op het geheel omdat de meeste uitstoot wordt gegenereerd door bestaand vastgoed. De snelheid waarmee bestaand vastgoed wordt vervangen door nieuwe ontwikkelingen is maar minimaal, en daarom is het nodig om de aandacht te vestigen op het bestaande vastgoed (Mansfield, 2009).

In een refurbishment proces worden ontwerpkeuzes gemaakt voor de milieu-impact bekend is. De beslissingsmakers maken keuzes op basis van hun persoonlijke gevoelens en behoeften. Vanuit de ontwerpers is er geen duidelijkheid op de redenering van de beslissingsmakers en ontwerpers hebben daardoor geen inzicht in de gevoelens en behoeften van beslissingsmakers. De milieu-impact van de refurbishment werkzaamheden kan worden bepaald met Life Cycle Assessment (LCA) maar deze methodiek kan pas worden toegepast wanneer materiaalkeuzes zijn gemaakt en het definitieve ontwerp afgerond is. Er zijn onderzoeken die gebruik maken van applicaties voor het berekenen van de milieu-impact maar hierin ontbreekt het koppelen van Bouw Informatie Modellen (BIM) aan de LCA-data.

Probleemstelling

Uit de literatuur is een tweeledig probleem geïdentificeerd: Enerzijds, het gebrek aan inzicht in de gevoelens en behoeften van de beslissingsmaker en hoe dit de duurzame ontwerpkeuzes in een refurbishment project beïnvloed. Anderzijds, de kwantificatie van de milieu-impact gegenereerd bij de gemaakte ontwerpkeuzes in het refurbishment project.

De volgende onderzoeksvraag is gesteld: *Hoe kunnen ontwerpers MCA implementeren om klanten duurzame ontwerpkeuzes te laten maken en BIM koppelen met LCA om ontwerpkeuzes te verifiëren en milieu-impact te kwantificeren in een refurbishment project?*

Het doel van het onderzoek is het identificeren van belangrijkste variabelen die beslissingsmakers aanzetten tot het maken van duurzame ontwerpkeuzes met behulp van Multi Criteria Analyse (MCA). Dit helpt ontwerpers begrijpen wat de gevoelens en behoeften zijn van de klant en deze verwerken in een refurbishment plan. Om inzicht te verkrijgen in de milieu-impact van de refurbishment werkzaamheden en deze te kunnen kwantificeren naar de klant ontwikkelt dit onderzoek een applicatie die geautomatiseerd een LCA analyse uitvoert op basis van een IFC gebouw model. Daarnaast geeft het onderzoek inzicht in de methoden om hergebruik van materiaal in een refurbishment plan mee te nemen in milieu calculaties.

Het onderzoek limiteert zich tot de beschikbare data vanuit een casus project, de beschikbare milieudata in de materiaaldatabases en de bestaande berekeningsmethoden die geadopteerd zijn. Ook is het onderzoek gelimiteerd gezien het zich focust op een pilotstudie en een kleine groep van experts.

Methodologie

Een gebouwontwerp is het resultaat van een verscheidenheid aan keuzes. Het is alleen niet altijd duidelijk wat de drijfveer achter deze keuzes is. Het is voor een duurzaam refurbishment ontwerp noodzakelijk om keuzes te maken op het gebied van materialen en ontwerp om de milieu-impact te beïnvloeden. Deze keuzes worden gemaakt door de experts die het ontwerp maken (Gohardani & Bjork, 2012). De keuzes die experts moeten maken vereisen een uitgebreide analyse op meerdere criteria die vaak moeilijk te kwantificeren zijn.

De Causaal Netwerk Elicatie Techniek Beslissings Assistent (CNET-DA) is een semi-gestructureerde interview techniek die gebruikt kan worden voor in kaart brengen van de mentale representatie van een keuze opdracht. CNET-DA kan gebruikt worden voor het analyseren van de voorkeuren van beslissingsmakers. De interview methode onthult het keuze netwerk en is een extensie op het Bayesian Belief Netwerk (dit is een causaal netwerk). CNET-DA opereert in het veld van de multi-criteria beslissings assistenten (Arentze, 2016). De CNET-DA methode berekent de utiliteit van verschillende keuze alternatieven en dit komt voort uit een afweging van verschillende keuze alternatieven met behulp van een afweging tussen kosten en baten (Dellaert e.a., 2017). Hoe hoger de utiliteit, hoe beter het alternatief bij de respondent past.

CNET-DA is een uitbreiding op een methoden die eerder is ingezet in consumentenonderzoek, namelijk de Causaal Netwerk Elicatie Techniek (CNET). Het is gebaseerd op de multi-attribuut utiliteit theorie wat een beweging is binnen de verscheidenheid aan MCA-methoden is. CNET-DA vormt een alternatief voor de AHP-methoden en CNET-DA breidt het multi-attribuut utiliteit raamwerk uit met de toevoeging van attribuut-benefit link.

Het CNET-DA interview proces bestaat uit verschillende stappen om de attributen en benefits te identificeren die uiteindelijk de utiliteit van de verschillende keuzealternatieven bepalen. Om de tijd benodigd voor CNET-DA te minimaliseren is een web-applicatie ontwikkeld die de respondent door de verschillende stappen laat lopen en direct de utiliteit en de beïnvloedende factoren resulteert.

Om de milieu-impact van de ontwerpkeuzes te bepalen is een methode voorgesteld en een applicatie ontwikkeld om de milieu-impact te berekenen met behulp van een BIM-model en een milieudatabase. Daarnaast is een algoritme ontwikkeld dat de milieu-impact berekent voor materialen die hergebruikt worden maar waar geen milieudata van bekend is. Het resultaat is de BIM gebaseerde Environmental Evaluatie (BEE) tool. De tool haalt hoeveelheden en materiaal informatie uit een IFC-model dat wordt geüpload door de gebruiker. Via de NL-SfB code worden materialen gelinkt aan de milieudata in de milieudatabase. De milieudatabase is handmatig gevuld met LCA-data uit productbladen en de NMD. De applicatie laat de gebruiker in 3D door het gebouw navigeren en componenten kunnen geselecteerd worden om het materiaal aan te passen, de resterende levensduur te wijzigen en aan te geven of het meegenomen moet worden in de milieuberekening.

Na elke aanpassing door de gebruiker wordt direct de milieu-impact opnieuw herberekent, er is dus sprake van real-time feedback. Als de gebruiker klaar is met het aanpassen en de berekening voltooid kan de gebruiker een rapportage exporteren naar PDF, de gemaakte wijzigingen kunnen worden geëxporteerd naar IFC. De applicatie is gebouwd als webapplicatie en daardoor benaderbaar met elk apparaat dat over een webbrowser beschikt. In totaliteit kan BEE automatisch de milieu-impact berekenen gebruikmakend van LCA milieudatabase en BIM data. De applicatie blijft afhankelijk van de gebruiker voor het uploaden van een IFC-bestand dat de benodigde property-sets bevat en is afhankelijk van de gebruiker om de resultaten van de calculatie te verifiëren.

Casus

Dit onderzoek stelt twee methoden voor om de milieu-impact van het refurbishment ontwerp te verbeteren en te analyseren. Om de resultaten te evalueren en gebruikersfeedback te ontvangen is een casestudie verricht waarin de voorgestelde methoden zijn geïmplementeerd. De uitgevoerde casus is een refurbishment project voor een ABN-Amro kantoor in Diemen, Nederland

Resultaten

Allereerst, heeft de casus inzicht gegeven in de implementatie van de applicaties CNET-DA en BEE in een refurbishment proces. Als tweede heeft de casus inzicht gegeven in de beslissingen gemaakt gedurende het refurbishment proces en wat dit betekende voor de milieu-impact. En als derde heeft de implementatie de kans gegeven om de applicaties te testen en de limitaties te identificeren. De CNET-DA tool heeft inzicht gegeven in de redenen en drijfveren voor ontwerpkeuzes gedurende het refurbishment proces. De resultaten van CNET-DA laten zien dat de alternatieven met de hoogste utiliteit niet altijd geïmplementeerd worden in het ontwerp. Dit laat zien dat er variabelen zijn die belangrijk zijn voor de beslissingsmaker maar die niet in het ontwerpproces zijn meegenomen. Ook bevestigt de eerder in de literatuur geïdentificeerde kloof. Het laat ook zien dat er een kans is voor ontwerpers om het ontwerp meer te vormen naar de behoefte van de klant.

De beslissingsmakers zijn geïnterviewd om de beleving van CNET-DA te beoordelen. De algemene respons is positief en beslissingsmakers voelen de resultaten passen bij hun persoonlijke gevoelens en behoeften. Ook zouden ze graag een verdere implementatie van CNET-DA zien in vervolgprojecten om meer ervaring op te doen.

Om de milieu-impact van de ontwerpkeuzes in kaart te brengen is BEE geïmplementeerd. BEE heeft de impact gecalculeerd van de verschillende componenten in het BIM-model. Met inzicht in de tapijttegels en het hergebruik van wandtegels blijkt dat de ontwerpkeuzes die gemaakt zijn de optimale keuze zijn geweest als er enkel gekeken wordt naar de milieu kosten index. De implementatie van BEE heeft ook de beperkingen van de tool laten zien wanneer er een volledig IFC-model van een casus gebruikt wordt. BEE is gelimiteerd tot IFC-bestanden tot 100MB, wat komt door het gebruik van het IFC.JS framework. Het geadopteerde framework bevindt zich nog vroeg in het ontwikkelingsproces en is nog niet geschikt voor grote, complexe, IFC-modellen. Buiten de beperkingen heeft de casus wel aangetoond dat BEE gebruikt kan worden voor het berekenen van de milieu-impact uitgedrukt in de milieukosten index gebruikmakend van een IFC-model

Conclusie & Discussie

Dit onderzoek stelt methoden voor om meer inzicht te verkrijgen in ontwerpkeuzes en daaruit resulterende milieu-impact in het refurbishment proces.

Specifiek stelt het onderzoek een methode voor om de voorkeuren van klanten/beslissingsmakers in kaart te brengen met daarbij ook inzicht in de bijbehorende gevoelens en behoeften voor duurzame ontwerpkeuzes. Dit stelt ontwerpers in staat om het ontwerp aan te passen aan deze gevoelens en behoeften en ook stelt het ze in staat de klant beter te begrijpen. Anderzijds, is het onderzoek gefocust op het ontwikkelen van een tool (BEE) die de milieukosten index vanuit een BIM-model kan berekenen. Deze tool houdt ook rekening met materialen die hergebruikt worden waarvan geen directe milieudata in milieudatabase beschikbaar zijn zonder hiervoor een volledige LCA studie voor uit te voeren. De volgende onderzoeksvraag is beantwoord: *Hoe kunnen ontwerpers MCA implementeren om klanten duurzame ontwerpkeuzes te laten maken en BIM koppelen met LCA om ontwerpkeuzes te verifiëren en milieu-impact te kwantificeren in een refurbishment project?*

Om MCA te implementeren en de voorkeuren van beslissingsmakers te evalueren is de CNET-DA methode voorgesteld en getest. Een methode is beschreven en het gebouw waarvoor ontwerpkeuzes moeten worden gemaakt is gesplitst in de lagen van het 6S model. De arbeidsintensiviteit en benodigde tijd voor de CNET-DA methode zijn gereduceerd door het ontwikkelen van een webapplicatie. Deze laat de gebruiker door de stappen van CNET-DA lopen en berekend automatisch het optimale resultaat. Dit is toegepast in een casus van een ABN-Amro renovatieproject en beoordeeld bij experts.

De implementatie van LCA en BIM-data is bereikt met de ontwikkelde tool BEE. Deze applicatie stelt gebruikers in staat om de milieukosten te berekenen op basis van bestaande LCA-milieudata en een BIM-model dat als IFC-bestand word geïmporteerd. De webapplicatie laat de gebruiker in 3D door het gebouw navigeren en berekent de milieu-impact in real-time.

Hoewel CNET-DA en BEE beide zijn toegepast in de casus, is er geen directe link gemaakt tussen de twee applicaties. De gebruiker van CNET-DA is in de praktijk ook anders dan de gebruiker van BEE, integratie van de twee tools in één is daarom ook niet noodzakelijk. Er kan echter wel een feedback cirkel gerealiseerd worden die de keuzes van de beslissingsmaker op het gebied van milieu-impact zou kunnen assisteren. Door BEE ook in te zetten in het vroege ontwerpproces en de uitkomsten van verschillende materialen te gebruiken als input in de CNET-DA beslissing assistent wordt de milieudata als attribuut meegenomen. De berekening van BEE in het vroege ontwerpproces zal nog afwijken van de uiteindelijke berekening maar geeft dan wel een indicatie. Uiteindelijk zal na het definitieve ontwerp de volledige BEE-milieu-impact berekening gemaakt kunnen worden. Door het implementeren van deze feedback cirkel worden beslissingsmakers aangespoord om ook naar de milieu-impact te kijken wanneer ze ontwerpkeuzes maken. ■

Abstract

When refurbishing office buildings, the decision makers play a key role in the refurbishment design. Office refurbishments are conducted for numerous reasons, but the general trend is to improve the buildings energy usage and thus environmental impact. The refurbishment process itself also has impact on the environment via e.g.: new building materials, waste, transport, and energy usage and thus, it is required to focus on a sustainable refurbishment design.

In the refurbishment process there is a lack of insight in the decision makers' feels and needs, this insight is required when creating a suitable sustainable refurbishment design. On the other hand, the quantification of the environmental impact of a refurbishment design remains difficult since current solutions do not link Building Information Models (BIM) to Life Cycle Assessment (LCA) data.

This thesis introduces two web-based tools CNET-DA and BEE. CNET-DA allows designers to gain insight into the feels and needs of decision makers by letting them indicate their preferences for a set of choice alternatives. CNET-DA has not been implemented before and therefore also insight is gained in the user experience of using the developed CNET-DA web-tool. The BIM based Environmental Evaluation (BEE) tool allows designers to calculate the environmental impact of a refurbishment project expressed in a costs index. This tool uses a BIM model (IFC file) as input and connects it to a database with LCA data. The user can modify the material specifications in the tool and the environmental costs are adjusted in real-time. A graphical representation (3D view) of the BIM allows for easy component selection.

Both developed tools are implemented in a case study of an ABN-Amro refurbishment project. Results of the case study showed decision makers not always choose the best suitable alternative. Furthermore, important decision attributes were identified, and the environmental impact calculations showed significant environmental savings on evaluated building components. Experts using the CNET-DA tool would like to see further future case studies with the decision assistant. In the end, the study contributes to the refurbishment design and decision-making process in the effort to reduce the environmental impact of the refurbishment process.

Key words: Life Cycle Assessment, Building Information Model, CNET-Decision Assistant, Environmental Impact Analysis.

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Contents

Glossary

Abbreviation	Definition
AEC	Architecture, Engineering and Construction
AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
API	Application programming interface
BIM	Building Information Model
BREEAM	Building Research Establishment Environmental Assessment Method
CNET	Causal Network Elicitation Technique
CNET-DA	Causal Network Elicitation Technique Decision Assistant
COVID-19	Coronavirus
DGBC	Dutch Green Building Council
DIA	Department of Internal Affairs
DN	Decision Network
GPR	Gemeentelijke Praktijk Regels
GUI	Graphical User Interface
HL	Hard Laddering
HTML	Hyper Text Markup Language (coding language)
HVAC	Heating, Ventilaton, Air Conditioning
IFC	Industry Foundation Classes (file format)
JS	JavaScript (coding language)
JSON	JavaScript Object Notation
LCA	Life Cycle Assessment
LCA-methods	Life Cycle Assessment methods
LEICAS	Life Cycle Environmental Impact and Costing Assessment
LOD	Level Of Development
LOI	Level Of Information
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
MKI	Environmental costs index (Milieu Kosten Indicator)
MPG	Milieu Prestatie Gebouwen
MR	Mental Representation

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Table 1 – continued from previous page

Abbreviation	Definition
MVC	Model View Controller
NMD	Nationale Milieu Database
NOSQL	Not Only SQL
nZEB	nearly Zero Energy Buildings
PV	Photo Voltaic panels
RAM	Random Accessible Memory
SREQ	System Requirements
TS	TypeScript (coding language)
UREQ	User Requirements

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Chapter 1

Introduction

1.1 Research context

Human activities are getting closer to the boundaries of the planet Earth. Besides other negative effects, one of the biggest and fastest evolving issues is climate change. A reduction in the emission of greenhouse gasses is needed to keep climate change at a manageable level. Emission levels need to be within the maximum carrying capacity of the Earth to keep the negative environmental effects to a minimum (Brejnrod et al., 2017).

Research by Steffen et al. (2015) has set indicator levels for parts of the world dividing the emissions into three categories; (1) below the boundary (safe), (2) zone of uncertainty (increasing risk), and (3) beyond the zone of uncertainty (high risk). Their research shows the developed countries being large polluters, especially regarding nitrogen and phosphorus pollution. Large zones in Europe and Northern America are beyond the zone of uncertainty when it comes to the amount of nitrogen and phosphorus emissions.

The building sector has a big influence on the emission of greenhouse gasses. Large amounts of materials and energy are needed when constructing a building. In total, the building sector is found responsible for over 40% of the energy usage and 30% of all greenhouse gasses emitted worldwide (Brejnrod et al., 2017).

Many sustainability policies and initiatives are focused on new-build developments, but comparing the impact generated by new development is only minimal since most emissions are generated by the existing real estate and the replacement rate of existing real estate is minimal. Therefore, the emissions of existing real estate dominate, and the focus on sustainability and reduction of emissions should shift to the existing building stock, increasing the chances to achieve sustainability goals. Furthermore, sustainable refurbishment could be financially beneficial for real estate owners (Mansfield, 2009).

Improving existing buildings to reduce energy in the long term is found to be an important strategy in reducing the total energy used by a building. Nevertheless, refurbishment works carried out to reduce energy usage have an important negative impact on the environment itself. This is because the fabrication processes and installation of elements used for the refurbishment have embedded emissions and thus environmental impact themselves. According to the research of Ghose et al. (2019), it is found that refurbishment works during a building's lifespan account for 2 to 55% of the total embodied impact of a building (Ghose et al., 2019).

To measure circularity and to gain insight into the emissions and environmental impact of a building, the use of Life Cycle Assessment (LCA) is considered to be the most important method (Brejnrod et al., 2017; Ghose et al., 2019). LCA methods are considered an analysis framework used to estimate environmental impact. Prediction of service life determines the activities needed to maintain, repair, and replace building elements and their frequency (Grant & Ries, 2013). Many LCA methods calculate the environmental impact for each element of a building (Grant & Ries, 2013). A building's environmental impact can be quantified by the "embodied energy" and the "operational energy" per building element. The former applies to the total energy needed for the production and installation of a building element, whereas the latter applies to the energy usage during the lifespan of a building element.

Life Cycle Assessment in the built environment is mainly used during the building's early design stages. In this building phase, hard data like energy bills and actual consumption are not available since the building is not being built yet. Using hard data can improve the reliability of the impact analysis (Slavkovic et al., 2019). By utilizing the energy bills and comparing them to the initial calculations the validity can be determined after buildings are built or redeveloped. The integration of information that becomes available during a buildings operational phase could also improve the LCA method and its predictions (Grant & Ries, 2013).

Various authors noted the possibility of connecting LCA to BIM, but they also found the software that has been developed is still in the early stages. They acknowledge that further development is necessary. (Gemert, 2019; Oeveren, 2020; Verberne, 2016). The research of Verberne (2016) ensued in a spreadsheet-based circularity assessment model with no direct (automated) connections to the BIM model. Oeveren (2020) aimed to bridge this gap and automate the LCA calculation based on IFC models, but the implementation focused on new to build apartment buildings.

To improve the sustainability of the construction sector, it is important to analyze the impact of refurbishment works on the real estate itself. This does not confine to the material impact, but also the immaterial impact should be considered: Material impact is impact directly tangible and measurable to the material itself. This contains embodied and operational energy costs savings due to the reduction of energy, tax cuts, and subsidies. On the other hand, there is the immaterial impact, these are other benefits that do not directly influence the value of a property or help to reduce energy costs. Examples of immaterial impacts could be improvements for building users like health, experience, productivity, and satisfaction (Martens, 2020).

Furthermore, the expectation is that office design and demand will change in the near future due to the impact of the COVID-19 pandemic (Ackerman, 2021; Parker, 2020). Research still debates whether these changes will be driven by the cost factor (Parker, 2020) or that is driven from an employee well-being perspective (Ackerman, 2021). By investigating the real estate owner's perspective, it could potentially be possible to determine whether choices in the refurbishment process are driven from a cost perspective (material impact) or whether immaterial impact and thus well-being is a key decision factor.

1.2 Refurbishment

Renovation, refurbishment, and retrofit are often interchangeably used terms. While the European committee for standardization (2021) states these terms to be "planned large scale (substantial) modification and improvements to existing construction works". This is supported by the research of Kaltenegger (2021) who also differentiates different stages of refurbishment (partial-, normal- and total- refurbishment). Retrofit is more often used in the context of adding a feature or improvement of performance in a particular area (e.g. energy efficiency, ventilation capacity) (Hasik et al., 2019), which is not the focus of this study. To stay consistent with the terminology, this study used the term refurbishment for the remainder of the report, furthermore, there is no differentiation based on the intensity of the refurbishment. Acknowledging the definitions of European committee for standardization (2021) and Kaltenegger (2021), refurbishment is considered the planned and substantial modification and improvement of existing construction works.

1.2.1 Refurbishment process

A typical refurbishment project process is illustrated in Figure 1.2. The process starts with the definition of the scope, this is followed by the concept strategy design. In this phase, designers have to create a suitable design in line with the thoughts of the client. Therefore, it is important to understand what the client wants, and why the client wants something. Especially with the growing demand for circular and sustainable measures that are not always on the same perspective. The gap between the contractors and client perspectives and the demand for circularity and sustainability has been identified before in the research of Gerding et al. (2021). She also suggests further research into the decision-making process of actors in the design process. Figure 1.1 has been used before to indicate the gap in design quality between the client demands and the work actually conducted (John S., 2013). The overall issue of the in the literature identified gap between the client and contractor demands and the perspective has been verified during interviews of key stakeholders in the design process of the case study conducted later in this paper.

Figure 1.1: Quality of design, Tree Swing - Adapted from John S. (2013)

To exemplify the balance problem between reusable material and environmental impact two wall types are shown in Table 1.1. One is a sand-lime brick wall that is glued and cannot be disassembled to be reused on another site. The other is a steel-frame wall element that can be reused in different locations and can be mounted and dismounted repeatedly. Contrary, the non-reusable sand-lime brick wall has less of an environmental impact than the steel-frame wall element. And even the life expectancy of the steel-frame wall is higher. Contrary to the expectancy of the client that a material that can be reused must be better for the environment. This is one example that shows that a building component cannot always be circular and sustainable at the same time. In the design, the aim is to fulfill the needs, feels, and requirements of the client. Therefore, understanding the perspective of the client is important in the design phase (phase 2 Figure 1.2). Especially when the environmental impacts of materials can be contrary to basic expectations.

Material	Environmental Costs Index (MKI)	Mass	Life Expectancy
Sand-Lime Brick (Glued)	€2.28	128.5 kg/m2	75 Years
Steel-frame wall element	€7.08	28.6 kg/m2	25 Years

Table 1.1: Environmental impact index of two wall types (Stichting Nationale Milieudatabase, n.d.)

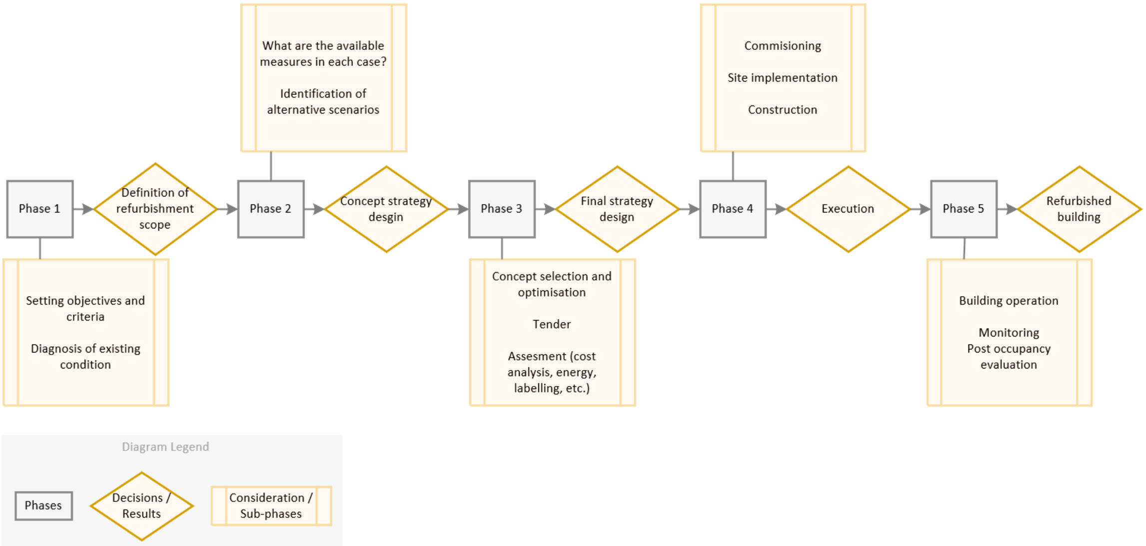


Figure 1.2: Building refurbishment process stages, adapted from Konstantinou and Knaack (2013)

1.2.2 Refurbishment motivations

In the Netherlands, office buildings are required to meet a minimum energy label C from January 1, 2023. This requirement is established by the Ministerial Department of Internal Affairs (DIA) and applies to all office buildings with a usable area of 100 m2 and above. The DIA has consulted Sira Consulting to estimate office buildings that would not meet this requirement, and Sira has identified more than 62,000 office buildings that would require measures to meet the label C requirement (Poll & Kooijman, 2020). These measures can differ from large refurbishments in which large building components are upgraded or replaced, to smaller measures such as the addition of solar panels or different heating/cooling sources. The aforementioned poses a big incentive for office building owners to refurbish and improve their impact on an operational level. There are also other incentives, such as increased employee productivity and the decrease of sick leave.

As stated by DGBC (2015) the productivity of the employee can increase with 10-15 % and sick leave decreases by 1,5% up to even 2,5%. Furthermore, the coronavirus (COVID-19) pandemic has a foreseeable impact on the design and necessity of office buildings. Some research suggests that work will virtualize and shift to the cloud, eliminating the need for large office buildings (Ackerman, 2021). Other research by Parker (2020), in addition to acknowledging a shift to digital workplaces, foresees a transition in the way office buildings are designed and used. Parker (2020) remains unclear in the exact form of design but does suggest the focus on an environment more resistant to pandemic influence and thus a safer work environment. Since the developments due to COVID-19 are so recent, more research will be needed to gain more insight into the design shift of office buildings.

1.2.3 Conclusion

This section has identified the issues related to understanding the needs and demands of clients, particularly from the perspective of sustainable refurbishment decisions. It also outlines the scope of refurbishment and outlines incentives that indicate that the refurbishment of offices is becoming more relevant. An example of the contrary high environmental impact that is assigned to reusable materials is shown and suggestions are made that support further investigations of the research questions in this thesis.

1.3 Problem statement

The literature previously discussed shows that there is an increasing number of methods to gain insight into the environmental impact of buildings. It also indicates that there is no clear path to help real estate owners with the decision-making in regard to sustainable refurbishment.

This section has identified the issues related to understanding the needs and demands of clients, particularly from the perspective of sustainable refurbishment decisions. It also outlines the scope of refurbishment and outlines incentives that indicate that the refurbishment of offices is becoming more relevant. An example of the contrary high environmental impact that is assigned to reusable materials is shown and suggestions are made that support further investigations of the research questions in this thesis. It is not always possible to be circular and sustainable at the same time and there is a clear gap between the refurbishment decisions and the environmental impact generated by them.

LCA methods used to analyze the environmental impact of buildings are aimed at the early design stages and it is unclear how they can be used to give insight into sustainable refurbishment projects. Calculations are not connected to building information models, and therefore there is no real-time insight into the effects of different refurbishment measures. It remains unclear what drives the refurbishment decisions made by real estate owners and what are the important factors for them. Since many LCA methods focus on the early design stages of new to-build buildings, there is a lot of knowledge left to gain into the implementation of LCA in existing real estate and the impact of refurbishment works on the environmental footprint of a building.

The research problem is two-sided: On the one side, the lack of insight into the actual needs and feels of the decision makers that support sustainable renovation decisions. On the other side, the quantification of the actual environmental impact generated by design choices made by the decision makers.

1.4 Research questions

The following research question is posed:

How can designers implement MCDA to help clients decide on sustainable refurbishment measures and implement BIM with LCA to verify and quantify the environmental impact of refurbishment works?

1.4.1 Sub Questions

The main question can be divided into multiple sub-questions that can help answer the main question:

- How is LCA applicable for refurbishment works and what defines refurbishment works?
- How can the LCA calculation be automated using the building information model and additional energy calculations?
- Which criteria and for what reasons are considered by real estate owners when deciding on refurbishment works?
- Which multi-criteria analysis can help real estate owners with decision making in (circular) refurbishment decisions?
- How can reused material be implemented in the environmental impact calculation?

1.5 Research objectives

1.5.1 Research goal

The research will add knowledge to the decision-making process for the sustainable refurbishment of office buildings. The goal of the research is to identify the key aspects that drive decision-makers in circular and sustainable refurbishment measures through multi-criteria decision-making methods. This will help designers understand the needs and feels of the client better and allow for an improved refurbishment plan. To gain insight into the impact of refurbishment works on the level of sustainability and provide quantitative feedback to the client this research focuses on the development of an application that allows for automated LCA analysis of IFC-Building models. Furthermore, this research will gain insight into the methods of re-utilizing existing building components into a refurbishment design and impact calculation.

1.5.2 Limitations

The research is limited by the availability of data from an existing case building. Besides, not all materials have an available environmental impact analysis. In addition, the research is limited since existing calculation methods get adopted, and the focus is often on early design stages instead of on refurbishment works. Lastly, the decision criteria are derived from the existing literature and a limited group of experts which limits their extent.

1.6 Reading guide

This research begins with an outline of the existing literature. This starts with defining the refurbishment process. Then it discusses life cycle assessment and how this is an important method for evaluating the environmental impact in the built environment. This is followed by an explanation about building information models and how this can be used in life cycle assessment. It also discusses the discrete choice problem in the refurbishment process and the multi-criteria decision analysis. The next chapter (Chapter 4) zooms in on the decision variables and how these can be assessed. It proposes the implementation of CNET-DA, which is a multi-criteria-decision-making analysis. Chapter 5 introduces BEE, a framework that uses LCA and BIM to evaluate the environmental impact of refurbishment works. In Chapter 6, a case study implements the proposed tools to evaluate the refurbishment works conducted at an office building of ABN AMRO. Finally, in the conclusion, the results of the research are evaluated (Chapter 7), a discussion of the results is made and a future outlook is sketched in the recommendations.

Chapter 2

Literature

As mentioned before, the building sector is a major influencer on total generated emissions, depletion of resources, use of energy, and creation of waste. Various authors have suggested methods and conducted analyses on methods to analyze the impact of a building to allow the overall sector to generate measures and influence the overall impact of the building sector (Brejnrod et al., 2017; Grant & Ries, 2013; Hasik et al., 2019; Olsson et al., 2016; Steffen et al., 2015; Vilches et al., 2016).

Furthermore, it is identified that there is no clear path to help real estate owners with their refurbishment decision. Also, there is a gap in understanding between the client's requirements and the interpretation of the contractor.

To gain insight into emissions and measure circularity, it is necessary to determine the environmental impact of the building. This can be achieved using the life cycle assessment methodology (LCA). As mentioned by Brejnrod et al. (2017), LCA is the most important method analysis framework for estimating the environmental impact.

This chapter explains the concept of Multi-Criteria Decision Analysis (MCDA), decision problems, and the concept of office space refurbishment. A literature study is conducted to find out how LCA helps to gain insight into the environmental impact and how this can be linked with BIM.

2.1 Multi-criteria decision making

A building design is a result of a set of choices, but the reasoning behind these choices is not always clear. Within sustainable refurbishment, it is required to tailor materials and energy consumption during the design process by making choices on refurbishment measures. These decisions are made based on the visions of the experts working on the refurbishment project (Gohardani & Bjork, 2012). The choices experts face require extensive analysis of multiple criteria, and often multiple criteria that are hard to quantify. For example, when deciding on a roof renovation decision-makers have to consider whether they would like a similar situation, or maybe a green vegetation roof, or a roof full of solar panels. Each of these alternatives has attributes that do not directly correlate, a green roof does not generate energy and a roof with solar panels looks totally different.

Analysis of the discrete choice can be achieved using various multi-criteria decision making (MCDM) methods. A common method is the Analytic Hierarchy Process (AHP) (Banai-Kashani, 1989; Cheng et al., 2002; Lin et al., 2015). To support the choice behavior among alternatives, AHP compares a set of alternatives and weighs them by different attributes. The method is used in similar discrete choice problems such as in urban travel demand (Banai-Kashani, 1989) where the alternatives are limited to the types of travel and depend on various factors that could differ for individuals. The choice problem is comparable to the building refurbishment sector, as it is highly influenced by the decision maker and has many environmental factors. AHP is also suggested by Lin et al. (2015) to help decide on the procurement method for building maintenance work. The framework proposed in their research used AHP to find an optimal solution. Lin et al. (2015) set out a survey among 20 public universities to find out who are the decision makers when it comes to building maintenance. They found that more than 35% of the respondents have over 15 years of relevant experience and only 23% have less than 5 years of experience, indicating a high level of expertise among decision makers. Even though, Lin et al. (2015) found out that the experience level is very high among the decision makers, they do emphasize the major downside of the AHP method and the likelihood of false outcomes. In the paper of Cheng et al. (2002) they evaluate why the AHP method can be misleading. The important factor in this is the relative importance assigned by the software or the person conducting the study. While AHP asks the interviewee to assign an importance value to an attribute by means of a qualitative label, it is later in the interpretation stage that this importance is quantified by the researcher and connected to a specific numerical weight. The researcher determines the quantification and can thus steer the results, this is a big flaw in the AHP process and is also addressed in the work of Arentze (2016).

2.2 Refurbishment

According to Kaltenegger (2021), a refurbishment process is similar to that of a newly constructed building with the difference being the building is already occupied and brings existing characteristics. But unlike the description of Kaltenegger (2021), which considers refurbishment as a separate process, the refurbishment and construction of a new building should be seen as part of one overarching process: The building's life cycle. This is supported by Gemert (2019) and Hasik et al. (2019). In Figure 2.1 the life stages of a building are shown. Within this research, the focus is on module B5, the refurbishment stage.

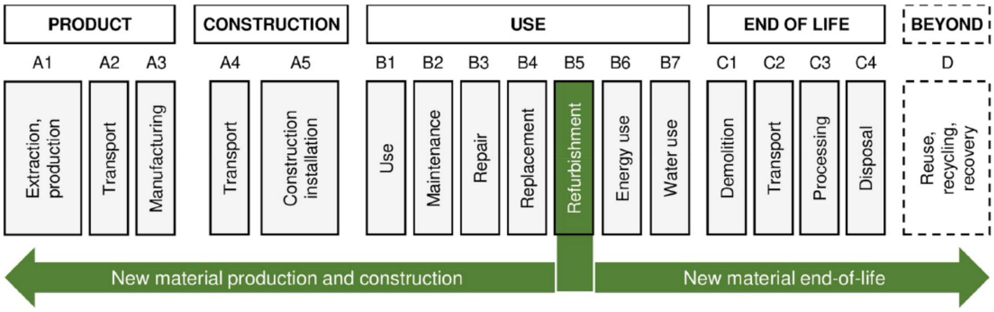


Figure 2.1: Building Life Cycle stages according to EN 15978 (Hasik et al., 2019)

Module B5 consists of the refurbishment stage. The EN 15978 terminates the refurbishment stage as part of the 'use' stage of the building [B1-B7]. According to this standard, the module B5 boundary description includes the following:

A1-A3 Production of new components of the building

A4 Transport of new components (includes lost materials during transport)

A5 Construction and waste management part of the refurbishment process (includes lost materials during refurbishment)

C1-C4 End-of-Life phase of the building components.

Hasik et al. (2019) has emphasized the importance of setting boundaries for the LCA study of a building. This involves determining the included life cycle modules for the existing building and the newly added building components. While for comparative assessment the existing building could be included in its original condition, it is not necessary for a refurbishment. The refurbishment module is separate in the EN 15978 and all the newly added components are counted towards this module. Based on the European committee for standardization, 2021 use stage (Module B) of components that are reused should also be included as impact of refurbishment since the prolonged lifespan could account for additional use, repair, and replacement of components. This is also supported by the research of Hasik et al. (2019) & Vilches et al. (2016). Since the standard and research of Vilches et al. (2016) remain unclear about the exact waste management elements that should be included Hasik et al. (2019) Recommend the inclusion of modules A-C for the newly added components in addition to module B when calculating the impact of refurbishment. The Beyond scope category in Figure 2.1 is shown dotted since the characteristics here compensate for the impact during other life stages. In other words, the positive effects that arise during the life cycle stages are bundled in here, creating a negative environmental impact. The use of a product therefore can have upsides to the environment. For example, when having a high recycling potential or when a product can be reused easily. These positive effect are represented by negative environmental impact values.

The specific process and system boundaries for the LCA refurbishment stage are shown in Figure 2.2, this figure is based on the paper by Hasik et al. (2019) and acknowledged in the research of Kaltenegger (2021).

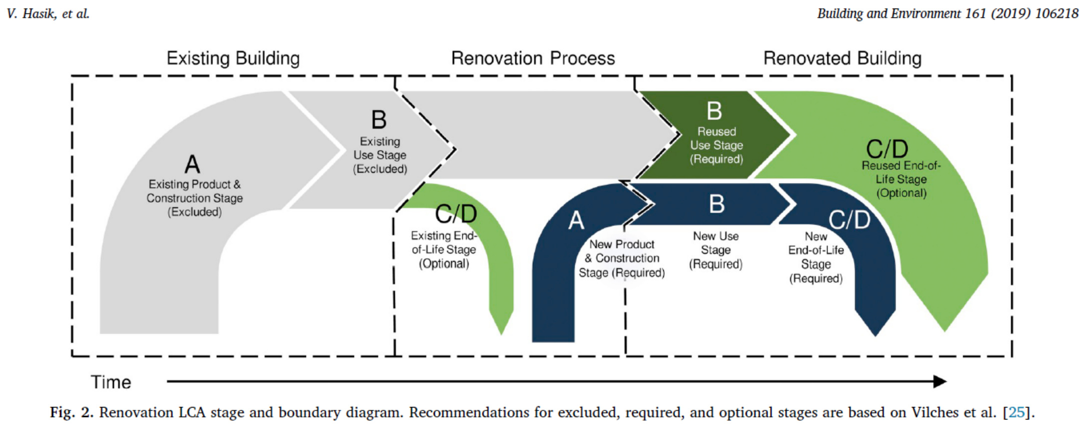


Figure 2.2: Refurbishment LCA stage and boundary diagram (Hasik et al., 2019)

Within Figure 2.2, the starting point is the construction of the existing building as is [A]. Followed by the 'Use' stage [B] after which the end-of-life stage starts for some parts of the building [C/D] that are demolished in the refurbishment process. The refurbishment process is followed by a new 'Use' stage [B]. Simultaneously, the same cycle starts for components that have been newly added to the building and enter their first 'Use' cycle. After which, a new end-of-life stage starts for the components to be refurbished in the building [C/D].

Considering the suggestions of Hasik et al. (2019) inventarisation is needed for the materials or components that are added during the refurbishment process. These materials can either be new or used and to stimulate the usage of new materials, an advantage is necessary when implementing the used materials. The advantage could be the impact related to the remaining life expectancy of the building. This can be achieved by only counting the environmental impact related to the remaining lifespan. This is elaborated in the next section.

2.2.1 Lifespan

The expected lifespan or sometimes called service life, of a building component can vary greatly between the different building shearing layers and individual components. Research of Grant and Ries (2013) already suggested to improve the impact analysis by incorporating the life expectancy of the material. As mentioned above, reuse of material also influences the impact of the building component (Hasik et al., 2019). If reused materials have their impact calculated similarly, that is, if they are newly produced, there is no advantage or stimulation to reuse or refurbish materials in the first place. Hence, it is suggested to recalculate the environmental impact by dividing the total impact of an element by the expected lifespan and multiplying this by the remaining lifespan. This way a stimulant is generated and issues as addressed by Grant and Ries (2013) and Horeni et al. (2014) are resolved. To achieve this, the following equation is proposed:

$$E = \sum_{c} \frac{E_c}{L} \cdot R \tag{2.1}$$

where:
E Represents the impact of a reused material/component
c represents the specific impact category the impact is calculated for material/component
E_c Is the environmental impact for the new implementation of material/component considering impact category $c$resulting from the NMD
L Is the total life expectancy for a material/component resulting from the NMD
R Is the remaining life expectancy for the reused material/component as determined by the assessor

Using the formula shown in Equation 2.1, it is possible to calculate the LCA for a building where materials are reused. This way, decision makers and designers gain a stimulant for the re-usage of existing materials and building components since it reduces the overall environmental impact of a refurbishment process.

2.3 Environmental impact

Increasing awareness about the importance of environmental protection and environmental impacts associated with the manufacturing and consumption of products and services such as the building industry has increased the interest in developing methods to better understand and address these impacts. One of these techniques is life cycle assessment (LCA) (International Organization for Standardization, 2006a). The building sector is becoming more aware of the impact the construction and refurbishment processes have on the environment. It is not only the sector itself, also clients become more aware of their environmental impact hence the importance of keeping track and implement measures reducing this impact in the building process (Gerding et al., 2021). To reduce environmental impact, it is important to quantify the impact of a building/refurbish project, this way it becomes easier to influence the level of environmental impact.

On the material side of the building sector, an effort is being made to close material cycles and reduce waste (Gerding et al., 2021). These are measures to mitigate the environmental impact of building and refurbishment processes. In the research of Gerding et al. (2021) they state that the implementation of circularity faced difficulties due to the lack of awareness, knowledge, and consideration during the life stages of a building, including during the design process. These issues are similar regarding the calculation of environmental impact and further support the need for easy quantification of impacts during building and refurbishment processes.

Besides the influence of design and materials, there is also the influence of energy and water usage. These operational factors highly influence the emissions during the 'use' stage of a building's life span. To reduce emissions during the 'use' stage, environmentalists and the European Union have initiated principles to set the road towards nearly zero energy buildings (nZEB). The goal of this is to identify and eliminate costs and emissions during the stages of a building's life span (Pernetti et al., 2018). In the research results of Pernetti et al. (2018) it is stated that the technologies for nearly zero energy buildings exist and that refurbishment of buildings is key in implementing these technologies. Reduction of energy usage will result in overall emissions and is, therefore, an important factor in the overall environmental impact of a building.

2.3.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is a method to quantify the potential environmental impact of a product or a service (Vilches et al., 2016). This method is currently standardized and defined in ISO 14040:2006 and ISO 14044:2006. Since 1990, several ISO standards regarding LCA have been introduced, adapted, and redacted into these two standards. The ISO 14040 is a general description of LCA and its intended purpose, the ISO 14044 details the requirements for conducting a LCA study. The application of LCA has been vastly growing in the building sector but often to evaluate new buildings. However, comparing the implementation of LCA in the building industry with other sectors. LCA has faced impediments in its adaptation, which according to Oeveren (2020) is because the the design uncertainties, long life span, and large number of different components of a building are difficult to analyze beforehand. The uncertainties within the design are key in developing valid end results. LCA can assist in identifying opportunities to improve the environmental performance of a product life cycle (International Organization for Standardization, 2006a). In the case of this study, the product is a building and the focus of the life cycle is refurbishment.

LCA also helps decision makers during the design process and confines the selection of relevant indicators linked to environmental performance. It also allows for assigning labels and making supported claims for marketing purposes. Within a LCA process, the energy and material flows are quantified and evaluated, it does not only give full insight into the impact of a full building, but also into the impact of the separate materials (Gemert, 2019).

Within LCA studies, environmental impacts are differentiated into impact categories. The European Committee for standardization (2011) provides the base for the 9 impact

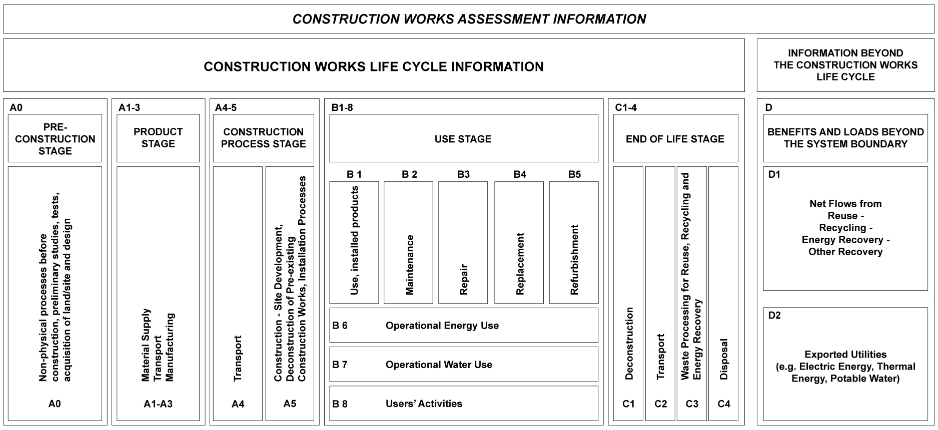


Figure 2.3: Information modules applied in the assessment of environmental performance of a building. (European committee for standardization, 2021)

categories, the research of Ghose et al. (2019) expands on this by splitting the categories of Eco-Toxicity, Human toxicity, and Abiotic depletion. The NMD in the Netherlands includes 11 of these categories, since the NMD is also used by Dutch legislation and in the obtainment of a building permit, this research is confined to the eleven impact categories of the NMD. In Table 2.1 an overview of the impact categories is shown. The NMD does not contain open access data on a element level of building information but does contain data on component level. This allows to quickly calculate a component such as a wall and not have to define information such as the elements (e.g. amount of bricks) that combined form the wall component.

European Committee for standardization (2011)	**Ghose et al. (2019)**	**Stichting Nationale Milieudatabase (n.d.)**
Global Warming Potential	Global Warming Potential	Global Warming Potential
Ozone Depletion Potential	Ozone Depletion Potential	Ozone Depletion Potential
Photo-chemical Oxidation Potential	Photo-chemical Oxidation Potential	Photo-chemical Oxidation Potential
Acidification Potential	Acidification Potential	Acidification Potential
Eutrophication Potential	Eutrophication Potential	Eutrophication Potential
Abiotic depletion	Abiotic Depletion (resources)	Abiotic Depletion (resources)
	Abiotic Depletion (fossil fuels)	Abiotic Depletion (fossil fuels)
Human Toxicity	Human Toxicity carcinogenic	Human toxicity Potential
	Human Toxicity non-carcinogenic	
Aquatic Eco-toxicity	Freshwater Eco-toxicity Potential	Freshwater Aquatic Eco-toxicity Potential
		Marine aquatic Eco-Toxicity potential
Terrestrial Eco-toxicity Potential	Particulate Matter Formation	Terrestrial Eco-toxicity Potential
	Ionizing Radiation	

Table 2.1: Overview impact categories according to various sources

The NMD monetizes the impact categories The NMD expresses the different categories in an equivalent unit. This allows for adding a cost factor to each unit to define the cost of the environmental impact (shadow costs). This monetization technique allows for the calculation of shadow costs (in euros) and is also used in the calculation method of the MPG DGMR, n.d. Gemert, 2019. In Table 2.2 the eleven impact categories that are used further along in this study are shown, as well as their respective abbreviations, units of measure, and cost factors as defined in the NMD.

NMD	**Abbreviation**	**Unit**	**Cost Factor** (E_c)
Global Warming Potential	GWP	kg CO2	0.05
Ozone Depletion Potential	ODP	kg CFK-11	30
Photo-chemical Oxidation Potential	POCP	kg ethylene	2
Acidification Potential	AP	kg SO2	4
Eutrophication Potential	EP	kg PO4	9
Abiotic Depletion (resources)	ADPc	kg antimony	0.16
Abiotic Depletion (fossil fuels)	APDf	kg antimony	0.16
Human toxicity Potential	HTP	kg C6H4Cl2	0.09
Freshwater Aquatic Eco-Toxicity potential	FAETP	kg C6H4Cl2	0.03
Marine aquatic Eco-Toxicity potential	MAETP	kg C6H4C12	0.0001
Terrestrial Eco-Toxicity potential	TETP	kg C6H4Cl2	0.06

Table 2.2: Overview NMD impact categories with their respective Unit

While LCA is very accurate and in depth, the method requires a lot of information up front and it can be very labour intensive. There is a high level of expertise required for an extensive analysis, and LCA operates in a broad range of environmental impact categories. This is especially the case for building materials embodied impact. Resulting in LCA studies mostly being conducted after the construction of a building (Gemert, 2019). Effort for the development of early decision support methods has been made in the research of Hasik et al. (2019), Olsson et al. (2016), and Verberne (2016) but, there is no link to a graphical interface or automated building data. A gap remains between calculation frameworks that utilize environmental databases and the implementation of building model data with graphical representations.

2.4 LCA tools

In the previous section, the methodology of LCA is discussed. While the method is in depth, requires a lot of upfront information, and depends on expert input, there are efforts made to enhance the process of conducting LCA studies by developing methodology and tooling.

Within the existing LCA tools, two types are distinguished. Graphical tools that have a visual representation of the building and non-graphical tools which do not provide a direct visual representation of the building. The first often uses Building information models (3D) as input, while the latter consists of Excel spreadsheets or software tools that use numerical input by the user. A non-exhaustive list of LCA tools can be found in Table 2.3.

The Dutch government has provided the Milieu Prestatie Gebouwen (MPG) as a public available tool to calculate the environmental impact on five different levels. It uses environmental data from the National Milieu Database (NMD), which contains the environmental product declarations (EPD) of building products that are used in the Netherlands. This tool is considered a non-graphical instrument. It also does not have a direct link with a BIM model and thus relies on manual input in a spreadsheet environment, which has been indicated as a risk for accuracy and dependent on the expertise of assessors (Kaltenegger, 2021).

Additionally, the Dutch building sector uses the Gemeentelijke Praktijk Regels (GPR) and BREEAM as non-graphical tools for LCA analysis. These tools are not required by the building decree, but these tools can be imposed by municipalities or the client. The research of Kaltenegger (2021) identifies the GPR tool as relatively easy to setup because it contains the eleven impact categories. It is also acknowledged that the high level of assessment expertise forms a disadvantage for the accessibility in the early design stages.

Graphical LCA tools have been developed over the past years. Examples of these can be found in Table 2.3. Within these graphical LCA tools, it is possible to distinguish plug-ins and stand-alone tools. The plug-ins depend on BIM software (e.g., Autodesk Revit, Trimble Tekla, Archicad) to retrieve the information. Stand alone software can be in the form of a web tool or a software package. In Table 2.3 a overview of tools and software types is shown.

Tool Name	***Knowledge level***	***Database***	***Type***
Non-Graphical	GPR	Nationale Milieu Database (NMD)	Webtool
	MPG calc	NMD	Standalone Windows tool
	BREEAM-NL	NMD	Webtool, Spreadsheet
Graphical	One-Click LCA	NMD, Ecoinvent	Webbased non-graphical, Plugin graphical
	Tally	Ecoinvent	Revit Plugin
	H\B:ERT	ICE Database	Revit Plugin

Table 2.3: LCA tools, *(References can be found in the Bibliography)*

In Table 2.3 the relevant LCA tools are mentioned. The list consists of both graphical and non-graphical LCA tools with the aim of analysis in the build environment. The tools enable users to gain insight into the impact of a building/refurbishment project. General LCA tools that operate on the component level have been left out of the list. It is also indicated on which platform type the LCA tool operates on. Interestingly, there are no stand-alone graphical tools available. All graphical tools identified work on a plugin-basis in a specific type of software, which could pose a challenge when building data is combined from different software packages. Otherwise, the tools all use external material databases and in the case of One-Click LCA, it is even possible to select a different database. Most of the tools such as GPR, MPG and BREEAM-NL use the Dutch NMD which is probably because the tools are developed with the Dutch building sector as intent.

2.5 Building Information Modelling

Building Information Models (BIM) contain all the information required to realize the concept of a building or refurbishment project. In the past drawings consisted of only line-based geometry drawn by hand or with the use of Computer Aided Design (CAD) tools. The line-based CAD geometry has been expand by adding more information to the geometry. This evolution results in BIM, BIM makes use of object-based geometry, stimulating the accessibility and operability of semantic data and allowing for a digital visualisation of the building model (Oeveren, 2020). BIM is becoming more extensively implemented in the Architecture, Engineering and Construction (AEC) industry. The object-based 3D geometry of BIM allows users to, for example: conduct clash detection, create 3D visualisation, cost estimation, and conduct structural calculations. The efficiency and exact use of the vast possibilities differ per user and grow with the development of BIM tools. The objects that are contained within a BIM model allow for the extraction of information such as but not only: quantity, dimensions, material type, color, structurality, insulation level.

2.6 Level Of Development

With the aim of integrating LCA and BIM, the two most important requirements for the BIM input data are firstly obtainable quantities and secondly identifiable objects. Obtainable quantities are necessary to conduct the calculation and determine the environmental impact. While the identification of the object enables the process of assigning material data to the quantities. The importance of this information is also addressed in the research of Gemert (2019), Kaltenegger (2021), and Oeveren (2020). IFC schemas contain 'property sets' which are used to store quantity information while the object information is handled by the 'IfcClassification' class.

The presence of this information can be classified by determining the level of development (LOD) for the BIM model. The LOD, is considered to be key by Gemert (2019) for the application of BIM-based LCA. The different levels of development are illustrated in Figure 2.4. It is important to note that the level of development is not the same as the level of detail. The latter determines how detailed the geometry of an building element is within the BIM model, but it does not indicate the detail of information about the element. The level of information (LOI) indicates the scope of information that is contained for an element. The Level of Development combines these two detail levels and is a overall indicator for both geometrical detail levels and information detail levels. The LOD during the design process can differ between building elements, therefore it is not definitive that a BIM model has a specific LOD. The accuracy and possibilities of the LCA depend directly on the LOD (Gemert, 2019; Kaltenegger, 2021; Oeveren, 2020). The research of Kaltenegger (2021) considers an input LOD of 300 as a minimum for considering LCA calculation.

While a minimum LOD of 300 is expected to contain sufficient information to conduct a LCA analysis impact. This thesis aims to allow flexibility on a component level in which it is preferred to zoom in on specific components while not requiring the whole input model to be at a specific LOD. On a component level, the LOD of the component does have a direct effect on the accuracy of the environmental assessment or LCA.

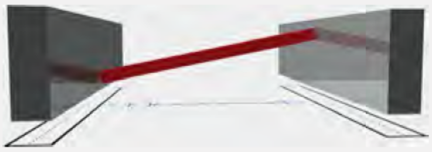
Level		Description
LOD 100		2D detail annotating a structural kicker between two beams
LOD 200		3D model showing an angled kicker with general size/shape/location
LOD 300		3D model showing a 4×4-inch angle kicker with specific size/shape/location
LOD 350		3D model showing a 4×4×1/4-inch angle kicker with the actual size/shape/location
LOD 400		As 350, plus special mounting and fabrication details

Figure 2.4: Levels of development in BIM models. (Hardin & McCool, 2015)

2.7 Connecting BIM and LCA

In the past, efforts have been made to intertwine the conduction of LCA studies with the BIM model as an input. Kaltenegger (2021) has developed the ROTUNDORO tool that helps users to gain insight into the environmental and economic aspects of different refurbishment packages on housing. Similarly Gemert (2019) has developed MPG-ENVIE, a BIM-based LCA tool that allows for embodied impact assessment in early design stages. And Oeveren (2020) developed LEICAS, a tool for Life Cycle Environmental Impact and Costing Assessment. This utilizes costing information to also give insight in the financial aspect. While LEICAS does not depend on specific measure packages or building type. It does focus on new to build real-estate, since the nature of refurbishment process there is a bad fit for calculating emissions in refurbishment projects. In Table 2.4 the three different tools are compared. Similarly, they all use the NMD as the main database for environmental data. While ROTUNDORO from Kaltenegger (2021) is focused on existing environment, the implementations from Gemert (2019) and Oeveren (2020) aim at addressing the early phases of the design process in new-to-be-built real estate.

Another shift identified is from stand-alone tools to web apps, which is indicated by the more recent work from Kaltenegger (2021), which developed a cloud-based tool rather than depending on local instances. ROTUNDORO is also proposed as a tool that used ready-to–to-implement packages, which is designed for a specific type of building. With the large differences of refurbishment scope in office buildings, it is not possible to define a specific package of measures to improve the building. Furthermore, ROTUNDORO focuses on reducing energy and thus emissions. The aim of this research is to give insight into the emissions of tailored refurbishment measures for office buildings.

	ROTUNDORO	***MPG-ENVIE***	***LEICAS***
Focus	Existing housing	Early design phases new developments	New developments (apartments)
Database	NMD	NMD	NMD, costs database
Measure packages	Specific measure packages	No specific packages	No specific packages
Input model	.IFC	.IFC	.IFC
3D visualisation	Yes	Yes, color coding by impact	Yes
Tool Type	Web-App (React)	Local package (Python)	Local package (Python)
Author	Kaltenegger (2021)	Gemert (2019)	Oeveren (2020)

Table 2.4: Research into BIM and LCA integrated tools, *(References can be found in the Bibliography)*

2.8 Conclusion

This chapter discusses refurbishment, multi-criteria decision making and Life Cycle Assessment. Refurbishment is considered as part of the buildings life cycle in which the building is repaired and improved for the future.

The choices made in a refurbishment process are the result of a set of choices and it is not always clear what the reasoning is that has resulted in certain decision. With the requirements for sustainable renovation and lower energy consumption the reasoning behind design choices becomes more important. Experts tasked with making the design choices have to analyse multiple criteria for different scenarios to find the optimal result. The scenarios form a discrete choice for the decision maker which can be analysed by using MCDM methods such as AHP. While AHP can analyse the result and give insight into the reasoning behind decision preferences, critique is given on the quantification of the importance levels of attributes with AHP.

This chapter also discusses the necessity of Life Cycle Assessment and the hurdles of the required information and expertise required for conducting such an analysis. Relevant available tools depend heavily on manual user input and lack graphical feedback. There is a missing link between the BIM model and the LCA analysis. It is therefore hard to conduct an environmental assessment of a refurbishment project and gain insight into the impact generated by refurbishment works. Nevertheless, it is also identified that information of material impact is available in various material databases and with the right input and expertise it is possible to conduct life cycle studies on a building project. However, current methods have not suggested how re-usage of materials can be accounted for in refurbishment projects. Therefore, the implementation of Equation 2.1 is suggested, as well as the ability to conduct an analysis on a specific set of building components.

The aim is therefore to improve the graphical representation during the conduction of an LCA study and increase the link with building data on a component level. Furthermore, the outlook is to decrease the dependency of methods on dedicated software by having a web-based open standard approach. The next chapter will first zoom into the decisions leading to the plans for refurbishments works. This is followed by Chapter 5 where the outline of the tool is proposed and further developed into a standalone LCA solution to analyse the impact of refurbishment works. The next chapter will first zoom into the decisions leading to the plans for refurbishments works.

Chapter 3

Methodology

3.1 Research design

This research is divided into five different stages as shown in figure 3.1.

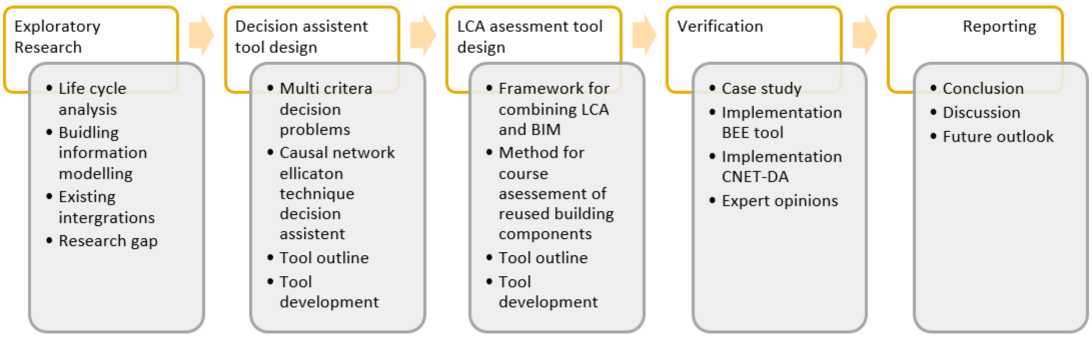


Figure 3.1: Research design stages

3.1.1 Exploratory Research

In the exploratory stage of the research, the literature is discussed to gather data regarding refurbishment and the three main topics within this research; BIM, LCA, and MCDA. This is conducted in the previous chapter. The literature discusses the refurbishment process and issues the current situation and indicates the limitations that require additional focus. It also discusses existing, likewise implementations of BIM, LCA, and MCDA in the field of architecture, engineering and construction (AEC). The overall guidance for this exploratory phase are the research questions mentioned in Section 1.4.1. In this exploratory phase, a methodology is proposed that can be used to calculate the environmental impact of reused building materials without conducting a full life cycle assessment, which is a key factor in stimulating the consideration of re-purposing existing building components. The identified research gaps and limitations in the literature form the base for the next two phases in which methodology and tooling are proposed to fill the gaps.

3.1.2 Decision assistant tool design

Within this stage, the decision problems within the building refurbishment process are discussed. An outline of the existing field is sketched and the limitations of current Multi Criteria Decision Analysis (MCDA) is identified. The Causal Network Elicitation Technique Decision Assistant (CNET-DA) is introduced as a methodology for decision problems in the refurbishment process. To implement CNET-DA, a methodology is framed and an application is designed to mitigate time-intensive interview method of traditional CNET. The designed application is later implemented in the verification stage.

3.1.3 LCA assessment tool design

The LCA assessment tool design stage entails the development process of BEE, a tool that allows users to quantify the environmental impact of building elements in the refurbishment process. The tool incorporates information from a Building Information Model (BIM) as well as environmental data from the Dutch National Environmental Database. It also allows users to easily estimate the environmental impact of reused materials using a life expectancy estimate. The tool is developed in Angular JS, a framework for developing web applications, which is identified to be a cross-platform future proof solution. Information regarding environmental data is stored using MongoDB, a cloud-based database solution which possesses future proofing advantages over traditional SQL solutions. The tool is able to work with building information models stored in the IFC data format, which has been a standard exchange format in the AEC industry. In the verification stage, the application is implemented in a case study to evaluate the results.

3.1.4 Verification

In the verification stage, a case study is conducted to bridge the identified gap in the refurbishment process by using the proposed methodology and the application of CNET-DA and BEE. A refurbishment project of ABN AMRO in Diemen, the Netherlands, has been chosen as the case for implementation. The project is suitable since it regards the refurbishment of an office location and the stakeholders have high requirements regarding sustainability and circularity. Verification of the design choices is conducted by interviewing experts and decision makers of this particular project and analysing the design choices using the CNET-DA tool. Besides evaluating the design choices of the project, interviewees are also asked to reflect on the CNET-DA methodology and tools to evaluate the implementation in the refurbishment process. Furthermore, BEE is tested using the BIM model of the ABN AMRO office refurbishment process and the possible implementation is tested and evaluated using expert opinions. The implementation of BEE shows the environmental impact generated by the design choices that are supported and identified using the CNET-DA tool.

3.1.5 Reporting

The reporting stage entails the conclusion, discussion, and future outlook. The research questions (see Section 1.4.1) are answered and the results of the case study are summarised. In the discussion, the research and its limitations are discussed, after which the future outlook gives recommendations for further research and suggests the possibilities of the proposed tools.

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Chapter 4

Decision Making

4.1 Study method

A building design is a result of a set of choices, but the reasoning behind these choices is not always clear. Within sustainable refurbishment, it is required to tailor materials and energy consumption during the design process by making choices on refurbishment measures. These decisions are made based on the visions of the experts working on the refurbishment project (Gohardani & Bjork, 2012). The choices experts are facing require extensive analysis of multiple criteria and often multiple criteria are hard to quantify.

4.1.1 Discrete choice problem

When refurbishing buildings, there is a given set of refurbishment measures (alternatives) for real estate owners/managers to choose from. A simple example is the choice of insulation, owners can choose to improve the insulation or not improve the insulation of a facade. This results in a discrete choice decision problem for refurbishment measures. Because of the nature of the choice problem and the subjective aspects, it depends on quantitative and qualitative inputs. To enable the finding of solutions, an individual facing a decision problem needs a mental representation (MR) of a decision problem that elucidates the variables evaluating the choice alternatives (Arentze et al., 2008). The MR will help decision makers evaluate their available actions and oversee the potential consequences of deliberate decision making (Craik, 1952). Understanding the MR is not only important for the decision makers themselves but also for advising parties supporting decision makers since they are key drivers in providing alternatives. With the understanding of the MR, the alternatives can be tailored to suit the decision maker better.

4.1.2 Decision maker

This research focuses on the client side of the refurbishment process. Therefore, important decision makers are considered real estate owners or managers. These people are not by definition experts on sustainability and circularity, but they are key figures in the decision making process. These decision makers are often supported by advisory parties and experts. As mentioned earlier, research has shown that decision makers have a high experience level. However, decision makers are still in need of tools to support. Therefore, a MCDM tool is relevant since they support decision makers in creating their decisions.

4.1.3 CNET-DA

The Causal Network Elicitation Technique Decision Assistant (CNET-DA) is a semi-structured interview method to measure the components of mental representation of choice tasks. CNET-DA can be used to analyze and identify the preferences of decision makers. The interview method reveals the Decision Network (DN) and is an extension of the Bayesian Belief Network (which is a causal network). CNET-DA is considered a multi criteria decision making assistant (Arentze, 2016). The CNET-DA method assigns a utility to the different choice options (alternatives) which is a combination between the expected gain and expected costs (Dellaert et al., 2017). The higher the utility, the better the alternative suits the interviewee.

CNET-DA is an extension of a method earlier used in consumer preference research, the Causal Network Elicitation Technique (CNET). It is based on the multi-attribute utility theory which is a trajectory within the methods of MCDM. CNET-DA is suggested as an alternative to the AHP method. The framework in which CNET-DA operates uses the multi-attribute utility framework and extends on this considering the addition of the attribute-benefit link that is added.

In contrast to methods such as stated choice in which an interviewee chooses directly between different alternatives, CNET-DA focuses on what the interviewee finds important (attributes), how important that attribute is, and calculates the utility without directly asking the interviewee to make a choice between the alternatives.

As mentioned earlier, AHP has already been successfully implemented in decision support systems (Banai-Kashani, 1989; Cheng et al., 2002; Lin et al., 2015). Also the risk of evaluation ranking is addressed. This is where CNET-DA stands out. CNET-DA asks the decision maker to rank the attributes of an alternative set relative to each other. This means that in the interpretation phase of the data there is no direct influence on the relative importance of attributes. While the absolute relative importance is not directly influenced, normalisation of values does occur during the post-processing. Arentze (2016) writes that one of the attribute benefit links should be set to 1 and the others are relative to that scale. This could mean that some utilities end up in negative values, while the absolute difference stays equal, the utility values differ. To normalize the scale a reference has to be chosen to establish a basis, it is proposed to use the maximum method in which the most important attribute is always scaled to 1 ensuring the utility results have an established reference.

The CNET-DA decision assistant as described by Arentze (2016) has not knowingly been implemented before in the context of decision making for real estate refurbishment decisions. In addition, the software for executing the CNET-DA method has not been written before. Therefore, this research explores a new angle in the area of multi criteria decision making.

Traditionally, CNET is a very time-consuming method for researches since interviewees need to be trained, locations need to be organized, and the data collected cannot be directly be processed electronically and thus needs to be coded by hand. This large consumption of time is costly and thus large-scale applications of CNET are unthinkable. Face-to-face interviews pose a risk for influencing interviewees (Horeni et al., 2014). While CNET-DA requires less labour since the sample size is smaller, it still for the same reasons as CNET, an inconvenient method when conducted by hand.

The trajectory of a traditional CNET interview is shown in figure 4.1. This trajectory is similar to the method used for CNET-DA. The start is with an introduction of the problem and instructions on the interview (1). This is followed by the ranking of decision variables for all alternatives in the order the respondent prefers them (2). The other parts of the interview consist of defining the rank order for the different decision alternatives. This start with open-ended questions and thus this part of the MR depends on the spontaneous recall of the respondent (Horeni et al., 2014). The first question is what their considerations are when deciding between the alternatives (3). This also forms the start point for the interpretation and structuring part of the first responses (4). Furthermore the respondent is asked to assign benefits to the different variables (5). The benefits are abstract concepts that cannot be measured in a physical way. They rather conceptualize a persons needs regarding the decisions (e.g. feelings of safety, pleasure). (Horeni et al., 2014). This is followed by identifying the relative importance of the attribute-benefit links. When the whole procedure is finished, a summary is presented (6), where the utilities of the alternatives are calculated, besides the relative importance of the different aspects are shown. Enabling the user to make a considered decision (7). Horeni et al. (2014) compares the CNET method with the Hard Laddering (HL) technique but also emphasizes that the mayor difference is that HL expects similar MR between individuals across choice problems but CNET does not. Therefore, they found HL an insensitive method for measuring MR. Yet, the HL method does force the interviewee to indicate attributes directly, what is not the case in CNET.

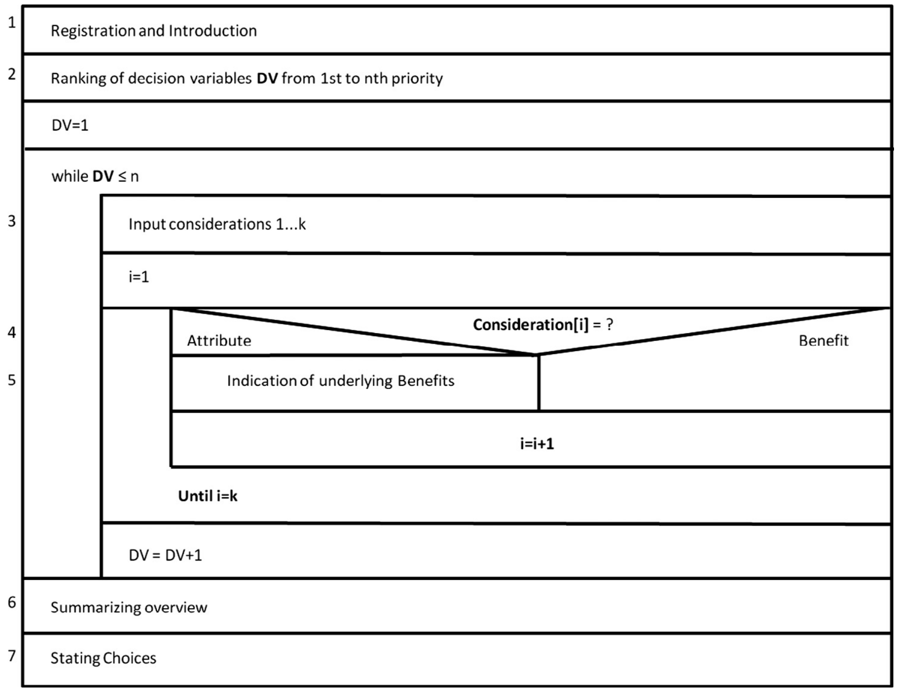

Figure 4.1: Nassi-Shneiderman-diagram for the CNET interview protocol. (Horeni et al., 2014)

To mitigate the time-intensive interview method, this research uses a digital version of the CNET decision making assistant (CNET-DA). This digital version is built using the described steps from Arentze (2016). The CNET-DA software is developed for the interviews that are conducted in this research, nevertheless the setup is generic and can be used for any decision problem with multiple alternatives.

4.1.4 Utility calculation

The CNET-DA helps the user make decisions by quantifying the utility of the different alternatives. The utility is a function determined by the strength and weight of the 'benefits' that are assigned to the alternatives. The links in Figure 3.2 represent all different links for which the individual strength, between the attribute and benefit, is calculated. This has as an advantage that it is not only possible to identify the best alternative (highest utility) but also determine the key benefit that drives this high utility.

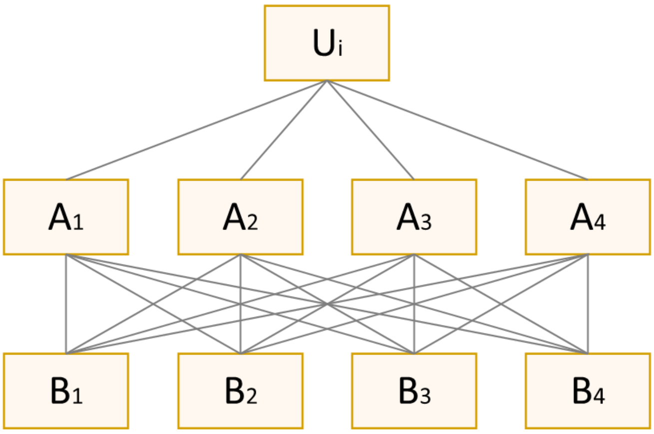

Figure 4.2: CNET-DA relationship diagram

This results in a formula for the utility Arentze (2016). The equation is the product of the relative weight as assessed by the decision maker (respondent) and the preference values determined by the decision maker for every link that is identified between an attribute and benefit:

$$U_i = \sum_{j=1}^{J} \sum_{k=1}^{K} I_{jk} \cdot W_{jk} \cdot R_{ijk} \tag{4.1}$$

where:
U_i Represents the utility of alternative i
I_{jk} Indicates in binary if there is a link between attribute j and benefit k ($I_{jk} = 1$) or no link ($I_{jk} = 0$)
W_{jk} Is the weight assigned to the consideration of attribute j for benefit k
R_{ijk} Is the preference value for alternative i regarding attribute j for benefit k

The values for the variables included in the formula are the result of the assessment by the user of CNET-DA. This starts with the preference values for R_{ijk} defined by the user in Step 2. It is possible that there is no link between an attribute or benefit according to the assessment of the user, this results automatically in a value of 0. Next, for the considerations where a link does exist, indicated by variable I, the weight W_{jk} is determined by the user in Step 3. This is done by stretching or shrinking a scale line. The scales are relative to each other with the longest scale having the value set to 1. The scales of the others are relative to this, which means if a scale half the length compared to the longest scale, it will have a value of 0.5.

$$W_{jk} = 1 \text{ For } jk \text{ on the longest scale (stretched) by the user.} \tag{4.2}$$

Fundamentally, W_{jk} can be decomposed into the product of s_{jk} and a_{jk};

$$W_{jk} = s_{jk} \cdot a_k \tag{4.3}$$

where:
s_{jk} Represents the strength of the link between attribute j and k
a_k Indicates the importance of benefit k

This decomposition of Equation 4.2 found in the work of Arentze (2016) explains why the different considerations involving the same benefit can have different weights. The weight difference is the result in a difference of the strength of the influence of the attribute benefit path (Arentze, 2016).

Comparing the weights of considerations related to the same benefit will result in the strength value for the attribute-benefit link. The strength values are defined by setting the sum of the strength values of the attribute paths leading to the same benefit to 1. Hence, the following equation (Arentze, 2016):

$$\sum_{j \in A_k} s_{jk} = 1 \text{ for each } k \tag{4.4}$$

where:
A_k Represents the set of attributes that has a path to benefit k. Evidently, in the case of only one path between attribute j and benefit k the strength is by definition equal to 1.

To calculate the values of S_{jk} the work of Arentze (2016) describes a multi step process in which one arbitrary attribute path is set to 1 in order to calculate the weight of the benefit which is then equal to the weight of the consideration. Using this, the alpha value can be calculated and the other strength values can be determined using the alpha value. Finally each strength value is divided by the sum of strength values to meet the constraint of Equation 4.4.

The steps in the work of Arentze (2016) can be derived into one single formula simplifying the calculation of S_{jk}. This is shown in Equation 4.5, the advantage of this equation is it is independent of the calculation of the alpha values and it can be directly conducted with the by the user determined values for W_{jk}.

$$s_{jk} = W_{jk} \cdot \frac{\sum_j s_{jk}}{\sum_j W_{jk}} \tag{4.5}$$

where:
s_{jk} Represents the strength of the link between attribute j and k
W_{jk} Is the weight assigned to the consideration of attribute j for benefit k

Which can be further derived into Equation 4.6 since the boundary condition of $\sum sjk$ is equal to 1 as stated in Equation 4.4.

$$s_{jk} = \frac{W_{jk}}{\sum_j W_{jk}} \tag{4.6}$$

where:
s_{jk} Represents the strength of the link between attribute j and k
W_{jk} Is the weight assigned to the consideration of attribute j for benefit k

To calculate the weight of the benefits (a_k) the equations above can be derived into the following equation:

$$a_k = \frac{\sum_j W_{jk}}{\sum_j s_{jk}} \tag{4.7}$$

where:
a_k Indicates the importance of benefit k
s_{jk} Represents the strength of the link between attribute j and k
W_{jk} Is the weight assigned to the consideration of attribute j for benefit k

Since the boundary condition of $\sum s_{jk}$ is equal to 1 as stated in Equation 4.4. Equation 4.7 can essentially be derived into the following:

$$a_k = \sum_j W_{jk} \tag{4.8}$$

where:
a_k Indicates the importance of benefit k
W_{jk} Is the weight assigned to the consideration of attribute j for benefit k

In the next section, the software is described that utilizes these formulas to generate a digital version of the CNET-DA method.

4.2 Software

Since there is no software ready to use for the CNET Decision Assistant, this has been developed for this research. This has been done according to the description by Arentze (2016). The software tool is written in Angular which is a platform to create web-based applications that are cross platform supported. Angular has been chosen to create an easy to maintain and develop future proof application and it requires a basic knowledge of programming to use. Complicated elements such as sliders and markups are predefined and only have to be imported.

The software consists of a 6 step web interface. A user either starts with a blank template or with a predefined decision problem. It is also possible to load a response that has been saved before to continue filling it in (Figure 4.3). Saving happens every time a user continues to the next step.

The decision problem and explanation of each step are defined in separate text files. This enables other users without programming skills to alter the tool to their needs. The resulting utility scores, preference values, importance weights and, link strengths are available in .CSV format to allow processing in other applications.

When a user has started or opened a decision problem, they are prompted to fill in some general respondent details. This is shown in figure 4.4, the screen also shows a general description and has room for some explanation about the tool. Furthermore, different choice alternatives are visible or can be filled in.

The second screen asks the respondent to rate the alternatives with different attributes, it also enables the respondent to add more attributes that are relevant. This evaluation table is shown in figure 4.5. The rating is from '–' worst to '++' best (–, -, 0, +, ++).

Thirdly, the respondent is asked to select the benefits that are relevant to each of the different attributes (Figure 4.6). Besides linking attributes to benefits, here is also an open-ended question to fill in why the respondent finds an attribute of importance.

The fourth step is the rating of the attribute-benefit links on a multi-point scale to the different alternatives. The start division of the alternatives on this scale is based on the input of the second screen. The multi-point scale is dimensionless with the purpose to not bias the respondent. For each attribute-benefit link, the user is asked to rate the alternatives on this multi-point scale in terms of preference value. This step is shown in figure 4.7.

The fifth steps consist of rating the attribute benefit links on relative importance, this is again on a dimensionless scale to not bias the user and done for each attribute benefit link (figure 4.8). After the importance is set by the interviewee, the software automatically detects which attribute benefit link is set the highest. This is then set to 1 (maximization technique), the scales of the other attribute benefit link's are set relative to the other scale.

The sixth and last page shows the resulting utility of the decision alternatives. See figure 4.9. It also shows the strength of the attribute benefit links and allows the user to review the individual importance weights. For further analysis, there is a drop down that shows the detailed calculation of each utility (figure 4.10).

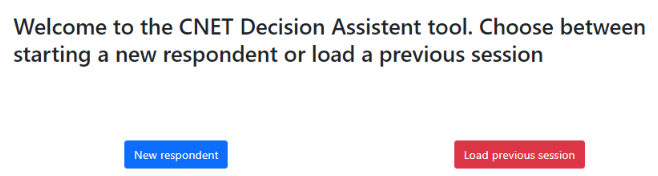

Figure 4.3: Start screen CNET-DA tool.

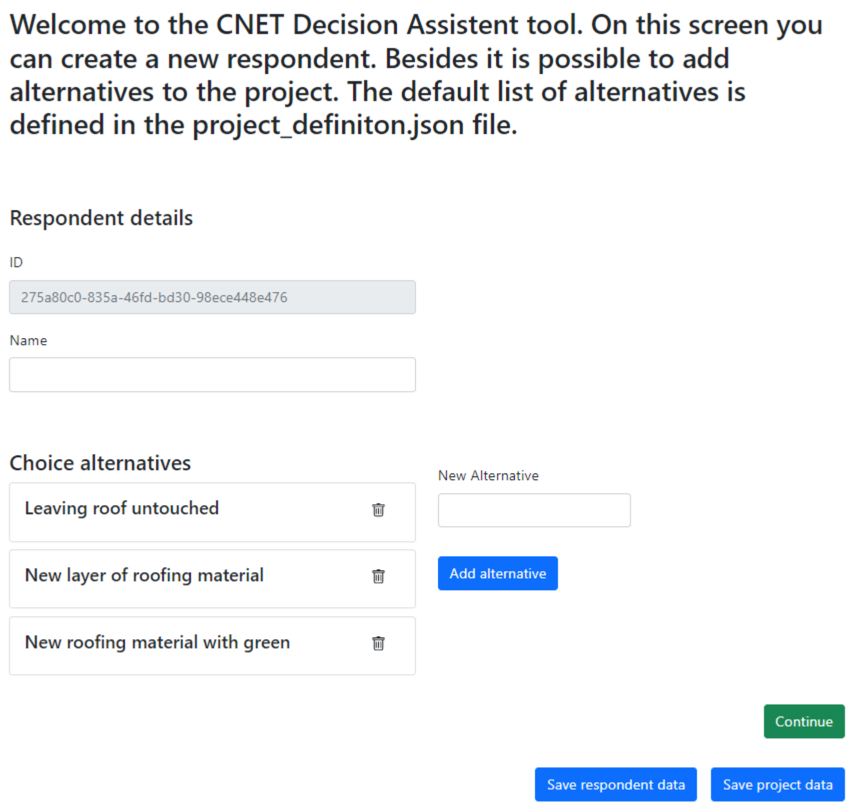

Figure 4.4: Step 1 CNET-DA tool.

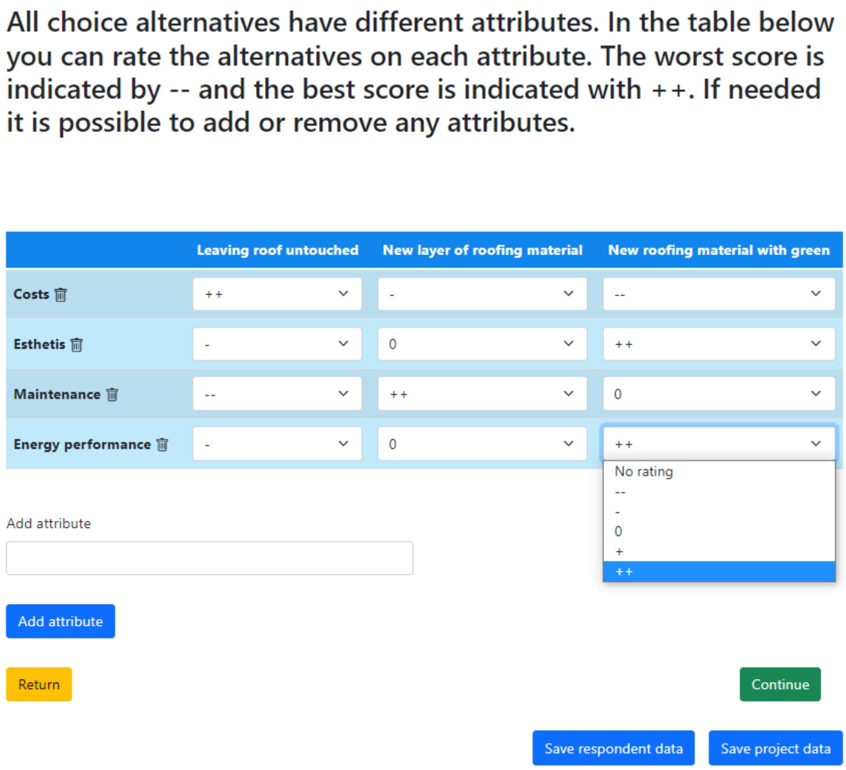

Figure 4.5: Step 2 CNET-DA tool, evaluation table

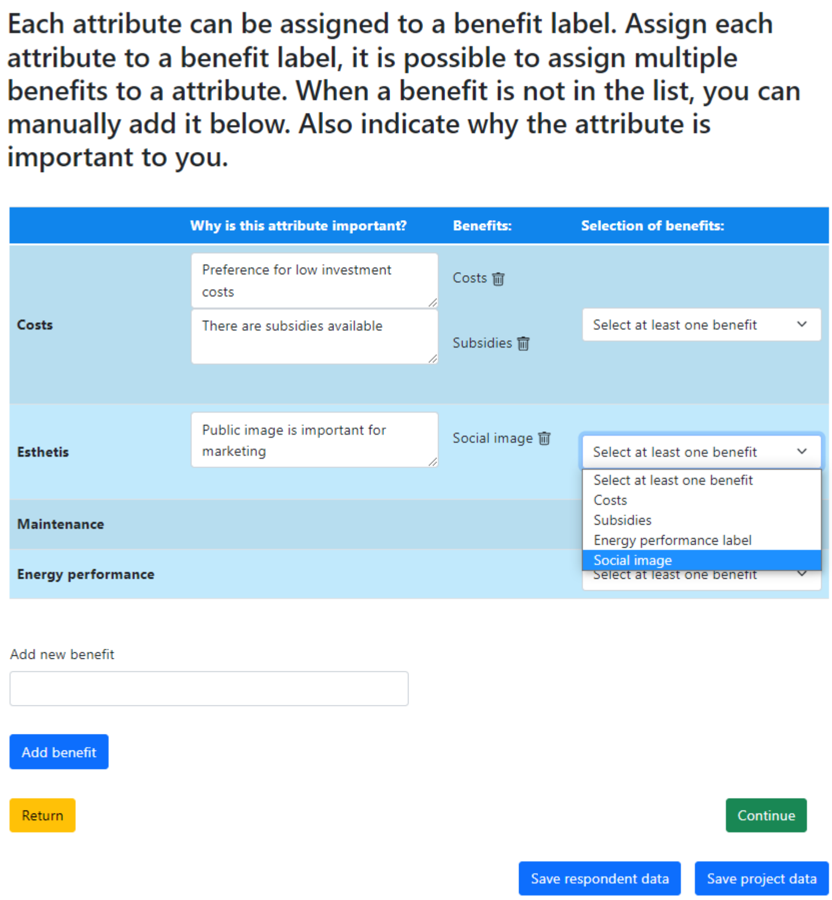

Figure 4.6: Step 3 CNET-DA tool, Attribute-benefit links table

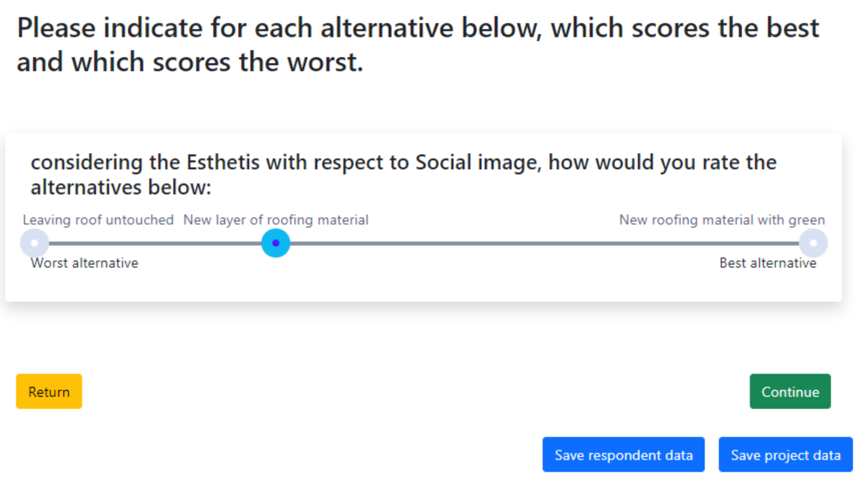

Figure 4.7: Step 4 CNET-DA tool, multi-point scale ranking

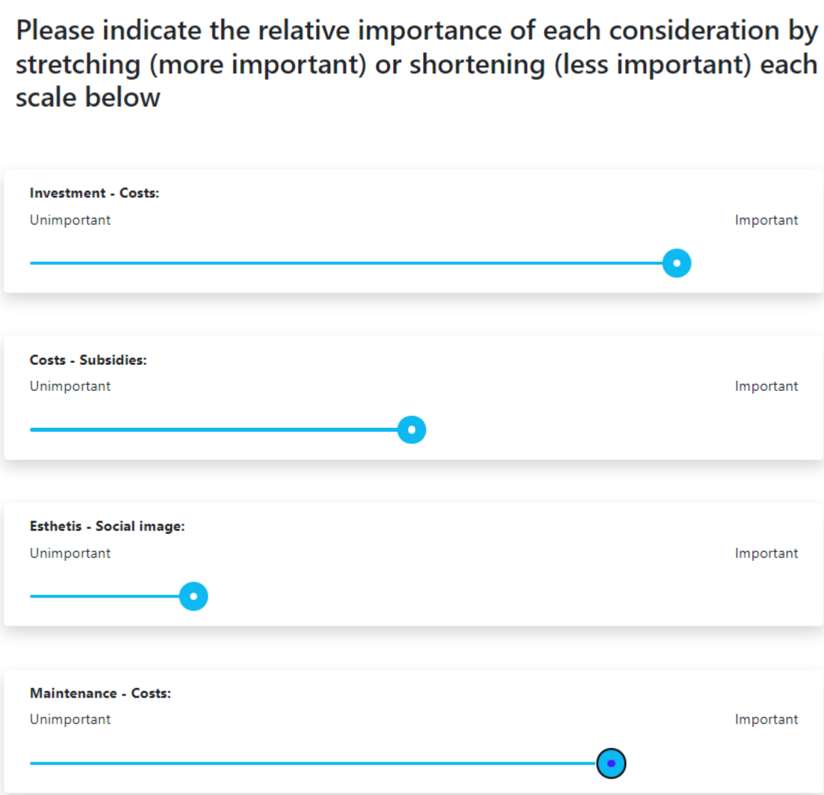

Figure 4.8: Step 5 CNET-DA tool, assessing importance weights

The utility below indicates which alternative scores best. The highest value is therefore the best alternative.

Utility by alternative

Placing a green roof:	4.67
Install new roofing:	1.36
No measures on the roof:	1

Attribute - benefit link strengths table

Service Interval - Total Cost	0.28
Maintenance Interval - Process Disruption	1
Investment Cost - Total Cost	0.55
Appearance - Social image	1
Appearance - Employee productivity	1
Heat protection - Climate adaptation	0.21
Heat protection - Energy consumption	0.47
Heat Resistant - Ecological Footprint	0.56
Water buffer - Climate adaptation	0.79
Energy performance - Energy consumption	0.53
Energy Performance - Total Cost	0.17
Energy Performance - Ecological Footprint	0.44

Alpha

Total costs	1.81
Proceshinder	0.5
social image	0.74
Employee productivity	0.26
Climate adaptation	1.27
Energy consumption	0.75
Ecological footprint	0.68

Relative weight (R)

	Service Interval Total Cost	Maintenance interval Process nuisance	Investment costs Total costs	Appearance Social image	Appearance Employee productivity	Heat protection Climate adaptation	Heat rejection Energy consumption	Heat rejection Ecological footprint	Water buffer Climate adaptation	Energy performance Energy consumption	Energy performance Total costs	Energy performance Ecological footprint
No measures on the roof	0	0	1	0	0	0	0	0	0	0	0	0
Install new roofing	0.5	0.5	0.56	0.02	0.02	0.06	0.06	0.16	0	0.18	0.18	0.19
Placing a green roof	1	1	0.46	0.92	0.92	1	1	1	1	0.35	0.35	0.15
Placing solar panels	0.33	0.33	0	1	1	0.28	0.28	0.45	0	1	1	1

Detailed calculation∨

Go back

Saving Respondent Data Saving project data

Figure 4.9: Step 6 CNET-DA tool, Evaluation results

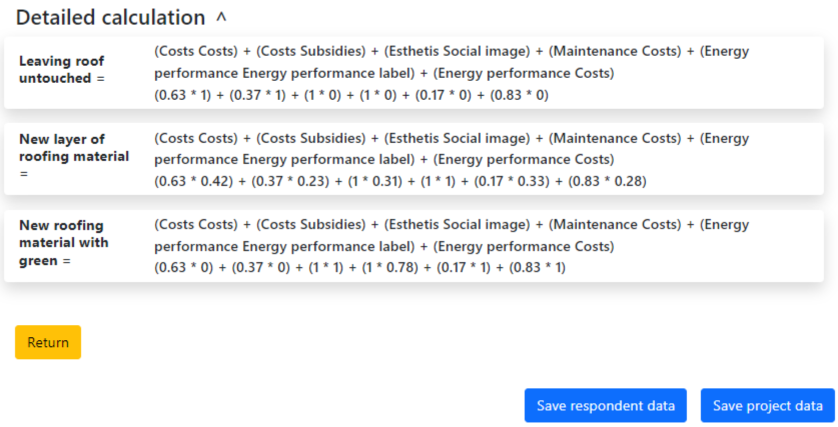

Figure 4.10: CNET-DA tool, detailed utility calculation drop down

4.3 Decision problems in building refurbishment

To implement the CNET-DA tool in a building or refurbishment process, it is important to identify the alternatives from which a decision maker tries to choose.
A building can be subdivided in different layers. Each of these shearing layers has a different life expectancy. There are long-lived layers (site, structure, skin) and short-lived layers (services, space plan, stuff) (Brand, 1994). This concept of thinking in shearing layers divides the refurbishment process, a building's structure can be fine and left alone while the refurbishment of short-lived layers such as stuff may need renewal. Thus, not all layers have to be considered in a given refurbishment project. Because every refurbishment project is unique by nature, the decisions for refurbishment work and scope are also unique. By limiting the scope of decision questions to the layer they are on (based on life expectancy), the refurbishment project is split in six different layers of Brand (1994). Another advantage of the division in layers is the difference in responsible decision makers between the layers. In the case of a tenant, depending on the lease agreement, some layers may be the responsibility of building owners, while others are the tenants responsibility.

While the building's site is considered eternal. One could argue that it can have an important role in the context of movable or temporary buildings. The site can be improved but that is more on the layers of space plan, surfaces, and stuff. In the context of movable real estate, it can be possible to make decisions on re-positioning the building.

4.4 Implementation and Results

To identify the user experience and verify the before-mentioned identified variables, a case study is conducted. The case study relies on interviews that are conducted to find decision variables, their preference values, and evaluate the overall fit for the implemented CNET-DA tool. This results in human participation and therefore the research is registered as human-related research in line with the ethical policies of the Eindhoven University of Technology. This safeguards the identifiable data of participating individuals. An elaboration on the case study and its results is found in Chapter 6.

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Chapter 5

BIM based assessment tool

5.1 Introduction

5.1.1 Purpose

This research aims to integrate BIM models into LCA environmental assessment methods to provide users with information on the environmental impacts of their design decisions.

This chapter elaborates on the implementation of BIM in LCA assessments. From the literature in Chapter 2, it has become clear that it is necessary to integrate environmental data and building models into life cycle evaluation.

The chapter starts with a description of the scope for the proposed tool followed by a general description of the application. Next, the requirements for the integration of BIM into LCA are defined. Followed by an explanation of the technical design of the tool and the architecture of the system. The components that compose the application are explained in more detail, as well as the requirements for information input.

5.1.2 Scope

The focus is on generating a tool that is capable of using BIM data as input, as well as information from environmental databases, and using this to calculate the environmental impact using the principles of LCA. Since the tool is essentially a BIM based Environmental Evaluation, it is called BEE later in this research. It is built to create an accessible method to assess the environmental impact that occurs when a building is refurbished.

BEE will enable a user to visualise and quantify the environmental impact in graphs and indicator numbers. Quantification happens on the component level of the BIM model which means it considers a Wall as one single component and not the individual Bricks or components it is made of. This is inline with the quantification level in the NMD, which, is the standard for Dutch legislation. Quantification is achieved by utilizing information

from the National Environmental Database and expressed in Euros through the NMD environmental impact index.
Visualisation is a key factor to mitigate risks, not only for environmental data but also for the BIM model itself. The tool design is web-based to ensure high usability and accessibility across all user platforms. Furthermore, the tool is able to change materials on a component level and show the environmental influence in real time. The user determines the scope of the environmental assessment and which building components are taken into account.

The software will use two types of input data. The first is the BIM model provided by the user; this contains all the components of the building. Second, the environmental database that contains the environmental impact of materials and building components.

5.2 General description

5.2.1 Product perspective

With increasing attention to environmental impact by clients, there is a rise in questions regarding sustainability, circularity, and thus overall environmental impact. Quantification and insight into the effects of refurbishment decisions require calculations and material specifications on a component level. Traditional tools such as those mentioned in Chapter 2 depend on spreadsheets and manual input of quantities and are prone to faults because of the lacking visual feedback.

In addition, the AEC industry is increasingly using the BIM models which offer a 3D semantic model of the components that form the building. There are different BIM modelling software tools available and depending on the expertise of the BIM modeller and the involved building components, a specific tool is used. While there are tools that are able to use this information for LCA calculations, they depend on the specific software and act as a Plug-in. Dependency on specific software and working only as a Plug-in on existing software limits the cross platform usability.

BEE aims to solve the difficulties mentioned above and allows the user to conduct an environmental analysis using the BIM model and LCA data from environmental databases.

The software will use two types of input data. The first is the BIM model provided by the user which contains all components the building is composed of. Secondly, the environmental database which contains the environmental impact of materials and building components. The constraints and requirements of the BIM model and the environmental database are discussed in Section 5.5.1.

5.2.2 Capabilities

BEE is an application that can be used to calculate the impact generated by a selected list of building components. This allows the user to visualize the impact generated by the refurbishment process of a building and compare different refurbishment scenarios. The user can select the material at the component level and differentiate the components at the individual level. This enables the user to assign material impacts for new components, or in the case of refurbished components, the selection of the impact for a refurbished component can be selected.

Users are able to import and view BIM data stored as .IFC files, edit the material assigned to a component, adjust the expected lifespan, and define if a component is considered in the environmental calculation. Visualisation helps the user by highlighting the selected building component whether selected from the component list or the 3D view itself. On the calculation screen, the user is able to view the material impact in the real-time calculation.

5.2.3 Constraints

BEE is a web-based application that is available on the main web browsers on the market (see Table 5.4). Handling of IFC files occurs on a local level, and therefore, the performance is influenced by the browser' available Random Accessible Memory (RAM) share. The overall results of the usage of BEE depend on the accuracy of the user, who determines the correct materials and the building components that are considered. Furthermore, the input environmental database limits the overall choice of materials and building components that could be considered.

5.2.4 User Characteristics

The tool does not differentiate different types of users, the functionality is similar for each person. A user can access the tool and load a project or import an IFC file. They are able to add and modify the material parameters of building components. They select which components should be considered for environmental calculations and define the material which is selected from the list in the environmental database. The user can change the materials and see in real-time the influence on the overall environmental impact. The User exports the calculation into a PDF report which graphs and indicator values and uses this to support and quantify the choices made from an environmental perspective. The user can also safe any changes made to the BIM model and save this as for future use.

5.2.5 Assumptions and dependencies

In order for BEE to function as specified in this document, there are several dependencies and assumptions. These are shown in Table 5.1.

Assumptions	*Dependencies*
• Availability of data • Data according to input specifications • Access to environmental database • Instructed user	• Functional server • IFC.js framework • Angular JS framework • MongoDB

Table 5.1: Assumptions and dependencies of BEE

5.3 Requirements

This section combines the different requirements that are necessary to conduct an LCA study using BIM. These are divided into user requirements (UREQ#) and system requirements (SREQ#). The requirements describe what the software should be capable of and how it should perform. These requirements are classified using the MoSCoW method. This method distinguishes four priority levels:

- Must have - The requirement must be met at the end of the project for achieving a minimum working tool.
- Should have - The requirement is important but not vital for a working tool. While painful, not achieving these requirements will not influence the main requirements of the tool.
- Could have - The requirement is a nice extra, but not vital to the system. This category contains components that could be considered a future outlook and sketches further possibilities.
- Won't have - The requirement will not be implemented in the tool. This priority level is a protection to the project scope and helps shaping expectations.

5.3.1 User Requirements

ID	Requirement	Priority
UREQ001	User can open a Building Information Model (BIM)	Must
UREQ002	The User can view and navigate the 3D BIM model	Must
UREQ003	User can save the project to software custom file	Must
UREQ005	The user can review the building components of the BIM model	Must
UREQ006	User can manipulate the material from a building component	Must
UREQ007	The user can review the calculated environmental impact	Must
UREQ008	User can export impact analysis to PDF	Must
UREQ009	The impact analysis shows included and excluded components	Must
UREQ010	The user is warned when trying to close the browser/tab	Must
UREQ011	The user can navigate trough the 3D BIM Model	Must
UREQ012	The user gets visual feedback when selecting a building component	Must
UREQ013	The user can review the selected building component	Must
UREQ014	The user can access the application via the web	Must
UREQ015	The user is always able to see the real-time total environmental impact	Should
UREQ016	The user is always able to see which database is selected	Should
UREQ017	The user is always able to see which project/file is currently opened	Should
UREQ004	User can select the input database from list	Could
UREQ018	The user can easily access the metadata of the current project or file	Could
UREQ019	The user can sort building components in the overview table	Could

Table 5.3: MoSCoW user requirement table

5.3.2 System Requirements

ID	Requirement	Priority
SREQ001	System can load an .IFC document	Must
SREQ002	When a user opens an .IFC the system opens project viewer	Must
SREQ005	The project overview shows a table of building components	Must
SREQ006	User can select exact material for each building component	Must
SREQ007	Calculation shows visual impact graphs	Must
SREQ008	User can export impact analysis to PDF	Must
SREQ009	Impact analysis shows list of included components	Must
SREQ010	Impact analysis shows list of Excluded components	Must

Continued on next page...

Table 5.4 – continued from previous page

ID	Requirement	Priority
SREQ011	The user is warned when trying to close the browser/tab	Must
SREQ012	When a user opens a project the system navigates to the material selector	Must
SREQ013	When no project is selected the system shall display 'no file loaded'	Must
SREQ014	The system provides a "zoom" function in the 3D viewer	Must
SREQ015	The system provides a "pan" function in the 3D viewer	Must
SREQ016	The system provides a "Orbit" function in the 3D viewer	Must
SREQ017	When a user selects a component, the component is highlighted	Must
SREQ018	When a user hovers a component, the component is highlighted	Must
SREQ019	Properties of a selected component are shown	Must
SREQ020	BEE shall be built as a web based application	Must
SREQ021	BEE shall function in Chrome version 98.0 and beyond	Must
SREQ022	BEE shall function in Firefox version 97.0 and beyond	Must
SREQ023	BEE shall function in Edge version 97.0 and beyond	Must
SREQ024	BEE shall function in Safari version 15.6 and beyond	Must
SREQ025	User can save project to .IFC file	Should
SREQ027	User is able to save the selected materials to .IFC	Should
SREQ031	The user is always able to see the real time total environmental impact	Should
SREQ032	The user is always able to see which database is selected	Should
SREQ033	The user is always able to see which project/file is currently opened	Should
SREQ035	The materials can be sorted by 'impact'	Should
SREQ036	The user can select building components from the 3D view	Should
SREQ003	System can save the project to software custom file	Could
SREQ004	User can select the input database from list	Could
SREQ026	User can add database via menu	Could
SREQ028	User is able to add a variant material tab	Could
SREQ029	User can compare variant data side by side	Could
SREQ030	User can open project while different project is opened	Could
SREQ034	The user can easily access the metadata of the current project/file	Could
SREQ037	Do an undo actions via dedicated button or shortcut	Could
SREQ038	User gets tool-tips when hovering over menu items	Could
SREQ039	A short tutorial on opening the program instructs the user how to use the tool	Could
SREQ040	The material list can be sorted by 'family', 'selected' and 'id'	Could

Continued on next page...

Table 5.4 – continued from previous page

ID	Requirement	Priority
SREQ041	The material list has a search function	Could
SREQ042	The system provides a "Home" function in the 3D viewer	Could
SREQ043	The user can operate the system without needing prior knowledge	Could
SREQ044	Compatibility with IFC files beyond IFC 2x3 or other extensions	Won't have
SREQ045	Simulation of costs performance	Won't have
SREQ046	Direct API link with Environmental database	Won't have

Table 5.4: MoSCoW system requirement table

5.4 System design

In this section, the overall technical design of the BEE tool is explained. It starts with the system architecture that explains the overall information flow and shows the different frameworks on which the application is built. It is followed by an explanation of MongoDB and Angular. Next, the overall backbone of the application is explained, which is followed by an explanation of the front-end. Lastly, the output report generated by the tool is discussed, and the requirements are set in Table 5.4 and 5.3 is checked in the requirement evaluation section.

5.4.1 System Architecture

The proposed application can be divided into two stand-alone applications. This division is made to allow for future proofing and resemble the layout of existing standardized databases like the NMD.

The first part is the environmental data system. This system contains all environmental data in a MongoDB database. This is illustrated in the upper part (blue) of Figure 5.1. MongoDB can be accessed via the API of Node.JS, in the proposed system, the BEE back-end directly accesses the API of Node.JS, but with a front-end in the first part of the system, it could also be possible to have the user directly access the environmental data, for example, by an HTML web page (Figure 5.1, top right in gray). This part of the system is similar to the NMD and it allows other applications to directly interact with the environmental data contained within this system.

The application needs to be web-based handle .IFC files use environmental data, calculate environmental impact, and interact with the user. To achieve this, the system can be broken down into a front-end and back-end. This is shown in the bottom part of Figure 5.1 (yellow. The BEE back-end directly calls upon the API of Node.JS to access the environmental data contained in the MongoDB. This method protects the flexibility since collecting data from another source can be achieved by calling upon a different API. The back-end is responsible for the calculation of the environmental impact, the visualisation of the user uploaded .IFC file and can be called upon by utilizing its API. The front-end is HTML and JavaScript (JS) based, it allows the user to upload the .IFC data that is utilized by the IFC.JS in the back-end. The IFC input data is contained within the user web browser and therefore is part of the front-end. Since the tool also contains its own API, other applications outside the scope of this research could interact directly with the calculation of environmental data or the visualisation of components.

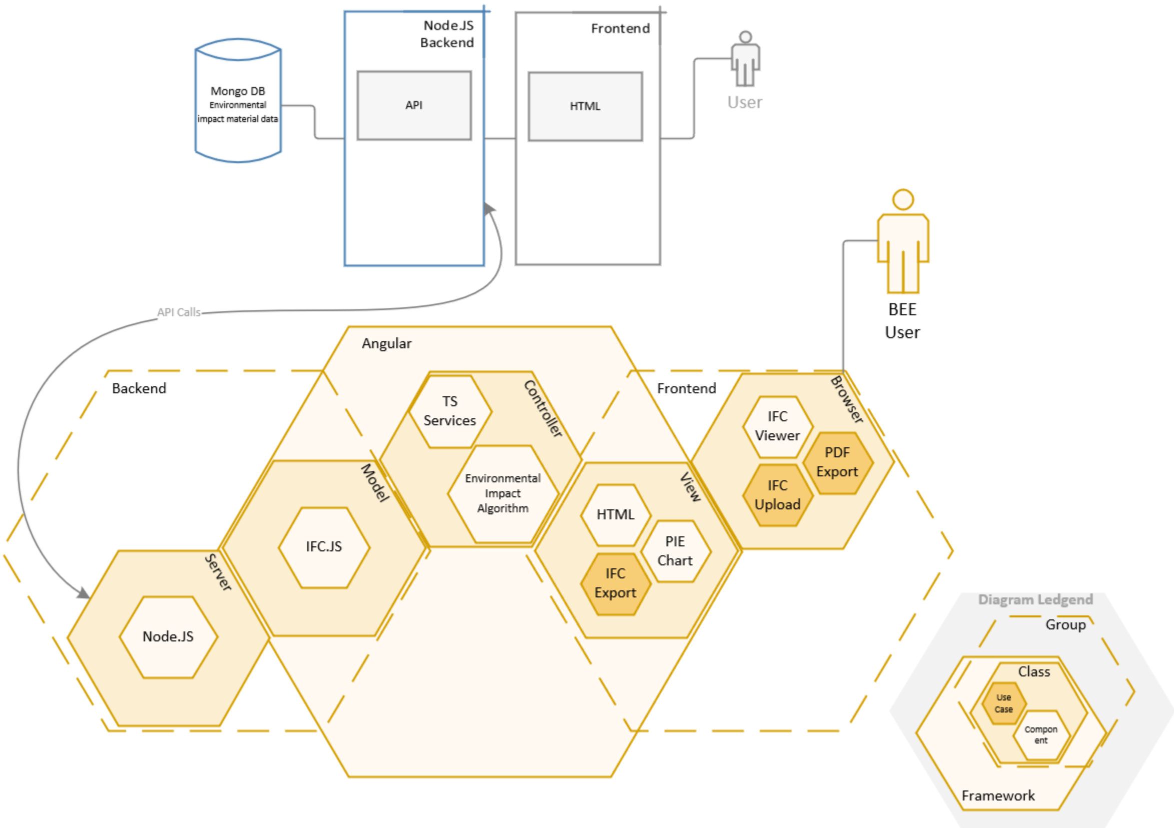

Figure 5.1: BEE System Architecture

MongoDB

The database selected for the development of BEE is MongoDB. MongoDB is an open source document-oriented database. Because it is document-oriented and does not depend on traditional tabular relations, it falls under the category of Not Only SQL (NOSQL) databases. The advantage of a documented-oriented database is its allowance for dynamic changes and thus future flexibility. It works as a collection of documents that act as a standalone entity; the entities are able to share similar key values such as the primary ID and do not follow a schema that depends on static relations.

Another future proof advantage of using MongoDB is the scalable cloud service which does not require the application to run its own database service and if needed, it can be scaled up easily when more bandwidth is required.

For the proposed application, MongoDB is responsible for the storage of environmental material data derived from the National Environmental Database. In addition, it stores information on recycled materials and their remaining life span as determined by the user.

In Figure 5.2 the database layout is shown. The database consists of four collections. The *material_dbs* collection contains the list of all materials for which environmental data is defined. These materials can have their impact defined in separate characteristics, these are eleven impact categories and defined in the *environmental_impact_characteristics* collection. These characteristics are defined per material for the different phases as in EN 15798, to reduce the risk of faults, the phases are defined as integers in the *life_cycle_stages* collection. The three collections are connected using the *material_characteristics* collection that stores the integer ID values of the materials and their respective characteristics for each phase.

Since all collections contain more than one document, the MongoDB standard requires that the collection name end with ‘s’. A further explanation of the names is given in Table 5.5. The exact content and information contained in the environmental impact characteristics in the database have been previously discussed in Table 2.2.

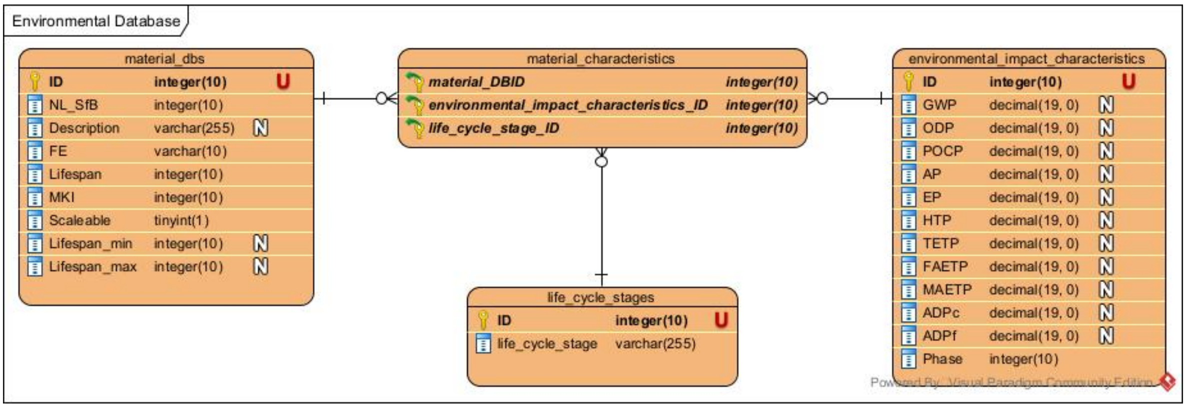

Figure 5.2: ERD diagram of material database

Identifier	Name	Description
ID	Identifier	Numerical identifier used for programming and relational purposes
NL_SfB	NL/SfB	Identifier from the Dutch coding standard for building components and materials
Description	Description	A textual descripton of the building material
FE	Functional Unit	The measuring unit for calculating the environmental data
Lifespan	Lifespan	The expected lifespan of a material
MKI	Environmental Costs Index	The total environmental costs of a material per unit (FE) expressed in euro
Scalable	Scalable	Defines wheter a material can be scaled by its unit or not
Lifespan_min	Minimum lifespan	The minium expected lifespan of a material
Lifespan_max	Maximum lifespan	The maximum expected lifespan of a material
Phase_name	Phase name	The textual name of the lifetime phase for which impact is considered
GWP	Global Warming Potential	Climate change expressed in CO2 equivalent
ODP	Ozone Depletion Potential	Indicator for degradation of stratospheric ozone layer in CFK-11 equivalent
POCP	Photochemcial Oxidation Potential	Phothochemical oxide forming (Smog) expressed in ethylene (C2H4)
AP	Acidification Potential	Indicator for acidification in SO2 equivalents
EP	Eutrophication Potential	Indicator for eurtophication in PO4 equivalents
HTP	Human Toxicity Potential	Human toxicity effects relative to 1,4-dichlorobenzene
TETP	Terrestial Ecotoxicity Potential	Terrestial ecotoxicity effects relative to 1,4-dichlorobenzene
FAETP	Freshwater Aquatic Ecotoxicity Potential	Freshwater aquatic toxicity effects relative to 1,4-dichlorobenzene
MAETP	Marine Aquatic Ecotoxicity Potential	Saltwater toxicity effects relative to 1,4-dichlorobenzene
ADPc	Abiotic Depletion Potential of Composites and minerals	Scarcity of material relative to antimony (Sb)
ADPf	Abiotic Depletion Potential of Fossil fuels	Scarcity of fossil fuels relative to antimony (Sb)

Table 5.5: Explanation of database variables

Angular

Angular is a framework that enables developers to generate web-based applications. Angular uses HTML and Type Script (TS) coding and runs on Node.js. Angular works by combining components, which allows for easy scaleability of the application. The fact that Angular is web-based mitigates the implementation issues generated by different user platforms. Web applications depend on the web browser rather than the user platform on which the browser is deployed.

For the proposed application, angular is responsible for the Graphical User Interface (GUI) of the tool, but also for the environmental impact calculation and the visualisation of the IFC data. These different aspects are coded as services within Angular and can be called upon when needed.

5.5 Back-end

In Figure 5.3 the activity diagram for BEE is shown.

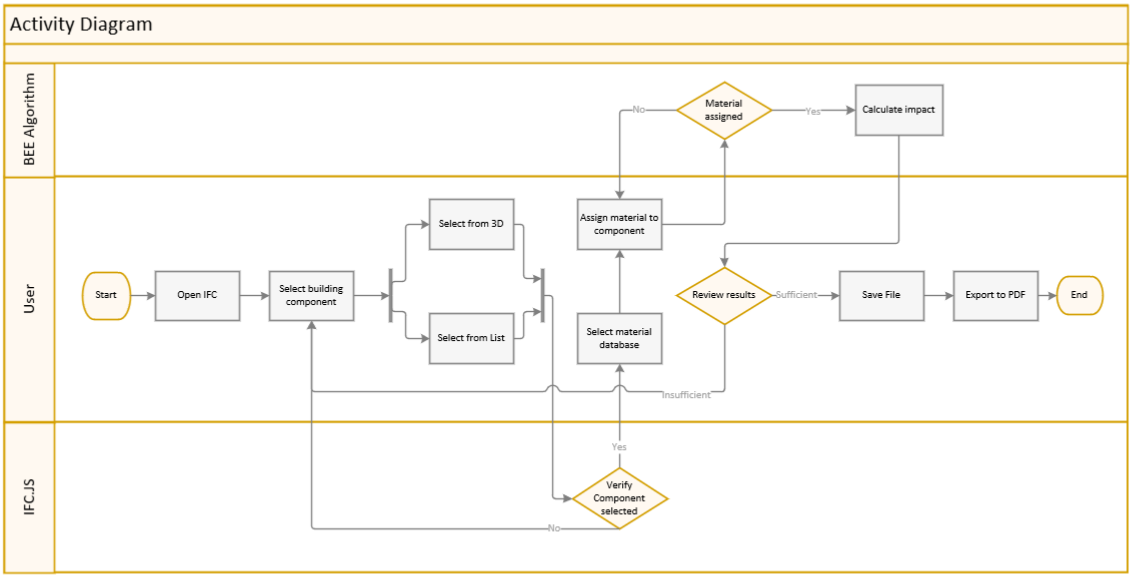

Figure 5.3: Activity diagram of BEE

5.5.1 Input Requirements

In order for BEE to calculate the environmental impact, some specific information is required as input information. BEE utilizes the IFC property sets to obtain its data. This research distinguishes four main sets of variables. These variables are not standard part of the BIM information set and therefore care should be taken to ensure this information is in the input IFC.

Identity data:

The first is component identity data. This dataset consists of the component type, the component name, and the material of the component. The material is coded as an NL-SfB code and corresponds to the identification system utilized by the NMD. This allows to connect the environmental data from MongoDB to the selected building component.

Quantities:

The second set contains information regarding the component's size, width, height, area, and volume. Whether the information of this property is needed for the calculation of environmental impact is dependant on the environmental data of the material. It could be the information is not within the IFC or that the information is available, but not needed in the calculation.

Include in calculation:

This is a single property attached to an component that indicates if the material should be included in the environmental calculation conducted by BEE. The tool requires this parameter, which is a Boolean indicating either true or false, to be in the IFC to process the material in the calculation. The parameter is not defined by default and absence of the parameter will automatically lead to the exclusion of the material in the environmental calculation.

Component LifeSpan:

This is a single property attached to an component that indicates the lifespan of a material in years. This is especially important when the material is re-purposed. The default value for this numerical value is 1000 years, which indicates the full life expectancy and is equivalent to the value for maximum life expectancy in the NMD. This value can be altered by the user to the expected life.

The information mentioned above is contained within the IFC. This must be a minimum version 2.3.x (IFC2x3) and contain the properties in Table 5.6. Some of these properties have multiple data instances; this is because the data is defined for multiple IFC component types. The availability depends on the inheritance of the IFC 2x3 standard.

Property	Type	Data
Q Lengte	Length	Length
Q Hoogte	Length	Height
	Length	Unconnected Height
	Length	Desired Stair Height
	Length	Railing Height
Q Breedte/Dikte	Length	Width
	Length	Actual Run Width
Q Dikte	Length	Thickness
Q Omtrek	Length	Perimeter
Q Oppervlakte	Area	Area
Q Inhoud	Volume	Volume
IfcIncluded	Boolean	IfcIncluded
IfcLifespan	Real	IfcLifespan

Table 5.6: Property requirements BEE

5.5.2 Use Cases

In Figure 5.4 the use case diagram for BEE is shown. In the figure the actors are visualised (IFC.JS and the User) they interact with the system which contains the different use cases via the solid lines. The dotted arrows indicate if a use case is dependent on another part of the system. The user does not have a direct interaction via the dotted line. Below the image for every use case an explanation is given.

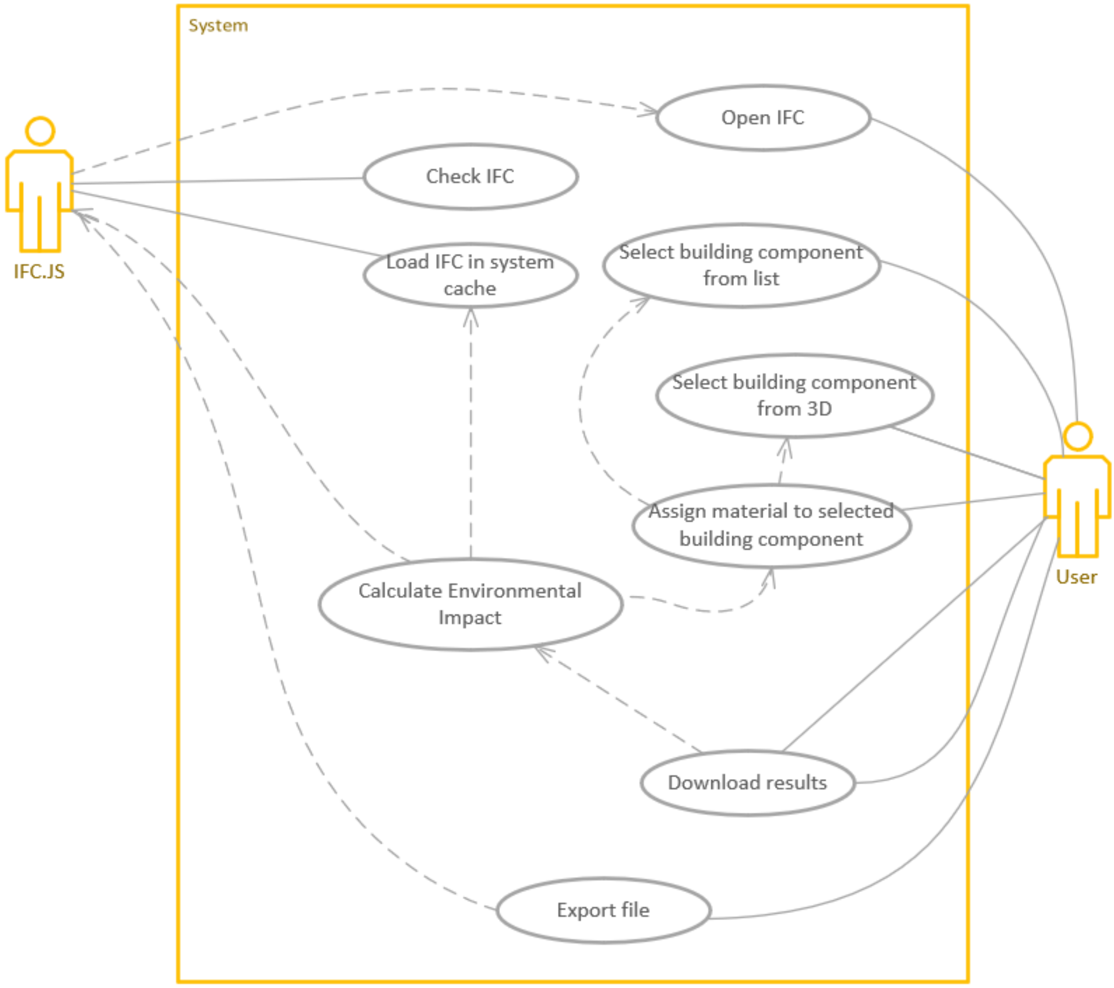

Figure 5.4: Use case diagram of BEE

Use case: Open IFC

This use case shows the actions taken when a user selects and loads an IFC file into the BEE application. If the user has selected and IFC file this is loaded into the cache memory of the machine the user operates on. The cache memory is a temporary file storage section on the users device and allows the tool to access the data without manipulating the original file. When the file is loaded the application will show the 3D representation of the model in the viewer section. At the same time the controller will load the list of components in the IFC and present them on the screen if it has completed the computation of the list in the component list section. These sections are elaborated in Section 5.6.1. When a user has no IFC selected the screen will prompt the user to select and IFC and does not show any other component.

A summary and pseudo code of the process are shown below in Algorithm 1.

Goal: User loads IFC file into BEE.

Actor: User

Pre-condition: The user has an IFC file with the required properties.

Post-condition: The IFC is loaded into the system cache.

Summary: User selects an IFC file to assess and load it into the system.

Priority: Must have

Requirements: UREQ001, UREQ2, SREQ001, SREQ002, SREQ003, SREQ010, SREQ011.

Algorithm 1 Open IFC

if User $\rightarrow$ *Select* : *IFC* **then**
    User IFC $\rightarrow$ *IFC in cache*
    Viewer $\rightarrow$ *Show* : *IFC 3D Model*
    Controller $\rightarrow$ *Load IFC component list*
    if *IFC Component List* = *complete* **then**
        Viewer $\rightarrow$ *Show* : *IFC component list*
    end if
else
    No IFC selected
end if

Use case: Select building component from list

In this use case the user selects a building component from the list of building components. To enable the user to select a component, the IFC should be loaded beforehand. When a user selects a component by double clicking on it the model viewer will highlight the selected component. It also shows the properties in the property section on the screen.

A summary and pseudo code of the process are shown below in Algorithm 2.

Goal: User selects a building component from the list of components.

Actor: User

Pre-condition: The IFC file has finished loading.

Post-condition: A building component is selected.

Summary: User selects an building component by clicking on it in the system.

Priority: Must have

Requirements: UREQ005, UREQ006, UREQ012, SREQ004, SREQ017.

Algorithm 2 Select building component from list

Require: *IFC loaded*
if User $\rightarrow$ *Select* : *component* (Double click) **then**
    Viewer $\rightarrow$ *Highlight Component*
    Viewer $\rightarrow$ *Show* : *Component Properties*
end if

Use case: Select building component from 3D

In this use case the user selects a building component from the 3D view of the building. To enable the user to select a component, the IFC should be loaded beforehand. When a user selects a component by double clicking on it in the model viewer it will highlight the selected component. It also shows the properties in the property section on the screen.

A summary and pseudo code of the process are shown below in Algorithm 3.

Goal: User selects a building component from the 3D view.

Actor: User

Pre-condition: The IFC file has finished loading.

Post-condition: A building component is selected.

Summary: User selects an building component by clicking on it in the system.

Priority: Must have

Requirements: UREQ005, UREQ006, UREQ010, SREQ017, SREQ029.

Algorithm 3 Select building component from 3D

Require: *IFC* $\rightarrow$ *loaded*
if User $\rightarrow$ *Select* : *component* (Double click) **then**
    Viewer $\rightarrow$ *Highlight Component*
    Viewer $\rightarrow$ *Show* : *Component Properties*
end if

Use case: Assign material to the selected building component

When a user has selected a component and can review the properties of the selected component the user is allowed to assign a material to the selected building component. The system checks if the material that the user selected is different from the existing property information and when this is changed, and thus not equal, it changes the property of the selected component in the model to include the new selected material. Also the controller updates the environmental calculation to use the characteristics of the newly selected material. Furthermore, the viewer updates the component list and component properties to show the newly selected component.

Another case is when a user has selected component and reviews the `Included` property. If the state of the true/false statement is changed by the user the controller updates the included and excluded component list. Also, the controller updates the environmental calculation.

When the user does not interact with the system no actions are taken. A summary and pseudo code of the process are shown in Algorithm 4.

Goal: User assigns material to a building component.

Actor: User

Pre-condition: Component is selected.

Post-condition: Material is assigned.

Summary: User assigns a material from the database to the selected building component.

Priority: Must have

Requirements: UREQ006, UREQ013, SREQ017.

Algorithm 4 Assign material to the selected building component

Require: $IFC \rightarrow Loaded$
Require: $Component\ Selected$
if User $\rightarrow$ $selected\, material \neq current\, material$ **then**
  Model $\rightarrow$ $Update : IFC\ Component\ Material$
  Controller $\rightarrow$ $Update : Environmental\ calculation$
  Viewer $\rightarrow$ $Update : component\, list$
  Viewer $\rightarrow$ $Update : component\, properties$
else if User $\rightarrow$ $selected\, material$ **Change** $included\ state$ **then**
  Controller $\rightarrow$ $Update : Included\ List$
  Controller $\rightarrow$ $Update : Excluded\ List$
  Controller $\rightarrow$ $Update : Environmental\ calculation$
end if

Use case: Environmental impact calculation

The environmental impact is calculated through an algorithm. This uses the data from the IFC file and MongoDB to calculate the environmental impact index in euros. The impact is dived for all materials in the eleven different categories for different building phases as are shown in Figure 2.1. Not all life cycle stages are defined, the information is limited to what is available in the NMD.

Calculating the environmental impact can be divided into several steps. These steps combine to form the algorithm that calculates the environmental impact. The algorithm is coded as a separate service component within the application.

The first step of the algorithm is to determine which materials to include in the environmental database and what the quantity of the material is. This is achieved by checking every building component in the IFC for the property $IfcIncluded$ that contains a true or false statement, determining if a component should be included in the calculation. If the property is not defined for an component, the component will be automatically ignored.

The algorithm will then determine whether a material is defined, if it is not defined, it is ignored in the calculation, if it is defined, then it will continue.

The algorithm determines then if the material defined for a component is scale-able (*Scaleable*) or not. Scale-able indicates if a material should be calculated by its component size (using quantity-data) or by its component count. Scale-ability of a material is defined in the $Materials\_dbs$ collection in MongoDB. If a material cannot be scaled, the variable for its size defined by `m` is set to 1. If the material can be scaled, the algorithm starts identifying the method of scaling. This is achieved by identifying the variable `FE` from MongoDB. `FE` is the functional unit and can be $m3$ (for cubic meters (volume), $m2$ for square meters (area), or $m1$ for length (Length meter). It then checks first for each of the three types of if a calculated area is available from the IFC property set, respectively being *Qvolume*, *Qarea*, *Qlength*. If the property is not direct available, it uses the length, height, and width ($QLength$,$QHeight$,$QWidth$)properties to calculate the volume, area, or length. This then is returned as the variable `m`.

The first step above is shown as pseudo code in Algorithm 5.

Goal: Calculating environmental impact.

Actor: BEE Algorithm (Controller)

Pre-condition: Material is changed, IFC is loaded.

Post-condition: Environmental impact is calculated.

Summary: Impact calculation algorithm is called every time a component or component changes state.

Priority: Must have

Requirements: UREQ007, UREQ015, SREQ005, SREQ007, SREQ008.

Algorithm 5 Environmental impact algorithm, determine material volume

Require: $IfcIncluded = 1$ ▷ Check if material should be included in calculation
Require: $NL - SfB > 0$ ▷ Check if the material is defined in NL-SfB

if $Scaleable = 0$ **then**
    $m = 1$
else ▷ The material is scalable
    if $FE = m3$ **then**
        if $QVolume > 0$ **then**
            $m = QVolume$
        else
            $m = QHeight \times QLength \times QWidth$
        end if
    else if $FE = m2$ **then**
        if $QArea > 0$ **then**
            $m = QArea$
        else
            $m = QHeight \times QLength$
        end if
    else if $FE = m1$ **then**
        $m = QLength$
    end if
end if

The second stage of the algorithm is to calculate the environmental impact and express this in the environmental costs index (`MKI`). The environmental impact of a material is determined by the following function 5.1:

$$MKI = \sum_{C} \sum_{P_C} E_c \cdot m \cdot W_{ef} \tag{5.1}$$

Where:
MKI Represents the impact of a reused material/component as an environmental impact index in euros
C represents the specific impact category, the impact is calculated for material/component
P_c Is the considered life cycle phase for category C
E_c Is the environmental impact for the new implementation of material/component considering impact category $c$resulting from the NMD
m is the calculated quantity of the material
W_{ef} Is the weight of the environmental category as defined by the NMD

This formula is converted into the second step of the algorithm (algorithm 6). The algorithm checks in the database if there are environmental data for a material in every building phase. The database contains information of seven life cycle phases; this is then multiplied by the earlier determined quantity `m`. The life cycle phase is indicated by `p` and the impact category by `c`. The impact over the life cycle can be reduced by the assessor as described in Section 2.2.1. Therefore, the algorithm also includes the Equation 2.1. The algorithm checks if the remaining lifespan `R` is defined, and if so, calculates the environmental impact index according to the remaining lifespan. If there is no remaining lifespan defined, the algorithm uses the default maximum lifespan `L` from MongoDB. If the expected maximum life span of an component in the IFC is larger then the lifespan defined in MongoDB, it ignores this value and used the maximum defined by the LCA data is used. Since the maximum and expected life is then equal, it does not use the life expectancy in the calculation. The LCA data in MongoDB is already calculated for the maximum life expectancy. This reduces the risk of in-reasonable life expectancy's

Algorithm 6 Environmental impact algorithm, calculate MKI

for p **do** ▷ calculate for every life cycle phase
    for c **do** ▷ calculate for every impact category
        if $R \leq L$ **then**
            $MKI_{pc} = m \times (\frac{E_c}{L} \times R)$ ▷ Calculate with remaining lifespan
        else
            $MKI_{pc} = m \times E_c$
        end if
    end for
end for
$\sum MKI_{pc} \rightarrow$ Show: $Table + Pie - Chart$ ▷ Sum of all impact categories over all life cycle phases

Use case: Download Results

This use case requires the environmental calculation to be conducted. When a user wants to download the results of the calculation they select the download results button. The viewer then shows the report on screen and the user is prompted to download the report as a PDF to their local machine.

A summary and pseudo code of the process are shown below in Algorithm 7.

Goal: Download environmental calculation results

Actor: User

Pre-condition: Environmental impact is calculated.

Post-condition: PDF with calculation is generated.

Summary: The user calls upon the results download function which generates a PDF summarizing the environmental impact results.

Priority: Must have

Requirements: UREQ008, SREQ008, SREQ009, SREQ010.

Algorithm 7 Download results

Require: *Environmental calculation*

1: **if** User → *Select* : *download results* **then**
2: Viewer → *print* : *environment calculation* → PDF
3: Download → PDF
4: **end if**

Use case: Export File

To allow the user to export the IFC file it first is required to have an IFC loaded in the system. When a user select the IFC export button the model will export the IFC and includes the state of the properties `Included` and the assigned material. The user is prompted a with a download popup and can save the IFC on their local machine.

A summary and pseudo code of the process are shown below in Algorithm 8.

Goal: Exporting IFC file from BEE.

Actor: User

Pre-condition: Material is changed, IFC is loaded.

Post-condition: IFC is exported.

Summary: User calls upon the export IFC function which generates an IFC containing the adjustments made in BEE and downloads it to the users computer.

Priority: Must have

Requirements: UREQ003, SREQ023, SREQ030.

Algorithm 8 Export File

Require: IFC → *Loaded*

1: **if** User → *Select* : *Export* IFC **then**
2: Model → *Export* : IFC Include $Material\ assigned$
3: Download → IFC
4: **end if**

5.6 Front-end

The front-end of BEE is constructed using HTML pages within the Angular framework. In Figure 5.5 the Model View Controller (MVC) architecture of BEE is visualized.

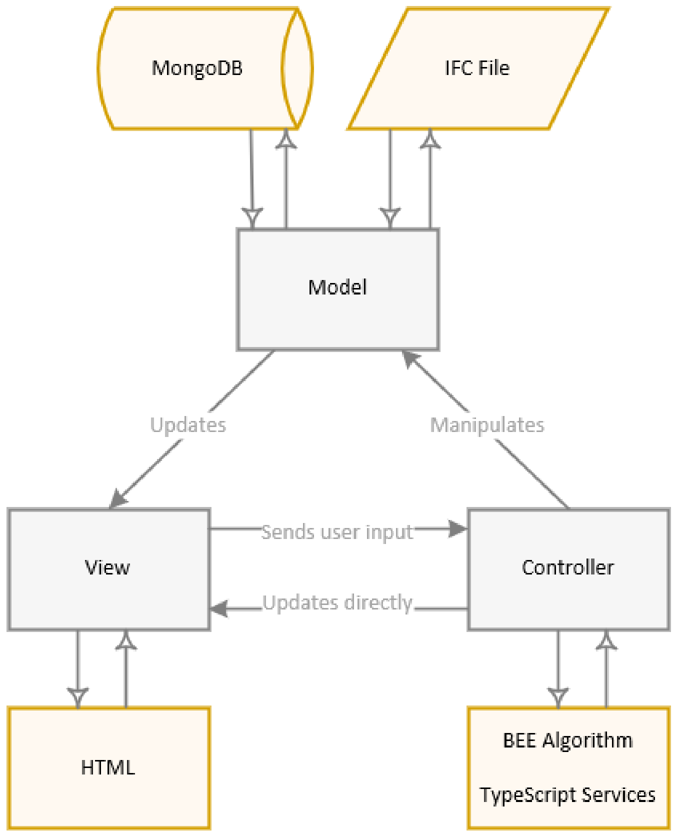

Figure 5.5: Model View Controller architecture of BEE

In BEE, the model is the IFC file loaded by the user and the MongoDB environmental database. This model is manipulated via the controllers which are the TypeScript services and the BEE algorithm. The model updates the view, which is the HTML webpage with which the user sees and interacts. The user sends the input to the controller through the HTML view.

5.6.1 Interface

To enable user interaction, the tool is developed around a Graphical User Interface (GUI). The GUI of BEE is shown in Figure 5.7. This interface is divided into five sections, of which there are four main quadrants. These quadrants (see Figure 5.6) are the result of the most important functionalities that should be available to the user at all times; environmental impact considered materials, 3D visualisation, and component properties. The left side of the screen (Quadrant A and C) contains the environmental calculation and the right side (Quadrant B and D) show the imported BIM data.

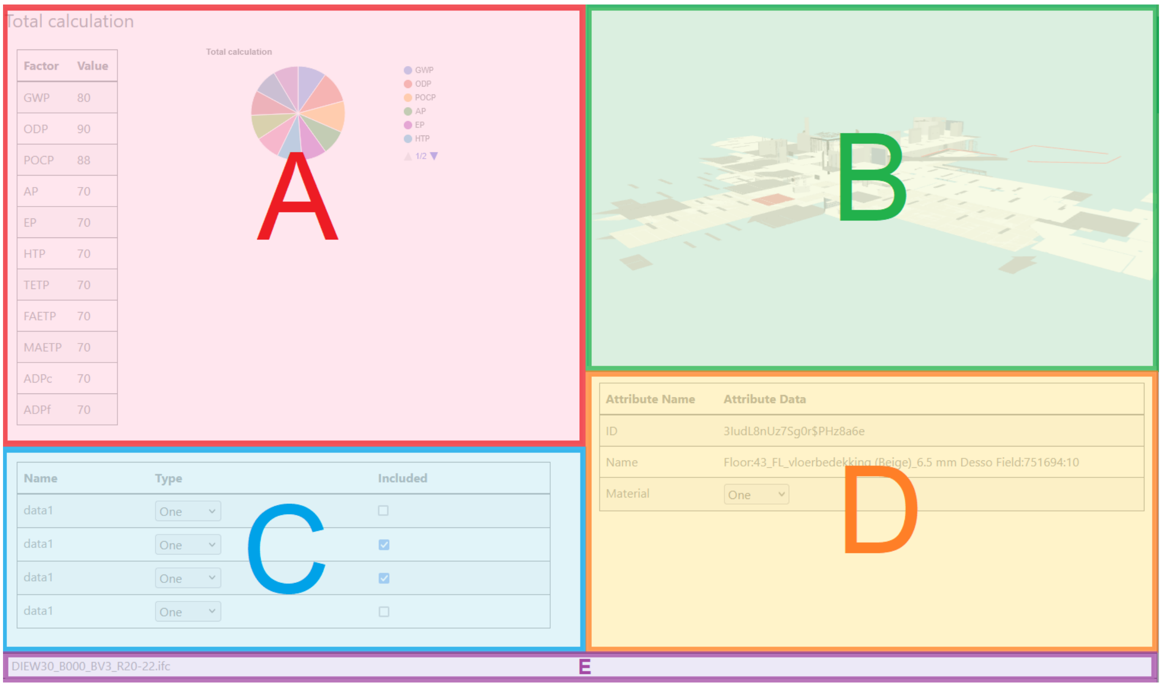

Figure 5.6: Graphical User Interface Sections - BEE

Quadrant A

The first quadrant (Figure 5.6, A) shows the environmental impact of the project. This is calculated in real time and depends on the user input. It shows in pie charts the impact for each building phase but also for the different impact categories. Furthermore, the table shows the environmental impact of the impact categories for all phases. All environmental impacts are calculated as an environmental cost index in euros (MKI).

Quadrant B

An important part of the GUI is the visualisation of the IFC file and thus the refurbishment project. This is shown in Figure 5.6, B. Therefore, the 3D representation of the BIM model (loaded as an .IFC file) is always shown in the top right corner of the application. This window allows the user

Quadrant C

The bottom left quadrant (Figure 5.6, C) shows the component list. This is a table with the building components that are in the file. The user can interact in this area to tell the application which materials it should consider, and also the exact material of the database can be defined.

Quadrant D

The bottom right quadrant (Figure 5.6, D) shows the information of an component that is selected by the user. It shows properties such as ID, Material, Size, Quantity, and whether it is included. The user can make adjustments to the inclusion parameter and material such as in the table of the bottom left quadrant (Figure 5.6, C) is also possible.

Section E

Bottom part of the screen contains the footer (Figure 5.6, E) . This component shows to the user at all times which file is loaded into the application, to which database it is connected, the total environmental costs and how many items are selected from the total list.

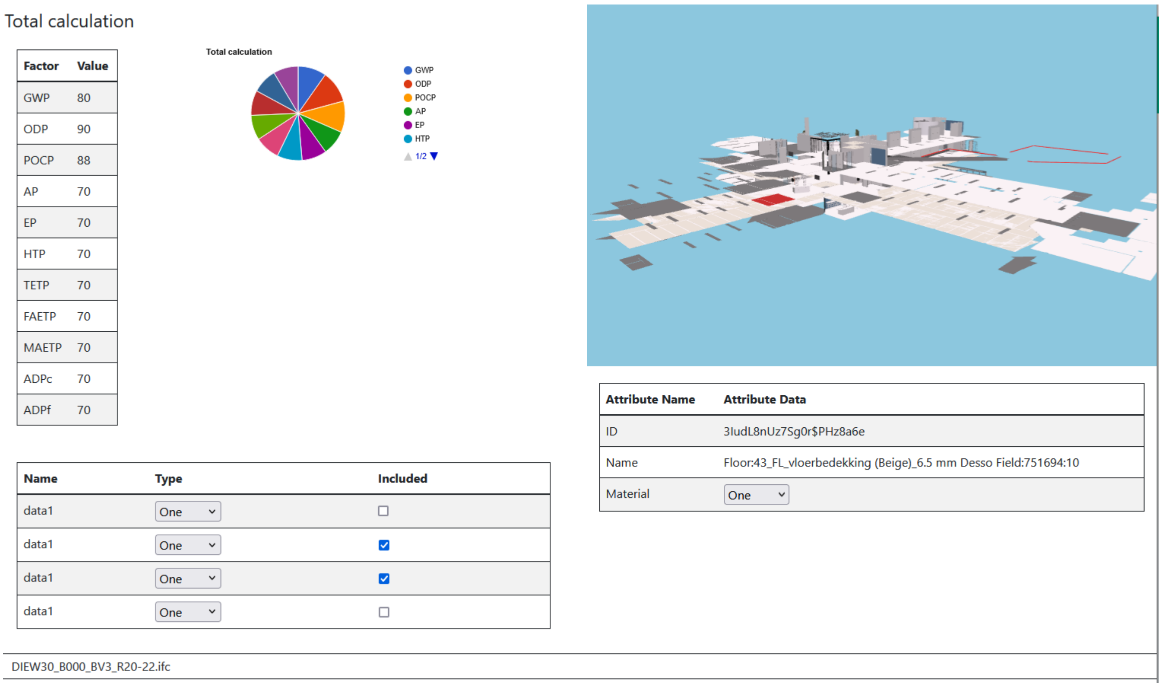

Figure 5.7: Graphical User Interface - BEE

5.6.2 Output report

An explanation of the report resulting from environmental data, which data are available in the report. How the report looks and what the user can do with the data.

The output report is a PDF that contains the list of components included and excluded in the building analysis. It also shows the environmental impact expressed in MKI for each life cycle phase and for each environmental impact category, of which there are eleven.

5.6.3 Requirement Evaluation

This section evaluates the requirements set in Section 5.3.2. For each requirement, the implementation is indicated with one of three colors: green for successful implementation, orange for implementation but not fully successful, and red indicates the need for future implementation. In addition to implementation evaluation, each of the requirements is also scored on the complexity level (C) of implementation difficulty on a 5-level scale, 1 for easy implementation and 5 for difficult implementation.

In Table 5.7 the user requirements are evaluated, and in Table 5.8 the system requirements are evaluated. In general, almost all requirements have been successfully implemented. The requirements that included the export of documents and the modification of IFC files were the most complex during the implementation stage.

User requirements evaluation

ID	Requirement	Priority	C
UREQ001	User can open a Building Information Model (BIM)	Must	3
UREQ002	The User can view and navigate the 3D BIM model	Must	2
UREQ003	User can save the project to software custom file	Must	5
UREQ005	The user can review the building components of the BIM model	Must	2
UREQ006	User can manipulate the material from a building component	Must	4
UREQ007	The user can review the calculated environmental impact	Must	1
UREQ008	User can export impact analysis to PDF	Must	3
UREQ009	The impact analysis shows included and excluded components	Must	2
UREQ010	The user is warned when trying to close the browser/tab	Must	1

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Table 5.7 – continued from previous page

ID	Requirement	Priority	C
UREQ011	The user can navigate trough the 3D BIM Model	Must	3
UREQ012	The user gets visual feedback when selecting a building component	Must	2
UREQ013	The user can review the selected building component	Must	1
UREQ014	The user can access the application via the web	Must	1
UREQ015	The user is always able to see the real-time total environmental impact	Should	1
UREQ016	The user is always able to see which database is selected	Should	1
UREQ017	The user is always able to see which project/file is currently opened	Should	1
UREQ004	User can select the input database from list	Could	-
UREQ018	The user can easily access the metadata of the current project or file	Could	-
UREQ019	The user can sort building components in the overview table	Could	-

Table 5.7: User requirement evaluation table

5.6.4 System Requirements evaluation

ID	Requirement	Priority	C
SREQ001	System can load an .IFC document	Must	3
SREQ002	When a user opens an .IFC the system opens project viewer	Must	1
SREQ005	The project overview shows a table of building components	Must	4
SREQ006	User can select exact material for each building component	Must	3
SREQ007	Calculation shows visual impact graphs	Must	2
SREQ008	User can export impact analysis to PDF	Must	3
SREQ009	Impact analysis shows list of included components	Must	3
SREQ010	Impact analysis shows list of Excluded components	Must	3
SREQ011	The user is warned when trying to close the browser/tab	Must	1
SREQ012	When a user opens a project the system navigates to the material selector	Must	1

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Table 5.8 – continued from previous page

ID	Requirement	Priority	C
SREQ013	When no project is selected the system shall display 'no file loaded'	Must	1
SREQ014	The system provides a "zoom" function in the 3D viewer	Must	1
SREQ015	The system provides a "pan" function in the 3D viewer	Must	1
SREQ016	The system provides a "Orbit" function in the 3D viewer	Must	1
SREQ017	When a user selects a component, the component is highlighted	Must	2
SREQ018	When a user hovers a component, the component is highlighted	Must	2
SREQ019	Properties of a selected component are shown	Must	4
SREQ020	BEE shall be built as a web based application	Must	2
SREQ021	BEE shall function in Chrome version 98.0 and beyond	Must	1
SREQ022	BEE shall function in Firefox version 97.0 and beyond	Must	1
SREQ023	BEE shall function in Edge version 97.0 and beyond	Must	1
SREQ024	BEE shall function in Safari version 15.6 and beyond	Must	1
SREQ025	User can save project to .IFC file	Should	5
SREQ027	User is able to save the selected materials to .IFC	Should	5
SREQ031	The user is always able to see the real time total environmental impact	Should	4
SREQ032	The user is always able to see which database is selected	Should	1
SREQ033	The user is always able to see which project/file is currently opened	Should	1
SREQ035	The materials can be sorted by 'impact'	Should	-
SREQ036	The user can select building components from the 3D view	Should	4
SREQ003	System can save the project to software custom file	Could	-
SREQ004	User can select the input database from list	Could	-
SREQ026	User can add database via menu	Could	-
SREQ028	User is able to add a variant material tab	Could	-
SREQ029	User can compare variant data side by side	Could	-
SREQ030	User can open project while different project is opened	Could	-
SREQ034	The user can easily access the metadata of the current project/file	Could	-
SREQ037	Do an undo actions via dedicated button or shortcut	Could	-
SREQ038	User gets tool-tips when hovering over menu items	Could	-

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Table 5.8 – continued from previous page

ID	Requirement	Priority	C
SREQ039	A short tutorial on opening the program instructs the user how to use the tool	Could	-
SREQ040	The material list can be sorted by 'family', 'selected' and 'id'	Could	-
SREQ041	The material list has a search function	Could	-
SREQ042	The system provides a "Home" function in the 3D viewer	Could	-
SREQ043	The user can operate the system without needing prior knowledge	Could	-
SREQ044	Compatibility with IFC files beyond IFC 2x3 or other extensions	Won't have	-
SREQ045	Simulation of costs performance	Won't have	-
SREQ046	Direct API link with Environmental database	Won't have	-

Table 5.8: System requirement evaluation table

Use case evaluation

This section evaluates the use cases as described in Section 5.5.2 and Figure 5.4.

The first use case, opening an IFC, has been successfully implemented. The user can load an IFC file and the BEE viewer shows the 3D representation of the BIM model. When the user opens an IFC, the controller loads the list of IFC components. If the file size is to large for the device to load the elements the tool stops the whole process. The file size can be reduced by reducing the LOD of the exported IFC or by considering only a part of the project at the same time by splitting the building and creating multiple IFC files to assess.

The second use case is the selection of building components from the list of components generated by BEE when an IFC is loaded. When a user selects a component, the properties of the selected component are shown and highlighted in the 3D view. Similarly, the third use case allows the user to select a component in the 3D view. The selected component is highlighted, and the properties are shown. Both of these use cases have been successfully implemented.

The fourth use case allows the user to assign a material to the selected building component. This is implemented successfully, but limited to the content of the environmental database.

The fifth use case is the calculation of environmental impact. This calculation runs in the background every time the user changes a material or property of a component. It only includes the components that have a 'true' statement for the `IfcIncluded` property (described in Section 5.5.1). Furthermore, it considers the remaining lifespan if this property is altered for a material. This use case has been successfully implemented.

The sixth and seventh use cases are the export of the environmental calculation report and the export of the BIM model to IFC. Both these use cases have been implemented successfully, a user can export the calculation report into a PDF file which contains the environmental impact per building phase and per category. It also contains a list of included and excluded components to verify the calculation. For share-ability and to recalculate the BIM model at another point in time and IFC is downloadable containing all the properties that may have been altered when using BEE.

5.6.5 Future improvement

As mentioned before, the use cases are successfully implemented, but BEE is limited to two parts. First, the tool is limited to size of the IFC input file, the maximum capability during the testing was 100MB. This issue comes from the method of using the STEP file using the IFC.JS framework. Therefore, it is suggested to look at improving the IFC.JS framework or to use a different file format and platform to handle BIM data. Future research could give insight into the alternatives that are better suited for web applications. Second, BEE is limited by the use of a custom environmental database that does not contain environmental data for all components. Future improvement can be found in the expansion of this database or by directly connecting to an existing database such as the NMD.

Chapter 6

Case Study ABN AMRO

6.1 Introduction

This research proposes two methods to improve the environmental ambition and assessment in the office renovation process. To evaluate performance in a real world situation, this research conducts a case study in which the proposed methods are implemented. This case study was conducted for an ABN AMRO office refurbishment project in Diemen, The Netherlands.
The office renovation is carried out by the main contractor Strukton Workshpere, who is the leader of the building team. Together with multiple contractors of multiple disciplines, they are contracted to renovate 3500 m2 of office space while achieving the sustainability and environmental goals of ABN AMRO. Another motivation for office refurbishment is the legislation of the Dutch government, which obliges office buildings to have an energy label C or better. Due to the COVID-19 pandemic, ABN AMRO reassessed its office space needs and this allowed further improvements in terms of sustainability and circularity in the design process.
This section describes the difficulties the office market poses, the overall outline of the refurbishment process, how the CNET-DA method is implemented and how BEE could be used to assess the environmental impact.

6.2 Tenant v.s. Building owner

In many cases, the owner of an office building is not the user of the building. As in the case for the office of ABN AMRO in Diemen. Office buildings are rented out, and the tenant uses the building for conducting their business. Not owning a building is an advantage for businesses since they do not require to invest heavily into a property, instead they only have to worry about the rent. Tenants can also view it as flexibility, as is the case for ABN AMRO, since their long-term vision involves a more centralised office approach rather than many smaller locations.
While the refurbishment process is intended as an upgrade for an office building, and key aspects are the reduction of energy usage and sustainability. Building owners lack attention to improve their real estate portfolio (Martens, 2020). Martens (2020) also found

that market value is the main driver in investment decisions and energy performance is based solely on initial costs. However, the research of Martens (2020) did identify the willingness of tenants to invest in reducing energy usage and improving sustainability. As in the case of ABN AMRO for Diemen office refurbishment.
However, this willingness to invest does not remove the boundaries that occur in the refurbishment process. The building owner and the tenant must be on the same line regarding the investments and changes that come with the building. Energy measures such as insulation, the addition of solar panels and the replacement of windows are big investments and take many years to see a return on the investment.

Dutch legislation provides tenant support in the process of convincing real estate owners to improve the environmental performance of the building with the label C requirement as mentioned before. Instability in the Dutch energy market in October 2021 and March 2022 has driven fossil fuels to record heights (NU.nl/ANP, 2022), which will decrease the time to see return on investment for building owners and stimulate environmental investments.

6.3 Refurbishment design

6.3.1 Building description

The ABN AMRO office building, located at Wisselwerking 58 in Diemen, The Netherlands, is a five-story tall building with a half-underground parking lot. The first four floors are dedicated office space, the fifth floor is for the buildings' installations. In total, the building contains over 7000 m2 of office space, the building is split vertically into two sections of 3500 m2. The refurbishments of the building consist of only half of the office space. In addition to the internal 3500 m2, it also regards the exterior facade and the roof.

Within the 3500 m2 of office space, there is space for 165 call centre workplaces, 360 Arbo workplaces (workplaces compliant with Dutch health and safety standards), and 70 additional workplaces such as concentration work spaces, meeting and brainstorm rooms, and touchdown spaces.

Environmental ambition

The environmental ambition of ABN AMRO consists of five key aspects:

- Reduce environmental impact by implementing the C2C principles
- Preference for second-use materials
- Minimize waste
- Maximum energy usage of 50 kWh per m2
- All energy must be generated sustainably.

Within this set of ambitions, Strukton and the building team consisting of contractors and designers have the freedom to invest in anything that helps to achieve the goals when a return on investment is expected to be within five years. Furthermore, Strukton has been granted the tender in which they also note that all materials removed from the building will be recycled for a minimum of 85%.

Regarding the aspects of minimizing waste and the preference for second-use materials, inventories have been made of the office location prior to the refurbishment process, as well as other locations that are no longer in use. These inventories have described the state as is and suggest materials that could be reused. Most of the materials are in the stuff layer and the space plan layer as described in Chapter 4. These inventories have been implemented to reuse materials such as partitioning office walls and doors, bins, ceiling systems, furniture, and complete toilets.

Regarding sustainably generated energy, designers have taken the measure of filling the roof with solar panels to generate as much energy as possible. To assess energy usage, energy meters have been implemented on each floor in each building section to enable local monitoring.

COVID-19 impact

Due to the COVID-19 pandemic that began just before the original refurbishment plans were executed, the designers were forced to adjust the plans. The focus of ABN AMRO shifted from high-intensity office buildings with lots of workplaces into an office which is used as a meeting place. Adjustment of design plans allowed one to simultaneously reduce the environmental impact generated by planned refurbishment works and implement more reused materials.

BIM model

To assess the state of the art of the building and generate drawings on which new plans can be projected, a BIM model of the building is generated. Since no previous BIM model was available, the current state of the building is captured using 3D laser scanning. This generates a point cloud that has been converted to a BIM model. In the BIM model, engineers have drawn the new office layout, installations, and floor plans. In the BIM protocol, the design parties have agreed to achieve a LOD 500, which means there is a high level of information available regarding the building components, its material properties, quantities, and geometry. This allows the implementation of environmental assessment tools such as BEE that use this information to calculate the environmental impact of a building.

6.4 Implementation CNET-DA

6.4.1 Outline

CNET-DA is implemented in the case study to assess decision-making about design choices. This is done by conducting interviews with key stakeholders. For this, five important stakeholders are identified. Two decision makers from the client, one decision maker from the engineering company and two design makers from the contractors company, one of which acts as project leader and the other as sustainability consultant.

The goal of using CNET-DA is to determine the important attributes and aspects of decision makers and to verify whether the clients' preferences are represented by the contracting parties. Furthermore, the aim is to identify incentives in the design process that drive towards sustainable or circular design choices. Furthermore, the case study should provide feedback from key stakeholder on verifying the implementation of the tool and verify that there is a benefit in using CNET-DA.

To test the CNET assistant and verify the decisions made in the project, the alternatives for all of the 6 different shearing layers of the building have to be determined first. Since the building is not re-positioned on another site, the layer 'site' is ignored. Furthermore, the structure of the building is untouched and therefore the 'structure' layer is also ignored.

The alternatives for the following shearing layers are the result of the building team that conducts the refurbishment. This building team consists of an architect, a construction company, a service installer, and various advisors. A building inspection is conducted to determine the state of the art, after which they all individually and together think out the different options that are available. From this option set, they eventually made choices that result in the final refurbishment package. The goal is to improve on the decision process and figure out what factors are weighing the most in deciding on refurbishment measures. Besides the alternatives mentioned, there are always different possibilities foreshadowing the invention of new technologies and materials. The aim is to illustrate the method and how it works in the case study.

For each of the alternative sets mentioned below, CNET-DA is used to figure out which alternative is the best suiting the customer demand. In total, CNET-DA is conducted 8 times to cover all shearing layers of a building. The benefits that are part of the alternatives are created by the expert filling in the CNET-DA method.

Some choice options could be considered part of multiple shearing layers. The division is made whether it has a visual impact or not. For example, photo voltaic panels (PV) on the roof or facade are strictly part of the 'services' layer. However, because of the high visual impact, it influences the way the building appears to the outside, they are part of the 'skin' layer.

skin

In the case study, the building's skin is considered being a point that can be refurbished. The Skin is split into two different sections, the roof and the facade. The different options are shown in Table 6.1.

Roof	*Facade*
• Leaving roof untouched • New layer of roofing material (overlay) • Adding a green roof • Adding solar panels on top of new roofing material	• Leaving facade untouched • Adding facade foil to increase looks • Adding green wall to part of the facade • Adding second layer of insulation • Applying solar panels instead of existing glass panels • Applying solar foil to existing glass panels

Table 6.1: Options for the different components of the 'skin' layer

services

For the services part, there are options that also overlay with the skin layer since the solar panels are mounted on the outside. Therefore, they are not further considered in the services section. Since elevators are in good condition, there are no alternatives or plans to refurbish these, therefore they are ignored. Furthermore, the services are further split into HVAC systems and lighting. The different options are shown in Table 6.2.

HVAC System	*Lighting*
• Keep existing building installation • Upgrade existing installations for energy efficiency • Completely replace the existing installation	• Replace and try to reuse existing lighting in other project • Refurbish and change existing lighting into LED • Leave as is

Table 6.2: Options for the different components of the 'services' layer

space plan

Besides the actual space plan, the shearing layer can be further subdivided into space plan, floor coverings and interior walls. The different options are shown in Table 6.3.

Space Plan	*Floor Coverings*	*Interior walls*
• Existing layout • High density open plan • Low density open plan	• Keep existing carpet tiles • New carpet tiles • recycle old carpet tiles and use new circular carpet tiles	• Closed walls • Glass walls, repurposed from old locations if possible

Table 6.3: Options for the different components of the 'space plan' layer

stuff

The last building shearing layer is stuff, this contains components that move monthly or even daily, such as furniture and appliances. The different options are shown in Table 6.4.

Stuff
• Reclaim furniture of old ABN Amro locations • Use reclaimed furniture of any location • Use new furniture • Hybrid, reclaimed ABN Amro furniture with additional new furniture.

Table 6.4: Options for the different components of the 'stuff' layer

6.4.2 Attributes and Benefits

In the previous section, the alternatives for the different building components are described. To assess the alternatives and assist decision makers in making their decision, it is important to also identify the attributes and benefits.

Since multiple decision makers are at stake for making a choice in the renovation project, a general set of attributes and benefits is identified before using CNET-DA. The set of attributes and benefits in Table 6.5 is developed using the input of decision makers and consultants during a brainstorm session. The table shows which attributes and which benefits were identified and also for which decision problem they have been identified. Despite the list of identified attributes and benefits, the user of CNET-DA still has the freedom and is stimulated to adjust the list of attributes and benefits to their preference. The CNET-DA software tool does not connect attributes to a specific benefit beforehand like the table below might suggest. This separation is intentional to ensure the user is not biased while using CNET-DA.

6.4.3 Interview design

The interviews conducted were all scheduled for one hour. Within this hour, the decision maker (interviewee) was asked to answer the questions in CNET-DA for three decision problems. The decision problems were identified earlier in Section 6.4 but to constrain the time of the interviews, four decision problems were identified that were relevant to the case. These problems are for the measures on the Roof, the HVAC system, the lighting, the facade, and the flooring. The interviewees were left free to choose three out of these four options. A full list of interviewees and the decision problems they answered can be found in Appendix B.

Attribute	***Benefit***	***Roof***	***Facade***	***HVAC System***	***Lighting***	***Space Plan***	***Floor Covering***	***Interior walls***
Aesthetics	Employee productivity	✓	✓		✓	✓	✓	✓
	Social image	✓	✓		✓	✓	✓	✓
Comfort	Employee productivity	✓	✓	✓	✓	✓	✓	
Energy performance	Energy usage	✓	✓	✓	✓			
	Environmental footprint	✓	✓	✓	✓			
	Financial costs	✓	✓	✓	✓			
	Social image	✓	✓	✓	✓			
Flexibility, re-usability	Environmental footprint	✓	✓	✓	✓	✓	✓	✓
	Financial costs	✓	✓	✓	✓	✓	✓	✓
Heat protection	Financial costs	✓	✓	✓				
	Employee productivity	✓	✓	✓				
Investment costs	Financial costs	✓	✓	✓	✓	✓	✓	✓
Maintenance interval	Financial costs	✓	✓	✓	✓		✓	
	Process impediment	✓	✓	✓	✓		✓	
Operational costs	Financial costs	✓	✓	✓	✓	✓		
Portion new material	Environmental footprint	✓	✓		✓		✓	✓
	Social image	✓	✓		✓		✓	✓
Space use	Efficient space use	✓		✓		✓		
	Financial costs	✓				✓		
Water buffer	Climate adaptation	✓	✓					

Table 6.5: Attribute and Benefits defined before conducting CNET-DA interviews

The interview started by explaining the objective of the interview, after which the interviewee was asked to choose one of the decision problems. The interviewee then goes through the steps of CNET-DA explaining along the way what question they are answering and verifying their interpretation of the question. All respondents were helped walking through the steps of CNET-DA by the interviewer and received a verbal explanation of what they were expected to do. Next, when the utility results of the decision problems are shown, the interviewee is asked if they could find themselves in the results and how they feel regarding the importance and preferences values of the attributes and benefits that they identified. The results of this are shown in Section 6.4.4.

After conducting the steps in CNET-DA for all three decision problems, the interviewee is asked open ended questions to identify how they feel about using CNET-DA: If they feel the utilities represent their personal feelings about the alternatives. Whether they would see the added value of using CNET-DA in the refurbishment process. If they would like to implement it in the future design process, and if they feel like they gained new insight by using CNET-DA. This resulted in qualitative feedback, further discussed in Section 6.4.5.

6.4.4 Results

In Table 6.6 the overall identified benefits are shown with their respective link strength values (S_{jk}). The higher the value, the stronger the link. The value is always between 0 and 1. The count indicates how often the link was identified. The overall count of identified attribute benefit links is shown in the Appendix C Table C.1. Table 6.7 shows the mean importance values (α_k for the benefits identified during the interviews with decision makers. The higher the value, the more important. The tables with results of individual interviews as well as an full overview can be found in Appendix C

From the results in Table 6.7, it can be concluded that 'total costs' have the highest importance. This is not surprising and is an expected steering element for decision problems. Other incentives, such as energy usage and environmental footprint also stand out. Respondents show less deviation on the aspects of social image, process impediment, and employee productivity while they are still relative important.

Attribute (j)	**Benefit** (k)	**Min** (S_{jk})	**Max** (S_{jk})	**Mean** (S_{jk})	**St. Dev.**	**Count**
Comfort	Efficient space usage	1	1	1	0	1
	Employee productivity	0.48	1	0.73	0.12	3
	Environmental footprint	0.46	0.46	0.46	0	1
	Social image	0.45	0.45	0.45	0	1
	Process impediment	0.42	0.44	0.43	0	1
	Energy usage	0.22	0.22	0.22	0	1
Energy performance	Climate adaptation	1	1	1	0	1
	Energy usage	0.29	1	0.58	0.04	5
	Social image	0.30	1	0.55	0.11	3
	Environmental footprint	0.22	0.44	0.35	0.04	3
	Total costs	0	0.33	0.16	0.04	5
Aesthetics	Efficient space usage	1	1	1	0	2
	Employee productivity	0.51	1	0.86	0.10	2
	Social image	0.30	1	0.65	0.16	3
	Environmental footprint	0.22	0.45	0.31	0	3
	Energy usage	0.24	0.29	0.27	0	2
	Climate adaptation	0.23	0.27	0.25	0	2
Heat protection	Climate adaptation	0.21	1	0.5	0	4
	Employee productivity	0.49	0.49	0.49	0	1
	Environmental footprint	0.27	0.56	0.40	0	4
	Energy usage	0.27	0.47	0.38	0	5
Investment costs	Total costs	0.23	0.75	0.54	0.05	5
	Energy usage	0.42	0.42	0.42	0	1
Maintenance interval	Process impediment	0.31	1	0.84	0.14	3
	Social image	0.45	0.45	0.45	0	1
	Employee productivity	0.30	0.38	0.34	0	1
	Total costs	0.17	0.50	0.29	0.03	5
Operational cost	Energy usage	0.45	0.52	0.48	0.01	3
	Employee productivity	0.23	0.38	0.31	0	1
	Process impediment	0.26	0.26	0.26	0	1
	Total costs	0.10	0.19	0.17	0.02	3
Quantity new material	Environmental footprint	0.54	1	0.77	0.09	3
	Social image	0.33	1	0.72	0.12	2
	Total costs	0.02	0.18	0.1	0	2
Water buffer	Climate adaptation	0.35	0.79	0.63	0	4
	Environmental footprint	0.29	0.69	0.51	0	3
	Social image	0.40	0.40	0.40	0	1
	Energy usage	0.38	0.38	0.38	0	1

Table 6.6: Identified attribute - benefits links and there respective mean link strength value.
Higher indicates a stronger link value range 0 - 1

Benefit (k)	**Min** (α_k)	**Max** (α_k)	**Mean** (α_k)	**St. Dev.**
Total costs	1.33	2.87	1.94	0.44
Energy usage	0.46	1.59	0.95	0.33
Climate adaptation	0.24	1.30	0.74	0.43
Environmental footprint	0.51	1.14	0.81	0.20
Social image	0.30	1.04	0.67	0.24
Employee productivity	0.25	1.20	0.66	0.32
Process impediment	0.22	1.02	0.53	0.28
Efficient space use	0.15	0.26	0.22	0.05

Table 6.7: Identified mean importance values of benefit (k)
Higher is more important, value range 0 - ∞

Considering the results of the alternatives for the roof of the case building, there is a strong preference for the green roof. This is shown in Table 6.8. This is contrary to the final design choice that was made during the project. This indicates that there are other factors that outweigh the preference for the green roof. The main supporters of the green roof are the social image and employee productivity. This essentially means that visible green would benefit the social image and employee productivity. From the perspective of a designer, bound by the usability to create a green roof, other solutions such as the creation of a park of green facades could be investigated to comply with the decision makers preference of green. This shows that not only the utility should be considered in the design process, but also that it helps to understand the preferences of decision makers, allowing a better fit of design.

The results also show that there are attributes that are not of the same importance to all interviewees, indicating the importance of aiming for the same design goals.

Alternative (i)	**Min**	**Max**	**Mean** (U_i)	**St. Dev.**
Adding green roof	3.72	5.34	4.56	0.54
New layer of roofing material	2.15	3.93	3.16	0.69
Placement of solar panels	1.36	3.43	2.43	0.71
No measures	0.92	1.49	1.08	0.21

Table 6.8: Utility values for roof alternatives - Skin layer
Higher indicates a better fit, value range 0 - ∞

For the lights, the preferences is strongly for the replacement of all the lights for new ones. This is in line with the final design choices of the case project. The utilities in Table 6.9 show a strong general preference to improve the lighting system over the current lighting system. The full list of respondents and their respective utility, links strengths and benefit weights can be found in Appendix C Table C.5.

Alternative (i)	**Max**	**Mean** (U_i)	**St. Dev.**
Replace and try to reuse existing lighting on other project	5.01	4.42	0.52
Refurbish and change existing lighting into LED	4.43	3.39	1.01
Leave as is	2.00	1.63	0.37

Table 6.9: Utility values for lighting - Services layer
Higher indicates a better fit, value range 0 - ∞

The utility of the different flooring alternatives is shown in Table 6.10. There is a strong tendency to replace existing carpet tiles. However, there is no real strong preference between the circular or traditional carpet tiles. Some respondents even showed a slight preference for traditional carpet tiles. The reason behind this is the strong preference for aesthetics and comfort and the reasonably unimportant preferences for environmental impact. The final design choice of the case project was the replacement with circular carpet tiles, which is supported by the slight preference for utility.

Alternative (i)	**Min**	**Max**	**Mean** (U_i)	**St. Dev.**
New carpet tiles (traditional)	2.92	3.93	3.43	0.51
Recycle old and new (circular) carpet tiles	2.40	2.93	2.67	0.27
Keep existing carpet tiles	0.99	1.51	1.25	0.26

Table 6.10: Utility values for flooring - Space plan layer
Higher indicates a better fit, value range 0 - ∞

The utilities for the HVAC system shown in Table 6.11 show the preference to upgrade or improve the building installation. The main drivers for this are employee productivity due to the expected improved comfort and the reduction of energy, improving the overall energy performance. During the ABN project, the installation is upgraded which is in line with the preferences. The difference between upgrading and completely replacing the installation is minor compared to the great difference between leaving the installation as is. The full table can be found in Appendix C Table C.11.

Alternative (j)	**Min**	**Max**	**Mean** (U_i)	**St. Dev.**
Replace HVAC in total	3.53	4.99	4.26	0.73
Optimize existing HVAC	2.79	4.32	3.555	0.765
Keep existing HVAC	1	2.47	1.735	0.735

Table 6.11: Utility values for HVAC - Services layer
Higher indicates a better fit, value range 0 - ∞

6.4.5 User feedback

To gain insight into the usability of the CNET-DA tool a user acceptance test is conducted. The results are registered as accepted or rejected. During the interview, each respondent was asked the same set of questions. First, if they felt like the outcome of the decision problem represented their thoughts and beliefs. Second, if the outcome of the decision assistant gave the respondent new insight into their own preferences. Third, whether the responded found the steps, questions and overall walk-through the CNET-DA intuitive. Fourth, whether they felt like they would benefit from using CNET-DA to gain insight into their decision preferences. Fifth and last, if they would be willing to use CNET-DA in a future project. The statements are shown in Table 6.12, and the results are shown in Table 6.13.

Statement number	**Summary of interview statements**
1	Outcome of CNET-DA represents thoughts and beliefs of respondent
2	Respondent gained new insight in preferences by using CNET-DA
3	Respondent feels like the CNET-DA tool step and asked question are intuitive
4	Respondent feels CNET-DA has added value to evaluate preferences
5	Respondent would be willing to implement CNET-DA in future project

Table 6.12: Summary of interview statements - CNET-DA user acceptance test

		Respondent 1	*Respondent 2*	*Respondent 3*	*Respondent 4*	*Respondent 5*	*Total Accept/Reject*
1 Representative outcome		✓	✗	✓	✓	✓	4/1
2 Gaining new insight		✓	✗	✓	✓	✗	3/2
3 Intuitiveness	Step 1	✓	✓	✓	✓	✓	5/0
	Step 2	✓	✗	✓	✓	✓	4/1
	Step 3	✓	✓	✓	✓	✓	5/0
	Step 4	✓	✓	✓	✓	✓	5/0
	Step 5	✓	✓	✓	✓	✓	5/0
4 CNET-DA has added value		✓	✓	✓	✓	✗	4/1
5 Willingness of implementation		✓	✓	✓	✓	✓	5/0

Table 6.13: User acceptance test CNET-DA

Outcome review

On the question if the respondent felt like the outcome properly represented their thoughts and beliefs, 5/5 respondents felt that the results show their personal preference. In case of roof decision problem 2/5 respond defensively that it was not a viable option to have green on the roof since it was the only location on which solar panels could be placed. On this, the suggestion was made if they would also be satisfied with other types of green infill around the building to achieve the benefits of 'employee productivity and 'social image, which both respondents acknowledged as a viable option. 1/5 respondents questioned the outcome of the 'facade' decision problem and asked for reiteration of the importance values. Changes in importance values did not lead to a change in rank of the outcome. This is because the importance values are considered relative to each other, so reducing all importance and not altering the relative differences did not change the utility order. The respondent, however, did agree with the result of the second iteration of the decision problem, which did bring the utilities closer to one another.

Gaining insight

The second question, if the respondent gained new insight, resulted in 3/5 respondents having gained new insights. All 3 respondents had gained new insight on the circular carpet tiles. They did not expect to have a insignificant preference difference between the alternatives of 'circular carpet tiles' and 'traditional carpet tiles'. 1/5 respondents even had a slight preference for traditional carpet tiles and questioned why that could be, since the expected preference was for circular carpet tiles. The difference in preference was generated by the lack of importance on 'social image' and 'ecological footprint' and a high importance on 'process impediment' and 'employee productivity'. Reviewing the link strength and weights of the attributes and benefits, all 3/5 interviewees who gained new incentives understood how the two alternative tile types could be so close in utility.

Intuitiveness

User were asked if the steps of the CNET-DA tool, the questions asked, and the response method were intuitive. 5/5 users understood the first step of the tool which is defining the choice alternatives. The second step is adding the attributes and scoring them on a scale of ++ to − (++, +, 0, -, −). In the case study, attributes were identified and defined beforehand. 1/5 of the respondents added an attribute (water storage) to the roof decision problem. 4/5 respondents did not alter the alternatives. 5/5 respondents found the scale of ++ to − intuitive and easy to use. The third step of CNET-DA is to link benefits to attributes. None of the respondents added a benefit to the list of benefits identified in advance. They all responded positive to the intuitiveness of this step. The fourth step asks the users to identify the position of the alternatives regarding the attribute benefits links on a multi-point scale. The fifth and final step asks the respondents to identify the importance of an attribute benefit link. The last two steps are identified as intuitive by 5/5 of the respondents, and none experienced issues during these steps.

Added value

The fourth question asked respondents if they would see the benefit of using CNET-DA to gain insight into their decision preferences. 4/5 of the respondents were similar to each other and intrigued by the possibilities and insights of CNET-DA. They would be willing to implement CNET-DA in a future design process to identify client preferences early and possibly improve the design. 1/5 respondents liked the upsides of CNET-DA by quantifying the feels and needs but did not see the added benefit over using Excel based multicritera scoring tables. The respondent argued that the tables are more transparent and easier to use.

Willingness of implementation

On the fifth and last question, if they would be willing to use CNET-DA in a future project. 5/5 respondents would be willing to use CNET-DA in a future project.

Concluding

Overall, each interviewee responded positively to the CNET-DA tool. Respondents saw relevant information in the tool and were sometimes surprised by the results. Users found that it was easier to answer the questions and walk through the steps after the first decision problem was solved.

Users were also asked if they would see them implement the tool in the future design process. To this, they responded positively, as it provides more insight into the incentive and would like to see future implementation in the early design process.

6.4.6 Results

During the interview round, CNET-DA has been verified as a viable tool to identify the preferences of stakeholders in the design process. CNET-DA gives insight into the relevant attributes that decision makers consider in the design process.

Overall, each interviewee responded positively to the CNET-DA tool. Respondents saw relevant insight in the tool and were sometimes surprised about the output. Users found that it was easier to answer the questions and walk through the steps after the first decision problem was solved.

All respondents were helped walking through the steps of CNET-DA by the interviewer and received a verbal explanation of what they were expected to do. A strong learning curve was identified because after conducting the first decision problem, all interviewees were able to conduct the next decision problem without having to check if they understood the question right.

The results generally support the eventual design choices in the case study of the ABN-Amro office refurbishment. The roof layer shows different preferences, but the design goals could also be implemented differently from the suggested alternatives. The design goals are identified by the attribute-benefit links and their respective weights. These incentives that are otherwise qualitative rather than quantitative are weighed using CNET-DA. The benefits that influence the attribute and thus the alternative choice can only be identified by the use of CNET-DA since this method adds the benefit layer in contrast to other methods.

Decision makers felt like their mind was adequately represented when reviewing the results of a decision analysis. With the proper instructions, the decision maker was able to walk through the steps of the decision assistant tool quickly. The time-consuming effort issues as suggested in Chapter 5 are reduced by implementing the online tool for conducting CNET-DA and automated utility calculation. However, the initial setup to identify the decision problem and relevant attributes still depends heavily on the interviewer. In addition, the first decision problem that each interviewee responded to required the support of the interviewer in answering questions. Therefore, while reducing the boundaries for implementing CNET-DA in the design process, they are not mitigated fully.

6.5 Implementation BEE

This section describes how the proposed methodology of BEE is implemented for the case of ABN AMRO office refurbishment. It discusses the problems that arise during implementation and how they could be migrated in the future.

Input IFC

Implementing BEE starts with the input IFC file. order for the BIM model, which is an IFC file, to work directly when uploaded in the BEE application, the addition of two additional properties was necessary to the existing model. The first property is called `IfcIncluded` and determines if a material is considered in the environmental calculation. This property is a Boolean as described in Section 5.5.1, meaning it is a true or false value. The property is added using Revit 2022.

This is achieved by defining a new project parameter as shown in Figure 6.1 and 6.2. In the first screen 6.1 the name of the parameter is defined, this is identical to the property name `IfcIncluded`. The next screen asks for the data details of the parameter 6.2 and for which categories (components) the parameter should be added.

The second property is called `IfcLifespan` and contains the lifespan of a material in years. The default value is 1000, indicating its full life span and this equivalents to the default value of the NMD. This property is added in a similar fashion as the previous, with the only important difference being the type of parameter, the `IfcLifespan` is defined with the type *Number*, this type is called *Real* in the IFC format. The property is added using Revit 2022.

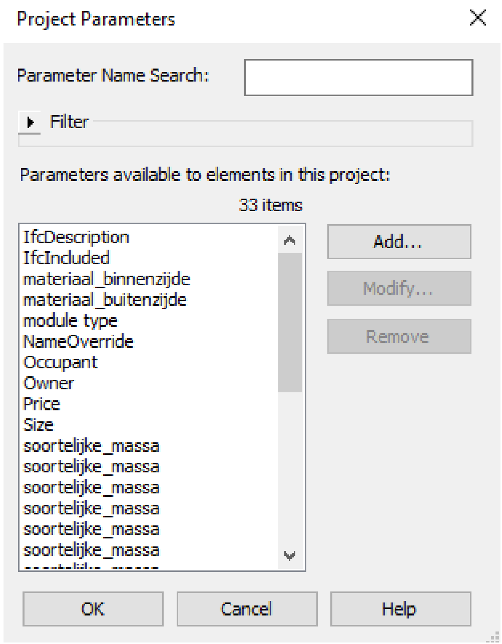

Figure 6.1: Revit: create new project parameter

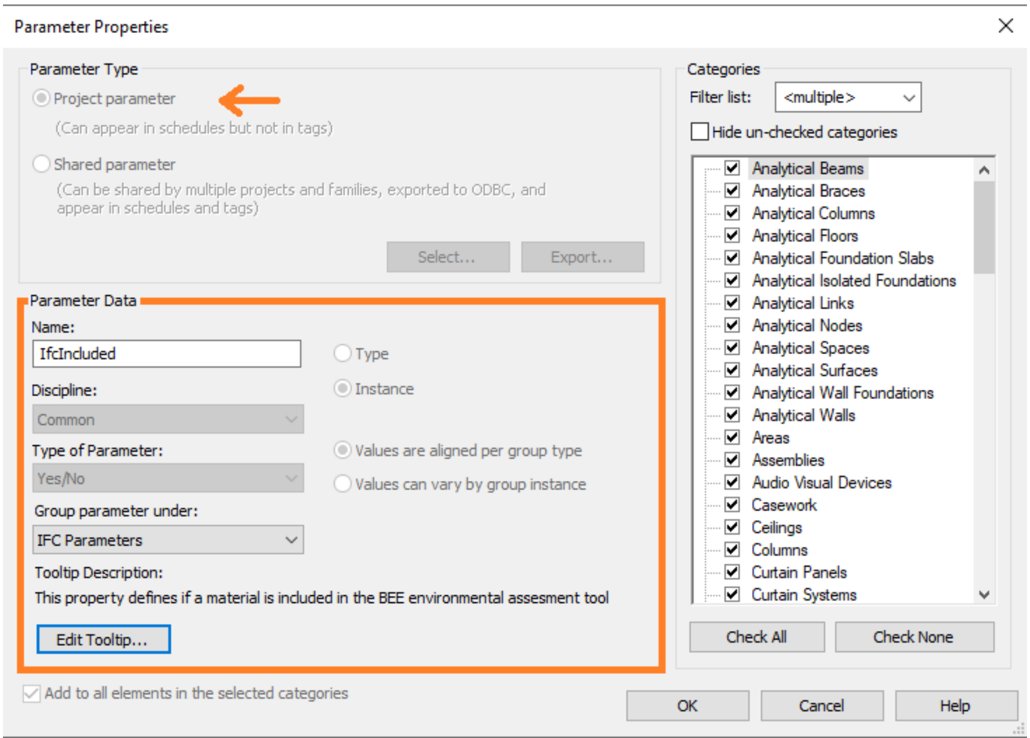

Figure 6.2: Revit: define new project parameter

When exporting the file from Revit a custom property set is used to export the required properties. The property set is stored as .txt file and in Revit is selected during the export to IFC process. A summary of the property set is shown in listing 6.5. In Appendix E, the full property set is shown.

```
PropertySet:  BEE I   IfcElement,IfcWall,IfcBeam...

        Q Lengte    Length  Length
  Q Hoogte    Length  Height
  Q Hoogte    Length  Unconnected Height
  Q Hoogte    Length  DesiredStair Height
  Q Hoogte    Length  RailingHeight
  Q Breedte/Dikte Length  Width
  Q Breedte/Dikte Length  Actual Run Width
  Q Dikte     Length  Thickness
  Q Omtrek    Length  Perimeter
  Q Diameter  Length  Diameter
  Q Oppervlakte   Area    Area
  Q Inhoud    Volume  Volume
  IfcIncluded Boolean IfcIncluded
  IfcLifespan Real    IfcLifespan
```

Listing 6.1 Environmental calculation algorithm

Calculating Environmental costs Index using BEE

When the IFC is loaded BEE can calculate the environmental impact expressed in the environmental costs index (MKI).

When loading the IFC file into BEE, issues with the tool were discovered. The tool is dependent on the IFC.JS library to handle the IFC format file. While 3D visualisation and navigation works good. The library requires extensive amount of time to load the component list of the building and sometimes the system crashed halfway because it lost track of its progress. It was identified the system preformed better when only considering one instead of multiple component types at once. This was discovered when trying to load an IFC that only contained one element type which kept the IFC file size below 100 MB while the full file causing crashing of the tool was over 300 MB.

To minimize calculation times and midi-gate implementation issues, environmental costs have been calculated for only the second phase of the refurbishment process. This is approximately half of the building and reduced the IFC file size to under 100 MB. Furthermore, calculations have been conducted that study one type of component at similar times. With these measures the calculation time was reduced to the range of 40-60 minutes and the tool would not crash.

To gain insight in renovation measures of the case study two components have been analysed. The first is the implementation of circular carpet tiles and how the environmental impact of this compares with traditional bitumen carpet tiles. The results are shown in Table 6.14 and the full report can be found in Appendix F. The results show that the environmental impact of the circular carpet tiles differ significantly for the traditional carpet tiles with a bitumen backer. The result of the CNET-DA decision problem for the carpet tiles decision problem (Table 6.10) showed that circular carpet tiles do not have a higher utility than the environmentally worse traditional carpet tiles. This higher utility indicates a stronger preference for the traditional carpet tiles while environmental costs differ significantly, and the choice has a large impact on the environmental impact of the refurbishment.

Floor-type	**MKI**	**GWP production**	**CNET-DA Mean U_i**
Circular carpet tiles	€ 48,787.-	5.09 kg CO2/M2	2.67
Traditional Bitumen tiles	€ 326,183.-	8.77 kg CO2/M2	3.43
Difference	€ 277,396.-		

Table 6.14: Difference in environmental costs of carpet tiles and the mean utility result of the CNET-DA case study

Secondly a calculation is conducted on the component of wall tiles. During the renovation process the existing tiles have been cleaned and replaced if they where damaged. Therefore, they are considered as re-purposed in this project. A calculation is conducted on the environmental impact in the case of the re-purposed tiles and compared to when tiles would be fully replaced. The results are shown in Table 6.15 and the full report can be found Appendix G. The cost indications are the environmental impacts expressed as the environmental costs index. The lifespan of the tiles has been estimated be a 10 year lifespan difference with replacing the tiles fully. Therefore, the lifespan is set to 65 years instead of the maximum life by the NMD of 75 years. The results show the environmental impact is almost halved by re-purposing the existing wall tiles.

Ceramic wall tiles	**MKI**	**Remaining Lifespan (R)**
Re-purposing existing wall tiles	€ 3601.-	65 Years
Complete new wall tiles	€ 6683.-	75 Years
Difference	€ 3082.-	

Table 6.15: Difference in environmental costs of reused wall tiles

6.6 Results

The case study has given insight in the implementation of the tools CNET-DA and BEE in the refurbishment process. Also the case study gave insight in the decisions made during the refurbishment and the environmental. It has also given the opportunity to test the tools and find out their limitations.

The CNET-DA tool has shown to give insight into the incentives of the decisions during the refurbishment process. While the result show the optimal result is not always implemented in the case it does indicate there are variables that are important to the decision makers but not taken into account during the design process. This confirms the gap indicated in the literature. It also shows there is an opportunity for designers to improve their design for the clients needs. The positive response from the interviewees on the tool and their experience that the results are in line with their feels and beliefs provide basis for further experimentation with the CNET-DA.

The application of BEE has shown how the environmental impact can be calculated for different components of BIM model. It also indicated the issues of scaleability when handling larger models and the limitations of the tool were identified. Insight is given for the components of floor carpet tiles and the reuse of wall tiles showing the choices made during the design process. For the before mentioned components the optimal design choice, considering the environmental costs, is made by the decision makers. Also, the case study has shown the tool is unable to handle IFC files formats over 100 MB, this limitation is accountable to the handling of the IFC file with the IFC.JS framework.

The in this thesis adopted IFC.JS framework is still in the early development stages and has not (yet) been designed for larger files sizes. As development of IFC.JS progresses the limitation could be mitigated and the usability of BEE would improve over time. Future improvement is uncertain since the development IFC.JS framework is not within the scope of this thesis.

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Chapter 7

Conclusion, Valorization & Discussion

This chapter states the conclusion. It starts with answering the research question and the sub-questions and is followed by the discussion. Afterward, the content of the thesis is discussed. Finally, recommendations and a future outlook are given.

7.1 Research Question

This research proposes methods to gain more insight into the early design process and the verification of refurbishment projects. Specifically, the research proposes a method to measure the preference of clients regarding their feels and needs for sustainable design choices in the refurbishment process. This allows the designers to tailor their design to the incentives of the client and understand why they prefer certain measures. On the other hand, the research is focused on creating a tool (BEE) for calculating the environmental costs index in a refurbishment process, which also allows for the implementation of reused materials. This includes a method to easily calculate the environmental impact of reused materials, without conducting a full LCA study but utilizing life cycle information from the NMD. The following research question has been answered:

How can designers implement MCDA to help clients decide on sustainable refurbishment measures and implement BIM with LCA to verify and quantify the environmental impact of refurbishment works?

To implement MCDA and assess the preferences of decision makers the CNET-DA method has been implemented. A methodology has been constructed and the building was divided into the shearing layers using the 6S model. The labor intensity issues of the CNET-DA method are minimized by designing and constructing a web application allowing to walk through the CNET-DA steps digitally, resulting in the automated calculation. This has been implemented in a case study refurbishment project of ABN Amro and reviewed by experts.

Implementation of LCA and BIM is achieved with the proposed tool BEE. This tool allows users to calculate the environmental cost index based on existing LCA environmental impact data and using BIM files, in the form of IFC, as data input.

Results of the implementation and case study of BEE and CNET-DA are discussed in the next section.

7.2 Sub-questions

Which LCA method is applicable for refurbishment works and what defines refurbishment works?

Existing methodologies allow for the assessment of building elements on a product level. The LCA is calculated according to the European committee for standardization (2021) and therefore it is a standardized norm. In this research, the elements are considered when they are combined into a BIM model and form a refurbishment design. This means the LCA deals with the total of materials that make up the building. Therefore, it is not exactly about what LCA method is applicable, but mainly which information source is the most useful. When considering existing databases with environmental data that have been determined via LCA calculations for building components, the NMD has been identified as the best suitable database. This database is the standard in the Netherlands and is also used by calculations, such as the MPG, which are sometimes mandatory for building permits.

When considering refurbishment works, not all components of the building are altered or newly added. For the refurbishment process, only components within the refurbishment project scope are considered in the environmental evaluation. Therefore, the proposition is made of evaluating the environmental impact of a refurbishment project as the sum of impact generated by materials within the scope. This research found the NMD does not contain information on materials that are reused or granted a second life. If such a building component or material had the environmental impact calculated as if it was a new product, the environmental impact would not be an incentive to reuse materials in that case, the reuse of material does not result in a lower environmental impact in the calculation. Therefore, this research proposes to consider only the environmental impact of the remaining life expectancy of a reused, re-purposed material or building component. This is calculated by dividing the environmental impact of the material if it was new, by the expected life of the material and multiplying this by the remaining life expectancy. This results in Equation 2.1. This method allows for a quick assessment of building components, without requiring the conduction of a full LCA method as described in the ISO 14044 and European committee for standardization (2021).

Which criteria and for what reasons are considered by real estate owners when deciding on refurbishment works?

During the case, study interviews were conducted with five major stakeholders using the CNET-DA tool. The CNET-DA tool allows gaining insight into the preferences of the interviewees regarding refurbishment decision problems. Besides the preferences, CNET-DA also identifies relevant attributes and benefits that fit the feels and needs of the interviewee. For every identified link between an attribute and benefit, the strength of the link is calculated. Furthermore, every benefit has an importance value calculated allowing the identification of the most important benefits for the decision makers.

From these interviews, the foremost reason for all the interviewees was the return on investment and thus overall costs. During the conduction of the case study using CNET-DA, the interviewers gave a high importance level for the benefit of lower total costs, with the reasoning that the return on investment is important. This criterion is not surprising and is also identified during the literature study. Along with the total costs the most important influencing benefits in respective order are the social image and the employee productivity. This shows that there are multiple factors addressing the decisions made during a design process and it is not solely determined by the costs. In Table 6.7 the average importance of all the identified benefits is shown. The overview of the identified attribute-benefit links and the strength of their respective links is shown in Table 6.6.

Regarding the design choices in the case study CNET-DA showed the decisions made in the refurbishment project did not always represent the eventual choices. This was identified for the 'roof' layer of the building for which every respondent showed the preference for a green roof with solar panels as a runner-up. In the project, the solar panels were implemented. Assessing the attribute-benefit links of the CNET-DA results showed the 'social image' and the employee 'productivity' as the main incentives for this preference. Designers could use this information to improve the design on another level to fulfill these needs and feels of the decision makers.

While it is a difficult to quantify what makes a design better for the social image and the employee productivity, the case study did show that the impact on the best fitting alternative was significant. For designers, it is key to understand how the decision makers aim to fulfill their needs for a good social image and high employee productivity, thus designers know they should steer their design on addressing those criteria.

How can the LCA calculation be automated using the building information model and additional energy calculations?

During this research, a method is proposed and developed to calculate the environmental impact of a building using BIM data and an Environmental database. The result of this development is a BIM based Environmental Evaluation (BEE) tool. The tool

extracts quantity information from an IFC file that is uploaded by the user and uses the NL-SfB code of the material to search the environmental impact from a material database. The environmental database used is manually filled with LCA environmental impact data from product sheets and the NMD. The tool allows the user to navigate the building in 3D and select a building component to edit the specific material of a building component or its lifespan. Furthermore, the user decides whether a building component should be considered in the environmental impact calculation via a checkbox.
After every alteration of the user, the environmental impact calculation is updated and gives the user real-time feedback. After a user has finished with alterations and the calculation, the user can export the results of the calculation as a PDF file and save the changes of building components to IFC. The whole application is developed as a Web-Application, which means any device with a compatible web browser can connect and use the BEE tool. Overall BEE is capable of automatically calculating the environmental impact using LCA environmental impact data. The tool relies on the user to upload an IFC that contains the required, therefore always requiring the expertise of a user to ensure the calculations are correct.

Which multi-criteria analysis can help real estate owners with decision-making in (circular) refurbishment decisions?

During the literature study, multiple methods to assess multi-criteria decision problems were identified. A major method considered is AHP, but this method has been criticized due to the influence of assessors during the final assessment. Furthermore, the goal was to identify not only the best-fitting alternative but also the criteria that are considered when determining the optimal alternative. Therefore, the implementation of CNET-DA is proposed as a new method in the area of building refurbishment to identify the preferences of decision makers and quantify the feels and needs in a utility for the set of choice alternatives.

Considering the above CNET-DA was developed to mitigate the labor-intensive handwritten methods, the calculation and process are automated into a web application, allowing for easy deployment and assessment of choice alternatives. The CNET-DA application is implemented in a case study of an ABN Amro office refurbishment, and the results identified important variables and criteria that decision makers consider. Identified considerations can help designers better fit the design to the client, improve the refurbishment process, and bridge the gap between the client's expectations and the contractor's work.

During the interview round of the case, study interviewees identified CNET-DA as a viable tool to identify the preferences of stakeholders in the design process. Interviewees responded positively to the intuitiveness of the tool and found the results of decision problems fit their own beliefs. The interviewees found the results of CNET-DA informative and helped to gain insight into important attributes and benefits. Lastly, all of the interviewees would be willing to implement CNET-DA in future projects. The individual response of the interviewees is shown in Table 6.13

How can reused material be implemented in the calculation?

During the literature study, it was identified the assessment of environmental impact regarding reused material and building components requires experts and information that is not always available during a refurbishment project. If reused materials have their impact calculated similarly if they are newly produced, there is no advantage or stimulation to reuse or refurbish materials in the first place. There are methods to fully calculate the LCA, but this requires high levels of expertise and in depth knowledge of the material. Therefore, this research suggests a linear connection between environmental impact and the lifespan of a material. This is proposed in Equation 2.1. The formula divides the object's environmental impact by its total life expectancy and multiplies this by the remaining life expectancy. The remaining life expectancy is a value in years determined by the assessor using BEE. Using this method, there is a direct stimulant in refurbishment projects to implement reused materials and components. Furthermore, it allows for quick and easy assessment of materials without having to conduct a complete new LCA study for the specific material that is reused.

7.3 Valorization

This research discussed CNET-DA and BEE as tools to improve the decision making process in the refurbishment process. While both CNET-DA and BEE have been implemented in the case study, no direct connection has been realized between the two tools. The proposed user for CNET-DA will differ from the user of BEE and therefore, there is no need for a combination of the two elements in one model. However, a feedback loop could be established to improve the decision making process and integrate the information on the environmental impact generated with BEE for the decision making in CNET-DA. By conducting the environmental impact analysis earlier in the process, the accuracy may be limited, but it does give an indication that can be used as an attribute in CNET-DA. The proposed feedback loop is shown in Figure 7.1. By creating the feedback loop and integrating BEE with CNET-DA an ultimate scenario arises allowing for improved decision making in the refurbishment process. This is beneficial for the decision makers who will get a better representation of their needs and feels, but also for the designer since they can better understand the requirements of their clients. Furthermore, by integrating the environmental impact cost index, the decision makers are directly confronted with the environmental impact of their decisions which forces them to take this into consideration when determining their preferences.

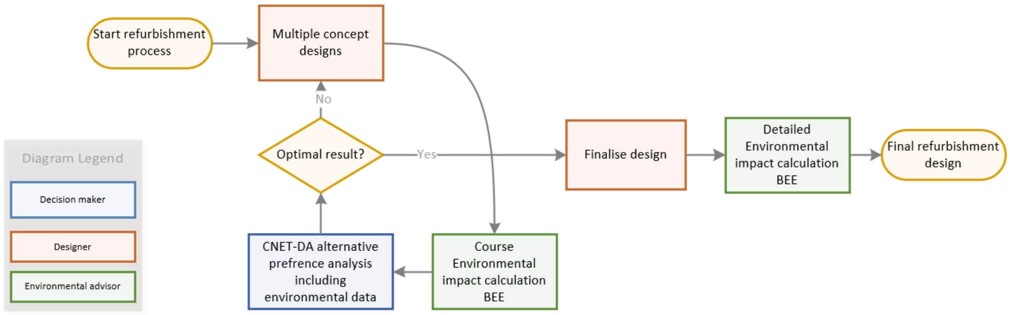

Figure 7.1: Integration of BEE and CNET-DA

7.4 Discussion

This research assessed CNET-DA in a case study to verify the choices made during the design process. To fully assess the potential of CNET-DA it would be necessary to conduct further research and test if the added value can be found in the early design process of multiple case studies. CNET-DA is new in the area of MCDA and therefore a broader investigation into the methods would be needed to identify the strengths and weaknesses. CNET-DA has not been tested directly against other MCDM method such as AHP and therefore the foundations for comparing the tool directly to other MCDM methods remain unstable. Further research could look into a direct comparison of the MCDM methods.

The CNET-DA tool as presented is the first iteration of the developed tool. The main aim has been digitizing the interview method and automating the calculation of attribute-benefit links, relative importance, and the overall utility of alternatives. The application is built according to the description of Arentze (2016) and visual design choices have been based only on the functionality. The CNET-DA tool is in early development and for it to be deployable as a foolproof stand-alone tool further design and improvement are needed. However, for testing purposes, the tool can be used by other researchers to improve further implementation. While the web-based approach through the angular framework and data format of JSON is not the most straightforward to use languages, it does provide a future proof basis as also identified during the development of BEE.

The presented application BEE in this research scratches only the surface of implementation possibilities of BIM and LCA. Currently, the BEE tool is capable of opening and exporting IFC files and conducting environmental impact calculations for IFC files with the specified property set. The user can navigate the IFC in 3D and select building components. The user can alter the NL-SfB material of building components and specify its lifespan in the case of reuse. The user can also export the file back to IFC containing all the alterations and print the report of the environmental impact calculation to PDF.

In the research design, the deliberate choice was made to conduct a case study and use a real-world BIM model. During the case study, it became clear that there is a big difference between the calculation of simple test models and a full real-world case. The choice of using IFC has the advantages of sharing data within the AEC industry and builds further upon the standard that is currently set. However, the STEP coding language creates many implementation problems and presents users of BEE with long processing times when using the application. Interpretation of geometrical information is not always possible and the IFC format does not allow for easy manipulation via the Angular framework that was implemented in this study. Possible solutions would be to convert the IFC into another file format that is easier to implement in web-based applications and that would improve information sharing. Because of the long processing times and the dependency of properties in the case file, the study could not fully conduct an environmental assessment of the full case building.

The input IFC file used in BEE requires the implementation of two additional properties (`IfcIncluded` and `IfcLifespan`). Furthermore, it is required to have materials identified by NL-SfB code and it should contain quantities. This limits the use of BEE to only IFC files that contain these properties.

The visualization and IFC handling of BEE are dependent on IFC.JS, this repository is still in early development. Improvement of IFC.JS could also lead to direct improvement of the processing times and mitigate issues that now occur when loading a given IFC file. Limitations of BEE are largely dependent on the utilization of IFC.JS and would not work without it. This makes the stability of the tool vulnerable if IFC.JS would no longer be supported or removed functionality.

BEE utilizes a custom designed MongoDB database containing environmental data. This database is built as an alternative to direct implementation with the NMD. This has been necessary, since the NMD does not openly provide direct API access to their database for research purposes. The funds for this research were insufficient to cope with the fees of direct API access. Connecting directly to the NMD would give access to more and more product specific environmental data which could open new perspectives on the usability of BEE and give more insight into the added value of the tool. However, the NMD is not perfect. The NMD contains many materials, such as concrete, for which they state an infinite life expectancy, and this is represented by 1000 years. In practice, the lifespan of 1000 years is unfeasible and would not be possible without regular maintenance intervals.

The split system architecture of BEE allows for future researchers to connect with other environmental databases or build custom applications on the environmental database currently utilized by BEE. An integrated approach could lead to a compacter system but it then remains questionable if the application could remain future proof.

Besides the used repositories in BEE, it is also dependent on the information input via IFC. As stated before, the current IFC format is questioned and improvements in the file format could lead to improvement in the interaction between applications in the AEC industry. Also, information stored in the property sets of the IFC determines if the file can be used as input in BEE. The property requirements must be met in order for the tool to function. The tool is unable to read building components without the right properties, this poses a risk, since there is no fault handling and building components could be missed resulting in a faulty environmental calculation.

7.5 Future Outlook & Recommendations

7.5.1 Integration

It is recommended for future research to conduct a case study in which the integration between CNET-DA and BEE is realized, such as proposed in Figure 7.1. From there, the potential for real-world application can be assessed and future steps can be determined. Currently, the integration of BEE is dependent on the users' input who, uses the CNET-DA needs and feels of the decision makers to optimize the result. The future outlook is the further out-roll of CNET-DA and BEE, which generates data that could be used to learn Artificial Intelligence (AI) to optimize the result automatically, depending on the building type and the users' type.

7.5.2 CNET-DA

This research has made a start in the implementation of CNET-DA as a tool to help decision makers decide on design choices. To unlock the further potential the recommendations are made to implement the tool in multiple case studies. Furthermore, the design and framework on which the tool is built could be deployed as an online application by which multiple users could assess the tool and use it on decision problems. Currently, CNET-DA is able to be deployed as a web application with a predefined list of decision alternatives, it does not contain any user authentication and therefore all predefined decision problems are accessible to all users. By creating a login module and project storage overview the tool can be implemented by users on multiple decision problems while safeguarding the information in an online platform. By creating one web application for all decision problems, the tool could gather information regarding attributes and benefits. By creating an algorithm that uses the information of previous decision problems, it could suggest and forecast attributes and benefits that are considered during a decision problem, improving the design and lowering the level of insight in creating choice alternatives.

The first step of the process in implementing the tool in future research is by creating a storage or upload method for decision problems and hosting the application on an online platform. Secondly, by creating documentation and course material the tool can be explained among students for experimentation and to stimulate use in future research. The third would be to collaborate with software designers to create the login environment and create a platform that is easily accessible and forth implements features such as a forecasting algorithm for attributes and benefits.

7.5.3 BEE

The implementation and case study were conducted while using BEE to calculate environmental calculations. During the implementation phase, the limitations of the tool as it currently built appeared. Therefore, the following recommendations are made:

IFC.JS

Currently, BEE uses the IFC.JS tool to load an IFC file directly. The IFC.JS tool is an open-source framework that is still in early development. This gives issues with loading times and visualizations of IFC models. It is therefore recommended to collaborate with the designers of IFC.JS to improve the framework and its documentation, to improve the framework and its ability to be implemented in tools such as BEE.

IFC file format

The BEE tool depends on the input of an IFC model. The model is limited by the IFC.JS framework and the calculation algorithm to 100 MB to ensure it is able to conduct the calculation. These issues arise when the algorithm reads the full STEP language that makes up the IFC and identifies the properties. The process of going through the step file and following all paths that lead to property sets are time consuming and heavy on computing. It is the question if the IFC file format which is written in the STEP language is the future for shareable BIM models. Therefore, future research should look into the IFC file format and how the share-ability can be maintained while reducing computing power on applications.

Environmental database

The case study in this research was confined by the environmental data publicly available. A direct connection to an existing environmental database such as the NMD has not been realized. Future research should look into further development that allows for direct connection to environmental data. This will allow using the BEE tool to its full potential without having to specify the environmental data characteristics for every component in the BIM model.

Reused materials

The Equation for calculating the environmental impact of the reused material shown in Equation 2.1 calculates the impact based on the total lifespan. The equation is proposed to generate data missing in the environmental database regarding the reuse of material. It does not account for the impact created by the process of reusing materials. The materials that are reused in renovation do not always have a material passport that provides this environmental data. Future research should investigate whether there are additional factors that should be implemented to accurately assess the impact of reused materials besides the impact of the material as if it was new.

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Appendix A

Calculation service

The code below is the calculation service that is utilized by the BEE application to determine the MKI.

```
import { Injectable } from '@angular/core';
import { BehaviorSubject, Observable } from 'rxjs';
import IFCObject from '../models/IFCObject';
import Phase from '../models/Phase';
import Material from '../models/Material';
import Characteristic from '../models/Characteristic';
import MaterialCharacteristics from '../models/MaterialCharacteristics';

@Injectable({
  providedIn: 'root'
})
export class CalculateService {

  private calculationSource: BehaviorSubject<any> = new BehaviorSubject<any>('');
  calculation: Observable<any> = this.calculationSource.asObservable();

  CHARACTERISTICS_CATEGORIES = [
    {cat: "ADPc", weight: 0.16},
    {cat: "ADPf", weight: 0.16},
    {cat: "GWP", weight: 0.05},
    {cat: "ODP", weight: 30},
    {cat: "POCP", weight: 2},
    {cat: "AP", weight: 4},
    {cat: "EP", weight: 9},
    {cat: "HTP", weight: 0.09},
    {cat: "FAETP", weight: 0.03},
    {cat: "MAETP", weight: 0.0001},
    {cat: "TETP", weight: 0.06},
  ];
  DEFAULT_LIFESPAN = 1000;

  constructor() { }

```

```
updateCalculation(ifcObjectList: IFCObject[]){

  let calculationData: any[] = [];

  ifcObjectList.forEach(ifcObject => {
    if(ifcObject.included){
      console.log(ifcObject.calculationData);
      ifcObject.calculationData.forEach(e => {
        let phaseMatch = calculationData.find(x => x.phase === e.phase);
        if(!phaseMatch){
          phaseMatch = {phase: e.phase, categories: []};
          calculationData.push(phaseMatch);
        }
        e.categories.forEach(ecat => {
          let cateMatch = phaseMatch.categories.find((x: { cat: string; }) => x.cat === ecat.cat);
          if(!cateMatch){
            cateMatch = {cat: ecat.cat, value: 0};
            phaseMatch.categories.push(cateMatch);
          }
          if(ecat.value > 0){
            cateMatch.value = cateMatch.value + ecat.value;
          }
        });
      });
    }
  });

  //Trigger calculation update view
  this.calculationSource.next(calculationData);
}

calculateSingle(ifcObject: IFCObject, phases: Phase[], materials: Material[], characteristics: Characteristic[], materialCharacteristics: MaterialCharacteristics[]){
  let materialMatch = materials.find(e => e.NL_SfB === ifcObject.NL_SfB);
  if(materialMatch){
    let multiplier = 1.0;

    if(materialMatch.FE === "m3"){
      multiplier = ifcObject.qVolume > 0 ?  ifcObject.qVolume : (ifcObject.qLength * ifcObject.qWidth * ifcObject.qHeight);
    } else if(materialMatch.FE === "m2"){
      multiplier = ifcObject.qArea > 0 ? ifcObject.qArea : (ifcObject.qLength * ifcObject.qWidth);
    } else {
      multiplier = ifcObject.qLength;
    }

    ifcObject = this.calculateMKI(
      ifcObject,
```

```
      multiplier,
      materialMatch,
      phases,
      characteristics,
      materialCharacteristics
    );

    return ifcObject;
  }
  return ifcObject;
}


calculateMKI(ifcObject: IFCObject, multiplier: number, material: Material, phases: Phase[], characteristics: Characteristic[], materialCharacteristics: MaterialCharacteristics[]){
  ifcObject.calculationData = [];
  phases.forEach(phase => {
    let calcMath = {phase: phase.Phase, categories: [{cat: "", value: 0}]};
    calcMath.categories = [];
    let matCharMatch = materialCharacteristics.find(e => e.Material_DBID === material.ID && phase.ID === e.PhaseID);
    if(matCharMatch){
      let charMatch = characteristics.find(e => e.ID === matCharMatch?.Material_DBID && e.Phase === phase.ID);
      if(charMatch){
        for(let i=0; i<this.CHARACTERISTICS_CATEGORIES.length; i++){
          if(ifcObject.lifespan === this.DEFAULT_LIFESPAN){
            ifcObject.lifespan = material.Lifespan;
          }
          let MKI: number = 0;
          let characteristicValue: any = charMatch[this.CHARACTERISTICS_CATEGORIES[i].cat as keyof Characteristic];
          if(typeof characteristicValue === 'object'){
            characteristicValue = characteristicValue.$numberDecimal;
          }

          console.log(this.CHARACTERISTICS_CATEGORIES[i].cat);
          console.log(characteristicValue);

          if(ifcObject.lifespan != material.Lifespan_max){
            MKI = Math.round(((multiplier * characteristicValue ) / material.Lifespan_max * ifcObject.lifespan * this.CHARACTERISTICS_CATEGORIES[i].weight) );
          } else {
            MKI = Math.round(multiplier * characteristicValue * this.CHARACTERISTICS_CATEGORIES[i].weight);
          }

          calcMath.categories.push({cat: this.CHARACTERISTICS_CATEGORIES[i].cat, value: MKI});
```

```
          }
          ifcObject.calculationData.push(calcMath);
        }
      }
    });

    return ifcObject;
  }
}
```

Listing A.1 Environmental calculation algorithm

Appendix B

List of interviewees for tool validation

Name	Company	Expertise	Date	Location
Gijs van Heijster	Strukton Worksphere	Sustainability, HVAC	22-02-2022	Worksphere Son
Sytze van Os	Strukton Worksphere	Project leader, Construction	04-03-2022	ABN Amro Diemen
Marco Bakker	ABN Amro - RHDHV	Asset management, HVAC	11-03-2022	ABN Amro Diemen
Arnold Verbeek	ABN Amro - RHDHV	Asset management	16-03-2022	Online meeting
Dirk Aarnoudse	BV3	HVAC, Consultancy	28-03-2022	Online meeting

Table B.1: Overview of the interviewees

	Decision problem				
Name	**Roof**	**Lights**	**Flooring**	**HVAC**	**Facade**
Gijs van Heijster	✓			✓	✓
Sytze van Os	✓	✓	✓		
Marco Bakker	✓	✓		✓	
Arnold Verbeek	✓	✓	✓		
Dirk Aarnoudse	✓				

Table B.2: Decision problems conducted per interviewee

Appendix C

Interview data

		Identified link count				
Attribute	**Benefit**	**Roof**	**Floor carpet**	**Lighting**	**Facade**	**HVAC**
Comfort	Environmental footprint			1		
	Efficient space usage			1		
	Energy usage			1		
	Social image			1		
	Proces impediment			1		1
	Employee productivity			3		2
	Total costs					1
Energy performance	Environmental footprint	3		1	1	1
	Energy usage	5		3	1	2
	Climate adaptation			1		1
	Social image	3		2		1
	Total costs	5		2	1	1
Quantity new material	Environmental footprint		2	3	1	2
	Social image		2	2	1	1
	Total costs			2		
Investment Costs	Energy usage	1				
	Total costs	5	2	3	1	2
Maintenance interval	Social image	1				
	Proces impediment	3	2	2	1	2
	Employee productivity		1	1		
	Total costs	5	2	3	1	2
Operational costs	Energy usage			3		1
	Proces impediment			1		1
	Employee productivity			1		1
	Total costs			3		2
Esthetics	Environmental footprint	3				
	Efficient space usage	2				
	Energy usage	2				
	Climate adaptation	2				
	Social image	3	1		1	
	Employee productivity	2	2		1	
Heat protection	Environmental footprint	4				
	Energy usage	5				
	Climate adaptation	4				
	Employee productivity	1				
Water buffer	Environmental footprint	3				
	Energy usage	1				
	Climate adaptation	4				
	Social image	1				

Table C.1: Identified attribute - benefit link count for the 5 decision problems

C.1 Roof (SKIN)

C.1.1 Roof: Utility table

Alternative (i)	**Resp. 1**	**Resp. 2**	**Resp. 4**	**Resp. 4**	**Resp. 5**	**Min Min**	**Max Max**	**Mean** (U_i)	**St. Dev.**
Adding green roof	5.34	4.67	4.78	4.30	3.72	3.72	5.34	4.56	0.54
New layer of roofing material	2.15	2.68	3.93	3.89	3.13	2.15	3.93	3.16	0.69
Placement of solar panels	2.00	1.36	3.43	2.85	2.50	1.36	3.43	2.43	0.71
No measures	0.92	1.00	1.00	1.00	1.49	0.92	1.49	1.08	0.21

Table C.2: Utility values for roof alternatives - Skin layer
Higher is more important, value range 0 - ∞

C.1.2 Roof: Attribute - Benefit link strengths

Attribute (j)	**Benefit** (k)	**Resp. 1**	**Resp. 2**	**Resp. 3**	**Resp. 4**	**Resp. 5**	**Min**	**Max**	**Mean** (S_{jk})	**St. Dev.**	**Count**
Energy performance	Environmental footprint	0.3	0.44	-	0.22	-	0.22	0.44	0.32	0.090921	3
	Energy usage	0.31	0.53	0.31	0.29	0.33	0.29	0.53	0.354	0.088904	5
	Social image	1	-	-	0.3	0.55	0.3	1	0.616667	0.289636	3
	total costs	0	0.17	0.33	0.12	0.15	0	0.33	0.154	0.105943	5
Investment costs	Energy usage			0.42	-	-	0.42	0.42	0.42	0	1
	total costs	0.5	0.55	0.23	0.49	0.48	0.23	0.55	0.45	0.112606	5
Maintenance interval	Social image	-	-	-	-	0.45	0.45	0.45	0.45	0	1
	Process impediment	-	1	1	1	-	1	1	1	0	3
	total costs	0.5	0.28	0.44	0.38	0.38	0.28	0.5	0.396	0.073103	5
Aesthetics	Environmental footprint	0.25	-	-	0.22	0.45	0.22	0.45	0.306667	0.102089	3
	Efficient space use	1	-	-	-	1	1	1	1	0	2
	Energy usage	0.24	-	-	0.29	-	0.24	0.29	0.265	0.025	2
	Climate adaptation	0.23	-	-	0.27	-	0.23	0.27	0.25	0.02	2
	Social image	-	1	1	0.3	-	0.3	1	0.766667	0.329983	3
	Employee productivity	-	1	-	-	0.51	0.51	1	0.755	0.245	2
Heat protection	Environmental footprint	0.45	0.56	0.31	0.27	-	0.27	0.56	0.3975	0.11519	4
	Energy usage	0.45	0.47	0.27	0.41	0.3	0.27	0.47	0.38	0.080498	5
	Climate adaptation	-	0.21	0.41	0.38	1	0.21	1	0.5	0.29858	4
	Employee productivity	-	-	-	-	0.49	0.49	0.49	0.49	0	1
Water buffer	Environmental footprint	-	-	0.69	0.29	0.55	0.29	0.69	0.51	0.165731	3
	Energy usage	-	-	-	-	0.38	0.38	0.38	0.38	0	1
	Climate adaptation	0.77	0.79	0.59	0.35	-	0.35	0.79	0.625	0.176847	4
	Social image	-	-	-	0.4	-	0.4	0.4	0.4	0	1

Table C.3: Attribute benefit link strengths; higher indicates stronger link. Values between 0 - 1

C.1.3 Roof: Benefit importance

Benefit (k)	**Resp. 1**	**Resp. 2**	**Resp. 3**	**Resp. 4**	**Resp. 5**	**Min**	**Max**	**Mean** (α)	**St. Dev.**	**Count**
Total costs	2.01	1.81	1.50	2.03	2.10	1.50	2.10	1.89	0.22	5
Energy usage	1.12	0.75	1.59	0.85	1.32	0.75	1.59	1.13	0.31	5
Climate adaptation	1.30	1.27	0.85	0.93	0.30	0.30	1.30	0.93	0.36	5
Environmental footprint	1.12	0.68	0.72	1.14	0.91	0.68	1.14	0.91	0.19	5
Social image	0.30	0.74	1.00	0.83	0.47	0.30	1.00	0.67	0.25	5
Employee productivity	-	0.26	-	-	0.63	0.26	0.63	0.45	0.19	2
Proces impediment	-	0.50	0.34	0.22	-	0.22	0.50	0.35	0.11	3
Efficient space use	0.15	-	-	-	0.26	0.15	0.26	0.21	0.06	2

Table C.4: Importance values for the identified benefit, the higher value is the higher importance, values from 0 - ∞

C.2 Lighting (SERVICES)

C.2.1 Lighting: Utility table

Alternative (i)	**Resp. 1**	**Resp. 3**	**Resp. 4**	**Max**	**Mean** (U_i)	**St. Dev.**
Replace and try to reuse existing lighting on other project	4.50	3.75	5.01	5.01	4.42	0.52
Refurbish and change existing lighting into LED	2.02	3.72	4.43	4.43	3.39	1.01
Leave as is	1.78	2.00	1.12	2.00	1.63	0.37

Table C.5: Utility values for lighting - Services layer
Higher is more important, value range 0 - ∞

C.2.2 Lighting: Attribute - Benefit link strength

Attribute (j)	**Benefit** (k)	**Resp. 1**	**Resp. 2**	**Resp. 4**	**Max**	**Mean** (S_{jk})	**Std. Dev.**	**Count**
Comfort	Environmental footprint	-	0.46	-	0.46	0.46	0	1
	Efficient space usage	1	-	-	1	1	0	1
	Energy usage	0.22	-	-	0.22	0.22	0	1
	Social image	0.45	-	-	0.45	0.45	0	1
	Process impediment	-	-	0.42	0.42	0.42	0	1
	Employee productivity	1	1	0.48	1	0.826667	0.24513	3
Energy performance	Environmental footprint	-	-	0.43	0.43	0.43	0	1
	Energy usage	0.33	0.5	0.48	0.5	0.436667	0.075865	3
	Climate adaptation	-	-	1	1	1	0	1
	Social image	0.55	-	0.42	0.55	0.485	0.065	2
	Total costs	0.11	0.18	-	0.18	0.145	0.035	2
Quantity new material	Environmental footprint	1	0.54	0.57	1	0.703333	0.210132	3
	Social image	-	1	0.58	1	0.79	0.21	2
	Total costs	0.02	-	0.18	0.18	0.1	0.08	2
Investment costs	Total costs	0.35	0.37	0.54	0.54	0.42	0.085245	3
Maintenance interval	Process impediment	-	1	0.31	1	0.655	0.345	2
	Employee productivity	-	-	0.3	0.3	0.3	0	1
	Total costs	0.35	0.26	0.17	0.35	0.26	0.073485	3
Operational costs	Energy usage	0.45	0.5	0.52	0.52	0.49	0.029439	3
	Process impediment	-	-	0.26	0.26	0.26	0	1
	Employee productivity	-	-	0.23	0.23	0.23	0	1
	Total costs	0.17	0.18	0.1	0.18	0.15	0.03559	3

Table C.6: Attribute benefit link strengths; higher indicates stronger link. Values between 0 - 1

C.2.3 Lighting: Benefit importance

Benefit (k)	**Resp. 1**	**Resp. 3**	**Resp. 4**	**Max**	**Mean** α	**Std. Dev.**	**Count**
Total costs	2.87	2.71	1.84	2.87	2.47	0.45	3
Energy usage	1.12	1.00	0.54	1.12	0.89	0.25	3
Social image	0.56	0.50	0.59	0.59	0.55	0.04	3
Employee productivity	0.25	0.57	1.20	1.20	0.67	0.39	3
Efficient space usage	0.25	-	-	0.25	0.25	0.00	1
Environmental footprint	0.95	0.93	0.58	0.95	0.82	0.17	3
Process impediment	-	0.29	1.02	1.02	0.66	0.37	2
Climate adaptation	-	-	0.24	0.24	0.24	0.00	1

Table C.7: Importance values for the identified benefit, the higher value is the higher importance, values from 0 - ∞

C.3 Flooring (SPACEPLAN)

C.3.1 Flooring: Utility table

Alternative (i)	**Resp. 1**	**Resp. 4**	**Min**	**Max**	**Mean** (U_i)	**St. Dev.**	**Count**
New carpet tiles (traditional)	2.92	3.93	2.92	3.93	3.43	0.51	2
Recycle old and new (circular) carpet tiles	2.40	2.93	2.40	2.93	2.67	0.27	2
Keep existing carpet tiles	1.51	0.99	0.99	1.51	1.25	0.26	2

Table C.8: Utility values for flooring - Space plan layer
Higher is more important, value range 0 - ∞

C.3.2 Flooring: Attribute - Benefit link strength

Attribute (j)	**Benefit** (k)	**Resp. 1**	**Resp. 4**	**Min**	**Max**	**Mean** ((S_{jk}))	**St. Dev.**	**Count**
Quantity new material	Environmental footprint	1	1	1	1	1	0	2
	Social image	0.5	1	0.5	1	0.75	0.25	2
Investment costs	Total costs	0.75	0.67	0.67	0.75	0.71	0.04	2
Maintenance interval	Process impediment	1	1	1	1	1	0	2
	Employee productivity	0.38	-	0.38	0.38	0.38	0	1
	Total costs	0.25	0.33	0.25	0.33	0.29	0.04	2
Aesthetics	Social image	0.5	-	0.5	0.5	0.5	0	1
	Employee productivity	0.62	1	0.62	1	0.81	0.19	2

Table C.9: Attribute benefit link strengths; higher indicates stronger link. Values between 0 - 1

C.3.3 Flooring: Benefit importance

Benefit (k)	**Resp 1**	**Resp. 4**	**Min**	**Max**	**Mean** (α)	**St. Dev.**	**Count**
Total costs	1.33	1.50	1.33	1.50	1.42	0.09	2
Employee productivity	0.82	1.00	0.82	1.00	0.91	0.09	2
Social image	0.98	0.47	0.47	0.98	0.73	0.26	2
Environmental footprint	0.51	0.53	0.51	0.53	0.52	0.01	2
Process impediment	0.36	0.50	0.36	0.50	0.43	0.07	2

Table C.10: Importance values for the identified benefit, the higher value is the higher importance, values from 0 - ∞

C.4 HVAC (SYSTEMS)

C.4.1 HVAC: Utility table

Alternative (i)	Resp. 2.	Resp. 3.	Min	Max	Mean (U_i)	St. Dev.	Count
Replace HVAC in total	3.53	4.99	3.53	4.99	4.26	0.73	2
Optimize existing HVAC	2.79	4.32	2.79	4.32	3.555	0.765	2
Keep existing HVAC	2.47	1	1	2.47	1.735	0.735	2

Table C.11: Utility values for HVAC - Services layer
Higher is more important, value range 0 - ∞

C.4.2 HVAC: Attribute - Benefit link strength

Attribute (j)	Benefit (k)	Resp. 2	Resp. 3	Min	Max	Mean (S_{jk})	St. Dev.	Count
Comfort	Process impediment		0.44	0.44	0.44	0.44	0	1
	Employee productivity	1	0.63	0.63	1	0.815	0.185	2
	Total costs	0.06		0.06	0.06	0.06	0	1
Energy performance	Environmental footprint		0.38	0.38	0.38	0.38	0	1
	Energy usage	1	0.54	0.54	1	0.77	0.23	2
	Climate adaptation		1	1	1	1	0	1
	Social image	1		1	1	1	0	1
	Total costs	0.14		0.14	0.14	0.14	0	1
Quantity new material	Environmental footprint	1	0.63	0.63	1	0.815	0.185	2
	Social image		1	1	1	1	0	1
Investment costs	Total costs	0.4	0.57	0.4	0.57	0.485	0.085	2
Maintenance interval	Process impediment	0.48	0.56	0.48	0.56	0.52	0.04	2
	Total costs	0.21	0.24	0.21	0.24	0.225	0.015	2
Operational costs	Energy usage		0.46	0.46	0.46	0.46	0	1
	Process impediment	0.52		0.52	0.52	0.52	0	1
	Employee productivity		0.38	0.38	0.38	0.38	0	1
	Total costs	0.19	0.19	0.19	0.19	0.19	0	2

Table C.12: Attribute benefit link strengths; higher indicates stronger link. Values between 0 - 1

C.4.3 HVAC: Benefit importance

Benefit (k)	Resp. 2.	Resp. 3.	Min	Max	Mean (α)	St. Dev.	Count
Total costs	2.47	1.76	1.76	2.47	2.12	0.35	2
Process impediment	1.02	1.02	1.02	1.02	1.02	0.00	2
Energy usage	0.43	0.72	0.43	0.72	0.58	0.15	2
Social image	0.22	0.5	0.22	0.50	0.36	0.14	2
Employee productivity	0.86	0.88	0.86	0.88	0.87	0.01	2
Environmental footprint	1	0.8	0.80	1.00	0.90	0.10	2
Climate adaptation		0.31	0.31	0.31	0.31	0.00	1

Table C.13: Importance values for the identified benefit, the higher value is the higher importance, values from 0 - ∞

C.5 Facade (SKIN)

C.5.1 Facade: Utility table

Alternative (i)	**Utility Resp. 2.**(U_i)
Solar panels as replacement existing facade	2.79
Additional insulation layer	2.76
Solar panel foil on existing glass facade	2.68
No measures to facade	2.31
Partly green wall on facade	1.97
Aesthetic foil on existing facade	1.91

Table C.14: Utility values for Facade - skin layer
Higher is more important, value range 0 - ∞

C.5.2 Facade: Attribute - Benefit link strength

Attribute (j)	**Benefit** (k)	**Link strength** (S_{jk})
Maintenance interval	Total costs	0.28
	Process impediment	1
Investment costs	Total costs	0.56
Aesthetics	Social image	0.67
	Employee productivity	1
Energy performance	Energy usage	1
	Total costs	0.17
	Environmental footprint	0.27
Quantity new material	Environmental footprint	0.73
	Social image	0.33

Table C.15: Attribute benefit link strengths; higher indicates stronger link. Values between 0 - 1

C.5.3 Facade: Benefit importance

Benefit (k)	**Resp. 2** (α)
Total costs	1.8
Process impediment	0.5
Social image	1.04
Employee productivity	0.3
Energy usage	0.46
Environmental footprint	0.9

Table C.16: Importance values for the identified benefit, the higher value is the higher importance, values from 0 - ∞

Appendix D

CNET-DA raw data

This chapter contains the raw output from the CNET-DA respondents. (Multiple pages)

ID	91178774-8c7f-43a7-8aeb-0013905d88b9		
name	Respondent 3		
attrib_alt_matrix			
attribute_name	**alternative_name**	**rating**	**rating_value**
Maintenance interval	No measures on the roof	--	0
Maintenance interval	Install new roofing	++	4
Maintenance interval	Placing solar panels	0	2
Maintenance interval	Placing a green roof	+	3
Investment costs	No measures on the roof	++	4
Investment costs	Install new roofing	-	1
Investment costs	Placing a green roof	--	0
Investment costs	Placing solar panels	-	1
Appearance	No measures on the roof	--	0
Appearance	Install new roofing	0	2
Appearance	Placing a green roof	++	4
Appearance	Placing solar panels	+	3
heat rejection	No measures on the roof	--	0
heat rejection	Install new roofing	+	3
heat rejection	Placing a green roof	++	4
heat rejection	Placing solar panels	+	3
Water buffer	No measures on the roof	--	0
Water buffer	Placing a green roof	++	4
Water buffer	Placing solar panels	0	2
Water buffer	Install new roofing	0	2
Energy performance	No measures on the roof	--	0
Energy performance	Install new roofing	+	3
Energy performance	Placing a green roof	+	3
Energy performance	Placing solar panels	++	4

atrrib_benefit_matrix

attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
Investment costs	**benefit**	**why_reason**
	Total costs	
	Energy consumption	
Appearance	**benefit**	**why_reason**
	social image	
heat rejection	**benefit**	**why_reason**
	Energy consumption	
	Ecological footprint	
	Climate adaptation	

attribute_name	benefit	why_reason
Water buffer	Ecological footprint	
	Climate adaptation	
Energy performance	Energy consumption	
	Total costs	

attrib_benefit_preference

attribute_name	benefit_name: benefit	benefit_name: why_reason	preference: alternative	preference: value
Maintenance interval	Total costs		No measures on the roof	0
			Placing solar panels	0.5
			Placing a green roof	0.87
			Install new roofing	1
Maintenance interval	Process hindrance		No measures on the roof	0
			Placing solar panels	0.5
			Placing a green roof	0.87
			Install new roofing	1
Investment costs	Total costs		Placing a green roof	0
			Install new roofing	0.33
			Placing solar panels	0.02
			No measures on the roof	1
Investment costs	Energy consumption		Placing a green roof	0
			Install new roofing	0.34
			Placing solar panels	0.02
			No measures on the roof	1
Appearance	social image		No measures on the roof	0
			Install new roofing	0.33
			Placing solar panels	0.79
			Placing a green roof	1
heat rejection	Energy consumption		No measures on the roof	0
			Install new roofing	0.62
			Placing solar panels	0.79
			Placing a green roof	1
heat rejection	Ecological footprint		No measures on the roof	0
			Install new roofing	0.62
			Placing solar panels	0.8
			Placing a green roof	1
heat rejection	Climate adaptation		No measures on the roof	0
			Install new roofing	0.62
			Placing solar panels	0.8
			Placing a green roof	1
Water buffer	Ecological footprint		No measures on the roof	0
			Placing solar panels	0.32
			Install new roofing	0.83
			Placing a green roof	1
Water buffer	Climate adaptation		No measures on the roof	0
			Placing solar panels	0.33
			Install new roofing	0.83
			Placing a green roof	1
	benefit	why_reason	alternative	value

Energy performance	Energy consumption		No measures on the roof	0
			Install new roofing	0.81
			Placing a green roof	0.91
			Placing solar panels	1
	benefit	**why_reason**	**alternative**	**value**
Energy performance	Total costs		No measures on the roof	0
			Install new roofing	0.81
			Placing a green roof	0.91
			Placing solar panels	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	970
Maintenance interval	Process hindrance	506
Investment costs	Total costs	504
Investment costs	Energy consumption	968
Appearance	social image	766
heat rejection	Energy consumption	963
heat rejection	Ecological footprint	502
heat rejection	Climate adaptation	793
Water buffer	Ecological footprint	500
Water buffer	Climate adaptation	500
Energy performance	Energy consumption	959
Energy performance	Total costs	957

utility

alternative	uValue
No measures on the roof	1
Install new roofing	3.93
Placing a green roof	4.78
Placing solar panels	3.43

ID	4157b4a9-1dc6-4c3c-8571-104c4896800e		
name	Respondent 3		
attrib_alt_matrix			
attribute_name	alternative_name	rating	rating_value
Maintenance interval	Replace and repurpose old lighting elsewhere	++	4
Maintenance interval	Refurbish and convert to LED	+	3
Maintenance interval	Keep current lighting	--	0
Investment costs	Replace and repurpose old lighting elsewhere	--	0
Investment costs	Refurbish and convert to LED	-	1
Investment costs	Keep current lighting	+	3
Operational costs	Replace and repurpose old lighting elsewhere	++	4
Operational costs	Refurbish and convert to LED	+	3
Operational costs	Keep current lighting	--	0
Comfort	Replace and repurpose old lighting elsewhere	++	4
Comfort	Refurbish and convert to LED	++	4
Comfort	Keep current lighting	-	1
Amount of new material	Replace and repurpose old lighting elsewhere	--	0
Amount of new material	Refurbish and convert to LED	-	1
Amount of new material	Keep current lighting	+	3
Energy performance	Replace and repurpose old lighting elsewhere	++	4
Energy performance	Refurbish and convert to LED	++	4
Energy performance	Keep current lighting	--	0

atrrib_benefit_matrix

attribute_name	benefits	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
Investment costs	**benefit**	**why_reason**
	Total costs	
Operational costs	**benefit**	**why_reason**
	Energy consumption	
	Total costs	
Comfort	**benefit**	**why_reason**
	Employee productivity	

	Ecological footprint	
Amount of new material	**benefit**	**why_reason**
	Ecological footprint	
	social image	
Energy performance	**benefit**	**why_reason**
	Total costs	
	Energy consumption	

attrib_benefit_preference

attribute_name	benefit_name: benefit	benefit_name: why_reason	preference: alternative	preference: value
Maintenance interval	Total costs		Keep current lighting	0
Maintenance interval	Total costs		Refurbish and convert to LED	0.31
Maintenance interval	Total costs		Replace and repurpose old lighting elsewhere	1
Maintenance interval	Process hindrance		Keep current lighting	0
Maintenance interval	Process hindrance		Refurbish and convert to LED	0.31
Maintenance interval	Process hindrance		Replace and repurpose old lighting elsewhere	1
Investment costs	Total costs		Replace and repurpose old lighting elsewhere	0
Investment costs	Total costs		Refurbish and convert to LED	0.36
Investment costs	Total costs		Keep current lighting	1
Operational costs	Energy consumption		Keep current lighting	0
Operational costs	Energy consumption		Refurbish and convert to LED	0.76
Operational costs	Energy consumption		Replace and repurpose old lighting elsewhere	1
Operational costs	Total costs		Keep current lighting	0
Operational costs	Total costs		Refurbish and convert to LED	0.77
Operational costs	Total costs		Replace and repurpose old lighting elsewhere	1
Comfort	Employee productivity		Keep current lighting	0
Comfort	Employee productivity		Replace and repurpose old lighting elsewhere	0.99
Comfort	Employee productivity		Refurbish and convert to LED	1
Comfort	Ecological footprint		Keep current lighting	0
Comfort	Ecological footprint		Replace and repurpose old lighting elsewhere	0.99
Comfort	Ecological footprint		Refurbish and convert to LED	1
Amount of new material	Ecological footprint		Replace and repurpose old lighting elsewhere	0
Amount of new material	Ecological footprint		Refurbish and convert to LED	0.28
Amount of new material	Ecological footprint		Keep current lighting	1
Amount of new material	social image		Replace and repurpose old lighting elsewhere	0
Amount of new material	social image		Refurbish and convert to LED	0.28
Amount of new material	social image		Keep current lighting	1
Energy performance	Total costs		Keep current lighting	0
Energy performance	Total costs		Replace and repurpose old lighting elsewhere	0.74
Energy performance	Total costs		Refurbish and convert to LED	1
	benefit	**why_reason**	**alternative**	**value**

Energy performance	Energy consumption		Keep current lighting	0
			Replace and repurpose old lighting elsewhere	0.78
			Refurbish and convert to LED	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	1000
Maintenance interval	Process hindrance	403
Investment costs	Total costs	599
Operational costs	Energy consumption	974
Operational costs	Total costs	964
Comfort	Employee productivity	950
Comfort	Ecological footprint	724
Amount of new material	Ecological footprint	505
Amount of new material	social image	507
Energy performance	Total costs	770
Energy performance	Energy consumption	770

utility

alternative	uValue
Replace and repurpose old lighting elsewhere	3.75
Refurbish and convert to LED	3.72
Keep current lighting	2

ID	2f90b39d-d5e6-4871-a5e0-cf4cc389c194
name	Respondent 3

attrib_alt_matrix

attribute_name	alternative_name	rating	rating_value
Maintenance interval	Keep current installation	--	0
Maintenance interval	Optimize/upgrade installation	0	2
Maintenance interval	Completely replace installation	++	4
Investment costs	Keep current installation	0	2
Investment costs	Optimize/upgrade installation	+	3
Investment costs	Completely replace installation	++	4
Operational costs	Keep current installation	--	0
Operational costs	Optimize/upgrade installation	0	2
Operational costs	Completely replace installation	++	4
Energy performance	Keep current installation	--	0
Energy performance	Optimize/upgrade installation	+	3
Energy performance	Completely replace installation	++	4
Comfort	Keep current installation	0	2
Comfort	Optimize/upgrade installation	+	3
Comfort	Completely replace installation	++	4
Amount of new material	Keep current installation	++	4
Amount of new material	Optimize/upgrade installation	-	1
Amount of new material	Completely replace installation	--	0

atrrib_benefit_matrix

attribute_name	benefits: benefit	why_reason
Maintenance interval	Process hindrance	
	Total costs	
Investment costs	Total costs	
Operational costs	Employee productivity	Less productive employees are more expensive
	Energy consumption	
	Total costs	
Energy performance	Climate adaptation	We should use less energy to compensate the environment
	Energy consumption	
	Ecological footprint	
Comfort	Employee productivity	
	Process hindrance	
Amount of new material	social image	Company image
	Ecological footprint	

attrib_benefit_preference

attribute_name	benefit_name		preference	
	benefit	**why_reason**	**alternative**	**value**
Maintenance interval	Process hindrance		Keep current installation	0
			Optimize/upgrade installation	0.72
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Maintenance interval	Total costs		Keep current installation	0
			Optimize/upgrade installation	0.72
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Investment costs	Total costs		Keep current installation	0
			Optimize/upgrade installation	0.71
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Operational costs	Employee productivity	Less productive employees are more expensive	Keep current installation	0
			Optimize/upgrade installation	0.7
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Operational costs	Energy consumption		Keep current installation	0
			Optimize/upgrade installation	0.72
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Operational costs	Total costs		Keep current installation	0
			Optimize/upgrade installation	0.81
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Energy performance	Climate adaptation	We should use less energy to compensate the environment	Keep current installation	0
			Optimize/upgrade installation	0.78
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Energy performance	Energy consumption		Keep current installation	0
			Optimize/upgrade installation	0.77
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Energy performance	Ecological footprint		Keep current installation	0
			Optimize/upgrade installation	0.77
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Comfort	Employee productivity		Keep current installation	0
			Optimize/upgrade installation	0.88
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Comfort	Process hindrance		Keep current installation	0
			Optimize/upgrade installation	0.89
			Completely replace installation	1
	benefit	**why_reason**	**alternative**	**value**
Amount of new material	social image	Company image	Completely replace installation	0
			Optimize/upgrade installation	0.5
			Keep current installation	1
	benefit	**why_reason**	**alternative**	**value**
Amount of new material	Ecological footprint		Completely replace installation	0
			Optimize/upgrade installation	0.5
			Keep current installation	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Process hindrance	971
Maintenance interval	Total costs	742
Investment costs	Total costs	736
Operational costs	Employee productivity	978
Operational costs	Energy consumption	977

Operational costs	Total costs	981
Energy performance	Climate adaptation	768
Energy performance	Energy consumption	973
Energy performance	Ecological footprint	762
Comfort	Employee productivity	954
Comfort	Process hindrance	772
Amount of new material	social image	500
Amount of new material	Ecological footprint	505

utility

alternative	**uValue**
Keep current installation	1
Optimize/upgrade installation	4.32
Completely replace installation	4.99

ID	e5771598-7c9d-437f-bb4a-c86371b427a5		
name	Respondent 2		
attrib_alt_matrix			
attribute_name	**alternative_name**	**rating**	**rating_value**
Maintenance interval	PV panels to replace existing facade	-	1
Maintenance interval	PV foil on existing glass plates	--	0
Maintenance interval	Partial green wall on facade	-	1
Maintenance interval	Apply aesthetic facade foil	-	1
Maintenance interval	No measures on the facade	0	2
Maintenance interval	Apply extra insulation	0	2
Investment costs	No measures on the facade	++	4
Investment costs	Apply aesthetic facade foil	+	3
Investment costs	Partial green wall on facade	0	2
Investment costs	Apply extra insulation	-	1
Investment costs	PV panels to replace existing facade	--	0
Investment costs	PV foil on existing glass plates	-	1
Appearance	No measures on the facade	--	0
Appearance	Apply aesthetic facade foil	--	0
Appearance	Partial green wall on facade	++	4
Appearance	PV panels to replace existing facade	++	4
Appearance	PV foil on existing glass plates	+	3
Appearance	Apply extra insulation	-	1
Energy performance	No measures on the facade	--	0
Energy performance	Apply aesthetic facade foil	--	0
Energy performance	Partial green wall on facade	-	1
Energy performance	PV panels to replace existing facade	++	4
Energy performance	PV foil on existing glass plates	++	4
Energy performance	Apply extra insulation	+	3
Amount of new material	No measures on the facade	++	4
Amount of new material	Apply aesthetic facade foil	+	3
Amount of new material	Partial green wall on facade	+	3
Amount of new material	PV panels to replace existing facade	--	0
Amount of new material	PV foil on existing glass plates	-	1
Amount of new material	Apply extra insulation	-	1

atrrib_benefit_matrix		
attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
Investment costs	**benefit**	**why_reason**

attribute_name	benefit	why_reason
Investment costs	Total costs	
Appearance	social image	
	Employee productivity	
Energy performance	Energy consumption	
	Total costs	
	Ecological footprint	
Amount of new material	Ecological footprint	
	social image	

attrib_benefit_preference

attribute_name	benefit_name: benefit	benefit_name: why_reason	preference: alternative	preference: value
Maintenance interval	Total costs		PV foil on existing glass plates	0
			PV panels to replace existing facade	0.13
			Partial green wall on facade	0.26
			Apply aesthetic facade foil	0.64
			No measures on the facade	0.97
			Apply extra insulation	1
Maintenance interval	Process hindrance		PV foil on existing glass plates	0
			PV panels to replace existing facade	0.13
			Partial green wall on facade	0.26
			Apply aesthetic facade foil	0.64
			No measures on the facade	0.97
			Apply extra insulation	1
Investment costs	Total costs		PV panels to replace existing facade	0
			Apply extra insulation	0
			PV foil on existing glass plates	0.1
			Partial green wall on facade	0.26
			Apply aesthetic facade foil	0.75
			No measures on the facade	1
Appearance	social image		No measures on the facade	0
			Apply aesthetic facade foil	0.28
			Apply extra insulation	0.37
			PV foil on existing glass plates	0.86
			Partial green wall on facade	0.94
			PV panels to replace existing facade	1
Appearance	Employee productivity		No measures on the facade	0
			Apply aesthetic facade foil	0.28
			Apply extra insulation	0.37
			PV foil on existing glass plates	0.86
			Partial green wall on facade	0.94
			PV panels to replace existing facade	1
Energy performance	Energy consumption		No measures on the facade	0
			Apply aesthetic facade foil	0
			Partial green wall on facade	0.24
			Apply extra insulation	0.85
			PV panels to replace existing facade	1
			PV foil on existing glass plates	1

attribute	benefit	why_reason	alternative	value
Energy performance	Total costs		No measures on the facade	0
			Apply aesthetic facade foil	0
			Partial green wall on facade	0.24
			Apply extra insulation	0.85
			PV panels to replace existing facade	1
			PV foil on existing glass plates	1

	benefit	why_reason	alternative	value
Energy performance	Ecological footprint		No measures on the facade	0
			Apply aesthetic facade foil	0
			Partial green wall on facade	0.18
			Apply extra insulation	0.74
			PV panels to replace existing facade	1
			PV foil on existing glass plates	1

	benefit	why_reason	alternative	value
Amount of new material	Ecological footprint		No measures on the facade	0
			Apply aesthetic facade foil	0
			Partial green wall on facade	0.18
			Apply extra insulation	0.74
			PV panels to replace existing facade	1
			PV foil on existing glass plates	1

	benefit	why_reason	alternative	value
Amount of new material	social image		PV panels to replace existing facade	0
			PV foil on existing glass plates	0.18
			Apply extra insulation	0.24
			Apply aesthetic facade foil	0.72
			Partial green wall on facade	0.5
			No measures on the facade	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	103
Maintenance interval	Process hindrance	101
Investment costs	Total costs	709
Appearance	social image	311
Appearance	Employee productivity	131
Energy performance	Energy consumption	715
Energy performance	Total costs	467
Energy performance	Ecological footprint	369
Amount of new material	Ecological footprint	725
Amount of new material	social image	371

utility

alternative	uValue
PV panels to replace existing facade	2.79
Apply extra insulation	2.76
PV foil on existing glass plates	2.68
No measures on the facade	2.31
Partial green wall on facade	1.97
Apply aesthetic facade foil	1.91

ID	bb1461f4-a29a-4949-8a21-7c4e5f73fbd6		
name	Respondent 2		
attrib_alt_matrix			
attribute_name	alternative_name	rating	rating_value
Maintenance interval	No measures on the roof	--	0
Maintenance interval	Placing solar panels	0	2
Maintenance interval	Install new roofing	+	3
Maintenance interval	Placing a green roof	++	4
Investment costs	No measures on the roof	++	4
Investment costs	Install new roofing	0	2
Investment costs	Placing a green roof	-	1
Investment costs	Placing solar panels	--	0
Appearance	No measures on the roof	0	2
Appearance	Install new roofing	0	2
Appearance	Placing a green roof	+	3
Appearance	Placing solar panels	++	4
heat rejection	No measures on the roof	-	1
heat rejection	Install new roofing	0	2
heat rejection	Placing a green roof	++	4
heat rejection	Placing solar panels	+	3
Water buffer	No measures on the roof	-	1
Water buffer	Install new roofing	-	1
Water buffer	Placing a green roof	+	3
Water buffer	Placing solar panels	-	1
Energy performance	No measures on the roof	--	0
Energy performance	Install new roofing	-	1
Energy performance	Placing a green roof	0	2
Energy performance	Placing solar panels	++	4

atrrib_benefit_matrix		
attribute_name	benefits	
Maintenance interval	benefit	why_reason
	Total costs	More maintenance, more hours -> more costs
	Process hindrance	More people on the floor
Investment costs	benefit	why_reason
	Total costs	
Appearance	benefit	why_reason
	social image	Communication to the outside world
	Employee productivity	More attractive for staff
heat rejection	benefit	why_reason
	Climate adaptation	Higher summer temperatures, so less indoor temperature exceedance
	Energy consumption	Less cooling means less energy
	Ecological footprint	Less energy means less ecological footprint

	benefit	why_reason
Water buffer	Climate adaptation	Heavier showers, relieve water drainage
Energy performance	**benefit**	**why_reason**
	Energy consumption	
	Total costs	Rising energy prices
	Ecological footprint	

attrib_benefit_preference

attribute_name	benefit_name		preference	
	benefit	**why_reason**	**alternative**	**value**
Maintenance interval	Total costs	More maintenance, more hours -> more costs	No measures on the roof	0
			Placing solar panels	0.33
			Install new roofing	0.5
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
Maintenance interval	Process hindrance	More people on the floor	No measures on the roof	0
			Placing solar panels	0.33
			Install new roofing	0.5
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
Investment costs	Total costs		Placing solar panels	0
			Placing a green roof	0.46
			Install new roofing	0.56
			No measures on the roof	1
	benefit	**why_reason**	**alternative**	**value**
Appearance	social image	Communication to the outside world	No measures on the roof	0
			Install new roofing	0.02
			Placing a green roof	0.92
			Placing solar panels	1
	benefit	**why_reason**	**alternative**	**value**
Appearance	Employee productivity	More attractive for staff	No measures on the roof	0
			Install new roofing	0.02
			Placing a green roof	0.92
			Placing solar panels	1
	benefit	**why_reason**	**alternative**	**value**
heat rejection	Climate adaptation	Higher summer temperatures, so less indoor temperature exceedance	No measures on the roof	0
			Install new roofing	0.06
			Placing solar panels	0.28
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
heat rejection	Energy consumption	Less cooling means less energy	No measures on the roof	0
			Install new roofing	0.06
			Placing solar panels	0.28
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
heat rejection	Ecological footprint	Less energy means less ecological footprint	No measures on the roof	0
			Install new roofing	0.16
			Placing solar panels	0.45
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
Water buffer	Climate adaptation	Heavier showers, relieve water drainage	No measures on the roof	0
			Install new roofing	0
			Placing solar panels	0
			Placing a green roof	1

	benefit	why_reason	alternative	value
Energy performance	Energy consumption		No measures on the roof	0
			Install new roofing	0.18
			Placing a green roof	0.35
			Placing solar panels	1

	benefit	why_reason	alternative	value
Energy performance	Total costs	Rising energy prices	No measures on the roof	0
			Install new roofing	0.18
			Placing a green roof	0.35
			Placing solar panels	1

	benefit	why_reason	alternative	value
Energy performance	Ecological footprint		No measures on the roof	0
			Install new roofing	0.19
			Placing a green roof	0.15
			Placing solar panels	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	131
Maintenance interval	Process hindrance	131
Investment costs	Total costs	697
Appearance	social image	218
Appearance	Employee productivity	76
heat rejection	Climate adaptation	145
heat rejection	Energy consumption	193
heat rejection	Ecological footprint	207
Water buffer	Climate adaptation	173
Energy performance	Energy consumption	775
Energy performance	Total costs	607
Energy performance	Ecological footprint	580

utility

alternative	uValue
No measures on the roof	1
Install new roofing	1.36
Placing a green roof	4.67
Placing solar panels	2.68

ID	1f161e46-a749-4431-a235-75ee53c44c65		
name	Respondent 2		
attrib_alt_matrix			
attribute_name	**alternative_name**	**rating**	**rating_value**
Maintenance interval	Keep current installation	0	2
Maintenance interval	Optimize/upgrade installation	+	3
Maintenance interval	Completely replace installation	++	4
Investment costs	Keep current installation	++	4
Investment costs	Optimize/upgrade installation	-	1
Investment costs	Completely replace installation	--	0
Operational costs	Keep current installation	-	1
Operational costs	Optimize/upgrade installation	0	2
Operational costs	Completely replace installation	++	4
Energy performance	Keep current installation	--	0
Energy performance	Optimize/upgrade installation	0	2
Energy performance	Completely replace installation	++	4
Comfort	Keep current installation	0	2
Comfort	Optimize/upgrade installation	+	3
Comfort	Completely replace installation	++	4
Amount of new material	Keep current installation	++	4
Amount of new material	Optimize/upgrade installation	-	1
Amount of new material	Completely replace installation	--	0

atrrib_benefit_matrix		
attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
Investment costs	**benefit**	**why_reason**
	Total costs	
Operational costs	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
Energy performance	**benefit**	**why_reason**
	Energy consumption	
	Total costs	
	social image	
Comfort	**benefit**	**why_reason**
	Employee productivity	
	Total costs	

	benefit	why_reason
Amount of new material	Ecological footprint	

attrib_benefit_preference

attribute_name	benefit	why_reason	alternative	value
Maintenance interval	Total costs		Keep current installation	0
			Optimize/upgrade installation	0.37
			Completely replace installation	1
Maintenance interval	Process hindrance		Keep current installation	0
			Optimize/upgrade installation	0.35
			Completely replace installation	1
Investment costs	Total costs		Completely replace installation	0
			Optimize/upgrade installation	0.16
			Keep current installation	1
Operational costs	Total costs		Completely replace installation	0
			Optimize/upgrade installation	0.16
			Keep current installation	1
Operational costs	Process hindrance		Keep current installation	0
			Optimize/upgrade installation	0.69
			Completely replace installation	1
Energy performance	Energy consumption		Keep current installation	0
			Optimize/upgrade installation	0.8
			Completely replace installation	1
Energy performance	Total costs		Keep current installation	0
			Optimize/upgrade installation	0.7
			Completely replace installation	1
Energy performance	social image		Keep current installation	0
			Optimize/upgrade installation	0.72
			Completely replace installation	1
Comfort	Employee productivity		Keep current installation	0
			Optimize/upgrade installation	0.45
			Completely replace installation	1
Comfort	Total costs		Keep current installation	0
			Optimize/upgrade installation	0.41
			Completely replace installation	1
Amount of new material	Ecological footprint		Completely replace installation	0
			Optimize/upgrade installation	0.64
			Keep current installation	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	1000
Maintenance interval	Process hindrance	953
Investment costs	Total costs	227
Operational costs	Total costs	789
Operational costs	Process hindrance	886
Energy performance	Energy consumption	980
Energy performance	Total costs	806
Energy performance	social image	516
Comfort	Employee productivity	1000
Comfort	Total costs	168
Amount of new material	Ecological footprint	168

utility

alternative	uValue
Keep current installation	2.47
Optimize/upgrade installation	2.79
Completely replace installation	3.53

ID	b8e227cf-62a8-4b76-a7d9-4c64900c63d6		
name	Respondent 1		
attrib_alt_matrix			
attribute_name	alternative_name	rating	rating_value
Maintenance interval	No measures on the roof	-	1
Maintenance interval	Install new roofing	+	3
Maintenance interval	Placing a green roof	++	4
Maintenance interval	Placing solar panels	--	0
Investment costs	No measures on the roof	++	4
Investment costs	Install new roofing	-	1
Investment costs	Placing a green roof	-	1
Investment costs	Placing solar panels	--	0
Appearance	No measures on the roof	0	2
Appearance	Install new roofing	+	3
Appearance	Placing a green roof	++	4
Appearance	Placing solar panels	-	1
heat rejection	No measures on the roof	0	2
heat rejection	Install new roofing	0	2
heat rejection	Placing a green roof	+	3
heat rejection	Placing solar panels	+	3
Water buffer	No measures on the roof	0	2
Water buffer	Install new roofing	0	2
Water buffer	Placing a green roof	++	4
Water buffer	Placing solar panels	-	1
Energy performance	No measures on the roof	0	2
Energy performance	Install new roofing	0	2
Energy performance	Placing a green roof	+	3
Energy performance	Placing solar panels	++	4

atrrib_benefit_matrix		
attribute_name	benefits	
Maintenance interval	benefit	why_reason
	Total costs	
Investment costs	benefit	why_reason
	Total costs	
Appearance	benefit	why_reason
	Climate adaptation	
	Efficient use of space	Makes optimal use of roof surface
	Energy consumption	With solar panels
	Ecological footprint	With green roof
heat rejection	benefit	why_reason
	Energy consumption	Less cooling required

	Ecological footprint	Uses less energy
Water buffer	**benefit**	**why_reason**
	Climate adaptation	Protect municipal sewer
Energy performance	**benefit**	**why_reason**
	Energy consumption	
	Ecological footprint	
	Total costs	
	social image	

attrib_benefit_preference

attribute_name	**benefit_name**		**preference**	
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Placing solar panels	0
			No measures on the roof	0.14
			Install new roofing	0.85
			Placing a green roof	1
Investment costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Placing solar panels	0
			No measures on the roof	0.14
			Install new roofing	0.85
			Placing a green roof	1
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Climate adaptation		Placing solar panels	0
			No measures on the roof	0.71
			Install new roofing	0.13
			Placing a green roof	1
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Efficient use of space	Makes optimal use of roof surface	Placing solar panels	0
			No measures on the roof	0.71
			Install new roofing	0.13
			Placing a green roof	1
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption	With solar panels	Placing solar panels	0
			No measures on the roof	0.01
			Install new roofing	0.01
			Placing a green roof	1
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint	With green roof	Placing solar panels	0
			No measures on the roof	0
			Install new roofing	0
			Placing a green roof	1
heat rejection	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption	Less cooling required	No measures on the roof	0
			Install new roofing	0.04
			Placing a green roof	0.97
			Placing solar panels	1
heat rejection	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint	Uses less energy	No measures on the roof	0
			Install new roofing	0.04
			Placing a green roof	0.96
			Placing solar panels	1
Water buffer	**benefit**	**why_reason**	**alternative**	**value**
	Climate adaptation	Protect municipal sewer	Placing solar panels	0
			No measures on the roof	0.32
			Install new roofing	0.32
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**

Energy performance	Energy consumption		No measures on the roof	0
			Install new roofing	0.02
			Placing a green roof	0.51
			Placing solar panels	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		No measures on the roof	0
			Install new roofing	0.02
			Placing a green roof	0.5
			Placing solar panels	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		No measures on the roof	0
			Install new roofing	0.01
			Placing a green roof	0.93
			Placing solar panels	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	social image		No measures on the roof	0
			Install new roofing	0.04
			Placing a green roof	0.05
			Placing solar panels	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	128
Investment costs	Total costs	128
Appearance	Climate adaptation	1000
Appearance	Efficient use of space	504
Appearance	Energy consumption	923
Appearance	Ecological footprint	934
heat rejection	Energy consumption	887
heat rejection	Ecological footprint	888
Water buffer	Climate adaptation	590
Energy performance	Energy consumption	898
Energy performance	Ecological footprint	864
Energy performance	Total costs	14
Energy performance	social image	778

utility

alternative	uValue
No measures on the roof	0.92
Install new roofing	2.15
Placing a green roof	5.34
Placing solar panels	2

ID	c364bc91-6595-415a-b5a6-a8f44e5ab914		
name	Respondent 1		
attrib_alt_matrix			
attribute_name	**alternative_name**	**rating**	**rating_value**
Maintenance interval	Replace and repurpose old lighting elsewhere	++	4
Maintenance interval	Refurbish and convert to LED	0	2
Maintenance interval	Keep current lighting	--	0
Investment costs	Replace and repurpose old lighting elsewhere	--	0
Investment costs	Refurbish and convert to LED	-	1
Investment costs	Keep current lighting	++	4
Operational costs	Replace and repurpose old lighting elsewhere	++	4
Operational costs	Refurbish and convert to LED	+	3
Operational costs	Keep current lighting	--	0
Comfort	Replace and repurpose old lighting elsewhere	++	4
Comfort	Refurbish and convert to LED	-	1
Comfort	Keep current lighting	0	2
Amount of new material	Replace and repurpose old lighting elsewhere	--	0
Amount of new material	Refurbish and convert to LED	+	3
Amount of new material	Keep current lighting	++	4
Energy performance	Replace and repurpose old lighting elsewhere	++	4
Energy performance	Refurbish and convert to LED	+	3
Energy performance	Keep current lighting	0	2

atrrib_benefit_matrix

attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	Less maintenance = less cost
Investment costs	**benefit**	**why_reason**
	Total costs	
Operational costs	**benefit**	**why_reason**
	Total costs	
	Energy consumption	
Comfort	**benefit**	**why_reason**
	social image	
	Energy consumption	

Comfort	Employee productivity	Good lighting = better productivity
	Efficient use of space	
Amount of new material	**benefit**	**why_reason**
	Total costs	
	Ecological footprint	
Energy performance	**benefit**	**why_reason**
	Energy consumption	
	social image	Overall company image
	Total costs	

attrib_benefit_preference

attribute_name	**benefit_name**		**preference**	
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Total costs	Less maintenance = less cost	Keep current lighting	0
			Refurbish and convert to LED	0.12
			Replace and repurpose old lighting elsewhere	1
Investment costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Keep current lighting	0
			Refurbish and convert to LED	0.12
			Replace and repurpose old lighting elsewhere	1
Operational costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Replace and repurpose old lighting elsewhere	0
			Refurbish and convert to LED	0.22
			Keep current lighting	1
Operational costs	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		Keep current lighting	0
			Refurbish and convert to LED	0.21
			Replace and repurpose old lighting elsewhere	1
Comfort	**benefit**	**why_reason**	**alternative**	**value**
	social image		Refurbish and convert to LED	0
			Keep current lighting	0.5
			Replace and repurpose old lighting elsewhere	1
Comfort	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		Refurbish and convert to LED	0
			Keep current lighting	0.49
			Replace and repurpose old lighting elsewhere	1
Comfort	**benefit**	**why_reason**	**alternative**	**value**
	Employee productivity	Good lighting = better productivity	Refurbish and convert to LED	0
			Keep current lighting	0.06
			Replace and repurpose old lighting elsewhere	1
Comfort	**benefit**	**why_reason**	**alternative**	**value**
	Efficient use of space		Refurbish and convert to LED	0
			Keep current lighting	0.05
			Replace and repurpose old lighting elsewhere	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Replace and repurpose old lighting elsewhere	0
			Refurbish and convert to LED	0.8
			Keep current lighting	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		Replace and repurpose old lighting elsewhere	0

			Refurbish and convert to LED	0.78
			Keep current lighting	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		Keep current lighting	0
			Refurbish and convert to LED	0.81
			Replace and repurpose old lighting elsewhere	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	social image	Overall company image	Keep current lighting	0
			Refurbish and convert to LED	0.77
			Replace and repurpose old lighting elsewhere	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Keep current lighting	0
			Refurbish and convert to LED	0.77
			Replace and repurpose old lighting elsewhere	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	12
Investment costs	Total costs	18
Operational costs	Total costs	507
Operational costs	Energy consumption	513
Comfort	social image	768
Comfort	Energy consumption	768
Comfort	Employee productivity	758
Comfort	Efficient use of space	767
Amount of new material	Total costs	26
Amount of new material	Ecological footprint	503
Energy performance	Energy consumption	873
Energy performance	social image	747
Energy performance	Total costs	753

utility

alternative	uValue
Replace and repurpose old lighting elsewhere	4.5
Refurbish and convert to LED	2.02
Keep current lighting	1.78

ID	4b8f841d-592a-45b1-8300-7da16c65b42a
name	Respondent 1

attrib_alt_matrix

attribute_name	alternative_name	rating	rating_value
Maintenance interval	Keep existing carpet tiles	--	0
Maintenance interval	Replacing carpet tiles	++	4
Maintenance interval	Recycle and apply new circular tiles	++	4
Investment costs	Replacing carpet tiles	-	1
Investment costs	Recycle and apply new circular tiles	--	0
Investment costs	Keep existing carpet tiles	0	2
Appearance	Keep existing carpet tiles	--	0
Appearance	Replacing carpet tiles	++	4
Appearance	Recycle and apply new circular tiles	++	4
Amount of new material	Keep existing carpet tiles	0	2
Amount of new material	Replacing carpet tiles	-	1
Amount of new material	Recycle and apply new circular tiles	-	1

atrrib_benefit_matrix

attribute_name	benefit	why_reason
Maintenance interval	Total costs	Less maintenance is better for the costs
	Process hindrance	Less maintenance means less nuisance
	Employee productivity	No hindrance and therefore inconvenience for employees
Investment costs	Total costs	
Appearance	Employee productivity	Employees in a clean environment
	social image	Marketing
Amount of new material	social image	Can be used as marketing
	Ecological footprint	Pollution from production tiles

attrib_benefit_preference

attribute_name	benefit	why_reason	alternative	value
Maintenance interval	Total costs	Less maintenance is better for the costs	Keep existing carpet tiles	0
			Replacing carpet tiles	1
			Recycle and apply new circular tiles	0.88
Maintenance interval	Process hindrance	Less maintenance means less nuisance	Keep existing carpet tiles	0
			Replacing carpet tiles	1
			Recycle and apply new circular tiles	0.87
Maintenance interval	Employee productivity	No hindrance and therefore inconvenience for employees	Keep existing carpet tiles	0
			Replacing carpet tiles	1

			Recycle and apply new circular tiles	0.81
Investment costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Recycle and apply new circular tiles	0
			Replacing carpet tiles	0.48
			Keep existing carpet tiles	1
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Employee productivity	Employees in a clean environment	Keep existing carpet tiles	0
			Replacing carpet tiles	1
			Recycle and apply new circular tiles	1
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	social image	Marketing	Keep existing carpet tiles	0
			Replacing carpet tiles	1
			Recycle and apply new circular tiles	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	social image	Can be used as marketing	Keep existing carpet tiles	0
			Replacing carpet tiles	0.89
			Recycle and apply new circular tiles	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint	Pollution from production tiles	Replacing carpet tiles	0
			Recycle and apply new circular tiles	0.1
			Keep existing carpet tiles	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	850
Maintenance interval	Process hindrance	926
Maintenance interval	Employee productivity	795
Investment costs	Total costs	354
Appearance	Employee productivity	806
Appearance	social image	766
Amount of new material	social image	856
Amount of new material	Ecological footprint	899

utility

alternative	uValue
Keep existing carpet tiles	1.51
Replacing carpet tiles	2.92
Recycle and apply new circular tiles	2.4

ID	2a1cf2e2-eee3-44f6-a935-a3c35350ef76		
name	Respondent 5		
attrib_alt_matrix			
attribute_name	**alternative_ name**	**rating**	**rating_value**
Maintenance interval	No measures on the roof	0	2
Maintenance interval	Install new roofing	++	4
Maintenance interval	Placing a green roof	-	1
Maintenance interval	Placing solar panels	-	1
Investment costs	No measures on the roof	++	4
Investment costs	Install new roofing	+	3
Investment costs	Placing a green roof	--	0
Investment costs	Placing solar panels	-	1
Appearance	No measures on the roof	--	0
Appearance	Install new roofing	0	2
Appearance	Placing a green roof	++	4
Appearance	Placing solar panels	+	3
heat rejection	No measures on the roof	--	0
heat rejection	Install new roofing	-	1
heat rejection	Placing a green roof	++	4
heat rejection	Placing solar panels	+	3
Water buffer	No measures on the roof	--	0
Water buffer	Install new roofing	--	0
Water buffer	Placing a green roof	++	4
Water buffer	Placing solar panels	0	2
Energy performance	No measures on the roof	--	0
Energy performance	Install new roofing	+	3
Energy performance	Placing a green roof	++	4
Energy performance	Placing solar panels	++	4

atrrib_benefit_matrix

attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	social image	Less maintenance is better for the organization's appearance
Investment costs	**benefit**	**why_reason**
	Total costs	
	benefit	**why_reason**

attribute	benefit	why_reason
Appearance	Efficient use of space	
	Employee productivity	
	Ecological footprint	
heat rejection	Climate adaptation	
	Energy consumption	Cooling load can be reduced
	Employee productivity	Better heat protection, fewer climate complaints and a better experience for employees
Water buffer	Ecological footprint	
	Energy consumption	
Energy performance	Energy consumption	
	Total costs	
	social image	Appearance of organization

attrib_benefit_preference

attribute_name	benefit	why_reason	alternative	value
Maintenance interval	Total costs		Placing a green roof	0
			Placing solar panels	0.14
			No measures on the roof	0.49
			Install new roofing	1
Maintenance interval	social image	Less maintenance is better for the organization's appearance	Placing a green roof	0
			Placing solar panels	0.14
			No measures on the roof	0.48
			Install new roofing	1
Investment costs	Total costs		Placing a green roof	0
			Placing solar panels	0.33
			Install new roofing	0.7
			No measures on the roof	1
Appearance	Efficient use of space		No measures on the roof	0
			Install new roofing	0.01
			Placing solar panels	0.7
			Placing a green roof	1
Appearance	Employee productivity		No measures on the roof	0
			Install new roofing	0.01
			Placing solar panels	0.7
			Placing a green roof	1
Appearance	Ecological footprint		No measures on the roof	0
			Install new roofing	0.01
			Placing solar panels	0.51
			Placing a green roof	1

	benefit	why_reason	alternative	value
heat rejection	Climate adaptation		No measures on the roof	0
			Install new roofing	0.33
			Placing solar panels	0.5
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
heat rejection	Energy consumption	Cooling load can be reduced	No measures on the roof	0
			Install new roofing	0.33
			Placing solar panels	0.5
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
heat rejection	Employee productivity	Better heat protection, fewer climate complaints and a better experience for employees	No measures on the roof	0
			Install new roofing	0.67
			Placing solar panels	0.5
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
Water buffer	Ecological footprint		No measures on the roof	0
			Install new roofing	0.5
			Placing solar panels	0.24
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
Water buffer	Energy consumption		No measures on the roof	0
			Install new roofing	0.5
			Placing solar panels	0.24
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
Energy performance	Energy consumption		No measures on the roof	0
			Install new roofing	0.5
			Placing solar panels	0.24
			Placing a green roof	1
	benefit	**why_reason**	**alternative**	**value**
Energy performance	Total costs		No measures on the roof	0
			Install new roofing	0.32
			Placing a green roof	0.69
			Placing solar panels	1
	benefit	**why_reason**	**alternative**	**value**
Energy performance	social image	Appearance of organization	No measures on the roof	0
			Install new roofing	0.67
			Placing a green roof	0.32
			Placing solar panels	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	776
Maintenance interval	social image	209
Investment costs	Total costs	504
Appearance	Efficient use of space	500
Appearance	Employee productivity	617
Appearance	Ecological footprint	789
heat rejection	Climate adaptation	786
heat rejection	Energy consumption	1000
heat rejection	Employee productivity	792
Water buffer	Ecological footprint	792
Water buffer	Energy consumption	789
Energy performance	Energy consumption	1000
Energy performance	Total costs	725

Energy performance	social image	595
utility		
alternative	**uValue**	
No measures on the roof	1.49	
Install new roofing	3.13	
Placing a green roof	3.72	
Placing solar panels	2.5	

ID	52dbe610-938f-443a-a20f-7cf29b449f47		
name	Respondent 4		
attrib_alt_matrix			
attribute_name	**alternative_name**	**rating**	**rating_value**
Maintenance interval	Keep existing carpet tiles	0	2
Maintenance interval	Replacing carpet tiles	++	4
Maintenance interval	Recycle and apply new circular tiles	++	4
Investment costs	Keep existing carpet tiles	0	2
Investment costs	Replacing carpet tiles	0	2
Investment costs	Recycle and apply new circular tiles	0	2
Appearance	Replacing carpet tiles	++	4
Appearance	Keep existing carpet tiles	0	2
Appearance	Recycle and apply new circular tiles	++	4
Amount of new material	Keep existing carpet tiles	0	2
Amount of new material	Replacing carpet tiles	--	0
Amount of new material	Recycle and apply new circular tiles	++	4
Acoustics	Recycle and apply new circular tiles	+	3
Acoustics	Replacing carpet tiles	0	2
Acoustics	Keep existing carpet tiles	-	1

atrrib_benefit_matrix

attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
Investment costs	**benefit**	**why_reason**
	Total costs	
Appearance	**benefit**	**why_reason**
	Employee productivity	
Amount of new material	**benefit**	**why_reason**
	Ecological footprint	
	social image	
Acoustics	**benefit**	**why_reason**
	Employee productivity	
	Process hindrance	

attrib_benefit_preference

attribute_name	**benefit_name**		**preference**	
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Keep existing carpet tiles	0
			Replacing carpet tiles	0.98
			Recycle and apply new circular tiles	1
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Process hindrance		Keep existing carpet tiles	0
			Replacing carpet tiles	0.98
			Recycle and apply new circular tiles	1
Investment costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Keep existing carpet tiles	0
			Replacing carpet tiles	0.97
			Recycle and apply new circular tiles	1
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Employee productivity		Keep existing carpet tiles	0
			Replacing carpet tiles	0.98
			Recycle and apply new circular tiles	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		Replacing carpet tiles	0
			Keep existing carpet tiles	0.99
			Recycle and apply new circular tiles	0.92
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	social image		Replacing carpet tiles	0
			Keep existing carpet tiles	0.99
			Recycle and apply new circular tiles	0.95
	benefit	**why_reason**	**alternative**	**value**
	Employee productivity		Keep existing carpet tiles	0

Acoustics			Replacing carpet tiles	0.99
			Recycle and apply new circular tiles	1
Acoustics	**benefit**	**why_reason**	**alternative**	**value**
	Process hindrance		Keep existing carpet tiles	0
			Replacing carpet tiles	0.99
			Recycle and apply new circular tiles	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	818
Maintenance interval	Process hindrance	816
Investment costs	Total costs	816
Appearance	Employee productivity	689
Amount of new material	Ecological footprint	800
Amount of new material	social image	716
Acoustics	Employee productivity	929
Acoustics	Process hindrance	934

utility

alternative	uValue
Keep existing carpet tiles	0.99
Replacing carpet tiles	3.92
Recycle and apply new circular tiles	4.93

ID			
name	Respondent 4		
attrib_alt_matrix			
attribute_name	**alternative_name**	**rating**	**rating_value**
Maintenance interval	Replace and repurpose old lighting elsewhere	++	4
Maintenance interval	Refurbish and convert to LED	+	3
Maintenance interval	Keep current lighting	--	0
Investment costs	Replace and repurpose old lighting elsewhere	+	3
Investment costs	Refurbish and convert to LED	+	3
Investment costs	Keep current lighting	-	1
Operational costs	Replace and repurpose old lighting elsewhere	++	4
Operational costs	Refurbish and convert to LED	+	3
Operational costs	Keep current lighting	--	0
Comfort	Replace and repurpose old lighting elsewhere	++	4
Comfort	Refurbish and convert to LED	+	3
Comfort	Keep current lighting	--	0
Amount of new material	Replace and repurpose old lighting elsewhere	--	0
Amount of new material	Refurbish and convert to LED	-	1
Amount of new material	Keep current lighting	-	1
Energy performance	Replace and repurpose old lighting elsewhere	++	4
Energy performance	Refurbish and convert to LED	+	3
Energy performance	Keep current lighting	--	0

atrrib_benefit_matrix

attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
	Employee productivity	
Investment costs	**benefit**	**why_reason**
	Total costs	
Operational costs	**benefit**	**why_reason**
	Energy consumption	
	Employee productivity	
	Process hindrance	
	Total costs	
Comfort	**benefit**	**why_reason**
	Employee productivity	
	Process hindrance	
Amount of new material	**benefit**	**why_reason**
	Ecological footprint	
	social image	
	Total costs	
Energy performance	**benefit**	**why_reason**
	Energy consumption	
	Ecological footprint	
	social image	
	Climate adaptation	

attrib_benefit_preference

attribute_name	**benefit_name**		**preference**	
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Keep current lighting	0
			Refurbish and convert to LED	0.73
			Replace and repurpose old lighting elsewhere	1
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Process hindrance		Keep current lighting	0
			Refurbish and convert to LED	0.74
			Replace and repurpose old lighting elsewhere	1
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Employee productivity		Keep current lighting	0
			Refurbish and convert to LED	0.83
			Replace and repurpose old lighting elsewhere	1
Investment costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Keep current lighting	0
			Replace and repurpose old lighting elsewhere	1
			Refurbish and convert to LED	0.36
Operational costs	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		Keep current lighting	0
			Refurbish and convert to LED	0.75

attribute	benefit	why_reason	alternative	value
			Replace and repurpose old lighting elsewhere	1
Operational costs	**benefit**	**why_reason**	**alternative**	**value**
	Employee productivity		Keep current lighting	0
			Refurbish and convert to LED	0.74
			Replace and repurpose old lighting elsewhere	1
Operational costs	**benefit**	**why_reason**	**alternative**	**value**
	Process hindrance		Keep current lighting	0
			Refurbish and convert to LED	0.89
			Replace and repurpose old lighting elsewhere	1
Operational costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Keep current lighting	0
			Refurbish and convert to LED	0.86
			Replace and repurpose old lighting elsewhere	1
Comfort	**benefit**	**why_reason**	**alternative**	**value**
	Employee productivity		Keep current lighting	0
			Refurbish and convert to LED	0.88
			Replace and repurpose old lighting elsewhere	1
Comfort	**benefit**	**why_reason**	**alternative**	**value**
	Process hindrance		Keep current lighting	0
			Refurbish and convert to LED	0.89
			Replace and repurpose old lighting elsewhere	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		Replace and repurpose old lighting elsewhere	0
			Refurbish and convert to LED	0.86
			Keep current lighting	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	social image		Replace and repurpose old lighting elsewhere	0
			Refurbish and convert to LED	0.86
			Keep current lighting	1
Amount of new material	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Replace and repurpose old lighting elsewhere	0
			Refurbish and convert to LED	0.88
			Keep current lighting	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		Keep current lighting	0
			Refurbish and convert to LED	0.77
			Replace and repurpose old lighting elsewhere	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		Keep current lighting	0
			Refurbish and convert to LED	0.77
			Replace and repurpose old lighting elsewhere	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	social image		Keep current lighting	0.49
			Refurbish and convert to LED	0.69
			Replace and repurpose old lighting elsewhere	0.99
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Climate adaptation		Keep current lighting	0
			Refurbish and convert to LED	0.72
			Replace and repurpose old lighting elsewhere	1

attrib_benefit_importance

attribute	benefit	importance
Maintenance interval	Total costs	709
Maintenance interval	Process hindrance	709
Maintenance interval	Employee productivity	800
Investment costs	Total costs	362
Operational costs	Energy consumption	756
Operational costs	Employee productivity	725
Operational costs	Process hindrance	719
Operational costs	Total costs	500

Comfort	Employee productivity	792
Comfort	Process hindrance	608
Amount of new material	Ecological footprint	850
Amount of new material	social image	853
Amount of new material	Total costs	843
Energy performance	Energy consumption	841
Energy performance	Ecological footprint	818
Energy performance	social image	818
Energy performance	Climate adaptation	785

utility

alternative	**uValue**
Replace and repurpose old lighting elsewhere	5.01
Refurbish and convert to LED	4.43
Keep current lighting	1.12

ID			
name	Respondent 4		
attrib_alt_matrix			
attribute_name	**alternative_name**	**rating**	**rating_value**
Maintenance interval	No measures on the roof	--	0
Maintenance interval	Install new roofing	++	4
Maintenance interval	Placing a green roof	+	3
Maintenance interval	Placing solar panels	+	3
Investment costs	No measures on the roof	+	3
Investment costs	Install new roofing	-	1
Investment costs	Placing a green roof	-	1
Investment costs	Placing solar panels	-	1
Appearance	No measures on the roof	0	2
Appearance	Install new roofing	+	3
Appearance	Placing a green roof	++	4
Appearance	Placing solar panels	++	4
heat rejection	No measures on the roof	--	0
heat rejection	Install new roofing	++	4
heat rejection	Placing a green roof	++	4
heat rejection	Placing solar panels	+	3
Water buffer	No measures on the roof	0	2
Water buffer	Install new roofing	0	2
Water buffer	Placing a green roof	++	4
Water buffer	Placing solar panels	0	2
Energy performance	No measures on the roof	--	0
Energy performance	Install new roofing	++	4
Energy performance	Placing a green roof	+	3
Energy performance	Placing solar panels	0	2

atrrib_benefit_matrix

attribute_name	**benefits**	
Maintenance interval	**benefit**	**why_reason**
	Total costs	
	Process hindrance	
Investment costs	**benefit**	**why_reason**
	Total costs	
Appearance	**benefit**	**why_reason**
	social image	
	Ecological footprint	
	Climate adaptation	
	Energy consumption	
heat rejection	**benefit**	**why_reason**
	Climate adaptation	
	Energy consumption	
	Ecological footprint	
Water buffer	**benefit**	**why_reason**
	Climate adaptation	
	Ecological footprint	
	social image	
Energy performance	**benefit**	**why_reason**
	Energy consumption	
	Total costs	
	Ecological footprint	
	social image	

attrib_benefit_preference

attribute_name	**benefit_name**		**preference**	
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		No measures on the roof	0
			Placing a green roof	0.33
			Placing solar panels	0.5
			Install new roofing	1
Maintenance interval	**benefit**	**why_reason**	**alternative**	**value**
	Process hindrance		No measures on the roof	0
			Placing a green roof	0.33
			Placing solar panels	0.5
			Install new roofing	1
Investment costs	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		Install new roofing	0.41
			Placing a green roof	0.1
			Placing solar panels	0
			No measures on the roof	1
	benefit	**why_reason**	**alternative**	**value**

Appearance	social image		No measures on the roof	0
			Install new roofing	0.59
			Placing a green roof	1
			Placing solar panels	0.86
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		No measures on the roof	0
			Install new roofing	0.59
			Placing a green roof	1
			Placing solar panels	0.88
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Climate adaptation		No measures on the roof	0
			Install new roofing	0.59
			Placing a green roof	1
			Placing solar panels	0.88
Appearance	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		No measures on the roof	0
			Install new roofing	0.59
			Placing a green roof	1
			Placing solar panels	0.89
heat rejection	**benefit**	**why_reason**	**alternative**	**value**
	Climate adaptation		No measures on the roof	0
			Placing solar panels	0.47
			Install new roofing	0.82
			Placing a green roof	1
heat rejection	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		No measures on the roof	0
			Placing solar panels	0.47
			Install new roofing	0.82
			Placing a green roof	1
heat rejection	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		No measures on the roof	0
			Placing solar panels	0.47
			Install new roofing	0.82
			Placing a green roof	1
Water buffer	**benefit**	**why_reason**	**alternative**	**value**
	Climate adaptation		No measures on the roof	0
			Install new roofing	0.22
			Placing solar panels	0.11
			Placing a green roof	1
Water buffer	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		No measures on the roof	0
			Install new roofing	0.23
			Placing solar panels	0.11
			Placing a green roof	1
Water buffer	**benefit**	**why_reason**	**alternative**	**value**
	social image		No measures on the roof	0
			Install new roofing	0.22
			Placing solar panels	0.11
			Placing a green roof	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Energy consumption		No measures on the roof	0
			Placing solar panels	0.78
			Placing a green roof	0.87
			Install new roofing	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Total costs		No measures on the roof	0
			Placing solar panels	0.78
			Placing a green roof	0.87
			Install new roofing	1
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	Ecological footprint		No measures on the roof	0
			Placing solar panels	1
			Placing a green roof	0.87
			Install new roofing	0.72
Energy performance	**benefit**	**why_reason**	**alternative**	**value**
	social image		No measures on the roof	0
			Placing solar panels	1
			Placing a green roof	0.87
			Install new roofing	0.63

attrib_benefit_importance

attribute	benefit	importance

Maintenance interval	Total costs	764
Maintenance interval	Process hindrance	217
Investment costs	Total costs	217
Appearance	social image	805
Appearance	Ecological footprint	802
Appearance	Climate adaptation	797
Appearance	Energy consumption	797
heat rejection	Climate adaptation	792
heat rejection	Energy consumption	793
heat rejection	Ecological footprint	702
Water buffer	Climate adaptation	704
Water buffer	Ecological footprint	701
Water buffer	social image	704
Energy performance	Energy consumption	799
Energy performance	Total costs	804
Energy performance	Ecological footprint	804
Energy performance	social image	795

utility

alternative	**uValue**
No measures on the roof	1
Install new roofing	3.89
Placing a green roof	4.3
Placing solar panels	2.85

Appendix E

Revit custom property set

```
#Revit custom property set for export Ifc
#
#Properties in this set are used to calculate
environmental impact in the BEE application.
#All lines starting with an # are not considered during the IFC export
#
#
PropertySet: BEE   I IfcElement,IfcSpace,IfcWall,IfcBeam,IfcSlab,
    IfcWindow,IfcAirTerminalBoxType,IfcAirTerminal,IfcAirToHeatRecovery,
    IfcBoilertype,IfcBuildingElementPart,IfcCableCarrierSegmentType,
    IfcCableSegmentType,IfcChillerType,IfcCoilType,IfcColumn,
    IfcCompressorType,IfcCodensorType,IfcCooledBeamType,IfcCovering,
    IfcCovering.CEILING,IfcCovering-PreDefinedType:CEILING,IfcCovering-
    PreDefinedType:FLOORING,IfcCurtainWall,IfcDamperType,
    IfcDiscreteAccessory,IfcPlate,IfcDistributionElement,
    IfcDistributionFlowElement, IfcDoor, IfcDuctFittingType,
    IfcDuctSegmentType, IfcDuctSilencerType, IfcElectricApplianceType,
    IfcElectricDistributionPoint, IfcElectricFlowStorageDevice,
    IfcElectricGeneratorType, IfcElectricHeaterType, IfcElectricMotortype
    , IfcEletricTimeControlType, IfcElementAssembly,
    IfcEnergyConversionDevice, IfcEvaportiveCoolerType,
    IfcEvaporativeType, IfcFanType, IfcFasterner, IfcFilterType,
    IfcFireSuppressionTerminalType, IfcFlowFitting, IfcFlowMeter,
    IfcFlowMobingDevice, IfcFlowSegment, Ifc FlowStorageDevice,
    IfcFlowTerminal, IfcFlowTreatmentDevice, IfcFooting, IfcFurnitureType
    , IfcGasTerminalType, IfcHeatExchangerType, IfcHumidifierType,
    IfcJunctionBoxType, IfcLampType, IfcLightFixtureType, IfcMember,
    ifcMotorConnectionType, IfcObject, IfcOpeningElement, IfcOutlet,
    IfcPile, IfcPipeFittingType, IfcPipeSegementType, IfcPlate,
    IfcProtectiveDeviceType, IfcPumpType, IfcRailing, IfcRamp,
    IfcReinforcingBar, IfcReinforcingMesh, IfcRoof,
    IfcSanitaryTerminalType, IfcSpaceHeaterType, IfcStackTerminalType,
    IfcStair, IfcSwitchingDeviceType, IfcTankType, IfcTendon,
    IfcTendonAnchor, IfcTransformerType IfcTransportType,
    IfcTransportElement, IfcTransportElement-PreDefinedType:ELEVATOR,
    IfcTransportElement:ELEVATOR, IfcTubeBundleType,
    IfcUnitaryEquipmentType, IfcValveType, IfcWasteTerminalType
```

```
#
#
    Q Lengte    Length  Length
  Q Hoogte    Length  Height
  Q Hoogte    Length  Unconnected Height
  Q Hoogte    Length  DesiredStair Height
  Q Hoogte    Length  RailingHeight
  Q Breedte/Dikte Length  Width
  Q Breedte/Dikte Length  Actual Run Width
  Q Dikte     Length  Thickness
  Q Omtrek    Length  Perimeter
  Q Diameter  Length  Diameter
  Q Oppervlakte   Area    Area
  Q Inhoud    Volume  Volume
  IfcIncluded Boolean IfcIncluded
  IfcLifespan Real    IfcLifespan

#
#End of propertyset
```

Listing E.1 Environmental calculation algorithm

Appendix F

BEE Calculation- Floortiles

F.1 Calculation results circular carpet tiles

(Multiple pages)

IFC file: DIEW30_B000_BV3_R20_detached-big-2.ifc - Database: http://localhost:8080

Calculation Data

Phase	ADPc	ADPf	GWP	ODP	POCP	AP	EP	HTP	FAETP	MAETP	TETP	SUM
Production	0.025	7916.094	13395.251	0.047	96.951	2610.627	1729.014	0.000	0.000	0.000	0.000	25748.009
Transport	0.000	1195.835	27.369	0.000	-1.874	9.032	5.116	0.000	0.000	0.000	0.000	1235.479
Building	0.009	5372.838	844.769	0.016	18.316	296.854	209.376	0.000	0.000	0.000	0.000	6742.179
Waste_Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Waste_Processing	0.000	2265.350	12158.362	0.000	21.475	671.605	373.751	0.000	0.000	0.000	0.000	15490.543
Waste_Disposal	0.000	3823.305	823.716	0.000	9.832	175.165	412.595	0.000	0.000	0.000	0.000	5244.612
Beyond_Scope	-0.004	-21.475	-4868.608	0.000	-25.580	-604.234	-153.480	0.000	0.000	0.000	0.000	-5673.380
SUM	0.031	20551.948	22380.860	0.063	119.120	3159.048	2576.373	0.000	0.000	0.000	0.000	48787.442

Included objects

Name	MKI
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925	22.041

Name	MKI
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:2	22.041
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:3	22.041
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:4	22.041
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:5	22.041
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:6	22.041
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:7	22.041
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:782663	152.197
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425	760.904
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:2	760.904
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:3	760.904
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:4	760.904
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:5	760.904
Floor:43_FL_vloerbedekking FF03_6.5 mm Arable 2915:4867093	49.778
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4867250	63.712
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4867250:2	63.712
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4867941	59.471
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4867941:2	59.471
Floor:43_FL_vloerbedekking FF06_6.5 mm Desso & EX for Home AA08 4311-640:4868156	30.822
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:2	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:3	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:4	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:5	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:6	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:7	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:8	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:9	288.317
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:10	288.317
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4869032	64.691

Name	MKI
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4869128	138.269
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4869128:2	138.269
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4869128:3	138.269
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4869468	42.421
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4869468:2	42.421
Floor:43_FL_vloerbedekking FF12_6.5 mm Granite 9004:4869745	46.708
Floor:43_FL_vloerbedekking FF13_6.5 mm Granite 2904:4869804	32.157
Floor:43_FL_vloerbedekking FF14_6.5 mm Desso & EX for Home AA08 9512-642:4869850	39.152
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907	66.625
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:2	66.625
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:3	66.625
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:4	66.625
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:5	66.625
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:6	66.625
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:7	66.625
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4871398	92.327
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4871398:2	92.327
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5057287	116.212
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5057287:2	116.212
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5057287:3	116.212
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:2	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:3	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:4	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:5	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:6	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:7	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:8	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:9	22.394

Name	**MKI**
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:10	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:11	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:12	22.394
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:13	22.394
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:853971	374.777
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698	997.246
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:2	997.246
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:3	997.246
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:4	997.246
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:5	997.246
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:6	997.246
Floor:43_FL_vloerbedekking FF03_6.5 mm Arable 2915:4939160	170.671
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614	128.373
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614:2	128.373
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614:3	128.373
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614:4	128.373
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998	86.697
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998:2	86.697
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998:3	86.697
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998:4	86.697
Floor:43_FL_vloerbedekking FF06_6.5 mm Desso & EX for Home AA08 4311-640:4940207	30.822
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:2	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:3	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:4	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:5	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:6	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:7	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:8	568.129

Name	MKI
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:9	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:10	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:11	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:12	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:13	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:14	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:15	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:16	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:17	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:18	568.129
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:19	568.129
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4941945	137.491
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4941945:2	137.491
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4942244	138.102
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4942244:2	138.102
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4942244:3	138.102
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4944886	42.421
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4944886:2	42.421
Floor:43_FL_vloerbedekking FF12_6.5 mm Granite 9004:4944924	46.708
Floor:43_FL_vloerbedekking FF13_6.5 mm Granite 2904:4944968	32.157
Floor:43_FL_vloerbedekking FF14_6.5 mm Desso & EX for Home AA08 9512-642:4945016	38.181
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:2	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:3	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:4	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:5	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:6	38.937
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4945671	60.726
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5041391	116.212

Name	**MKI**
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5041391:2	116.212
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5041391:3	116.212
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169	919.218
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169:2	919.218
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169:3	919.218
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169:4	919.218
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:2	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:3	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:4	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:5	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:6	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:7	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:8	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:9	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:10	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:11	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:12	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:13	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:14	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:15	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:16	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:17	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:18	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:19	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:20	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:21	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:22	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:23	132.566

Name	**MKI**
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:24	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:25	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:26	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:27	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:28	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:29	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:30	132.566
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:31	132.566
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178	833.042
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:2	833.042
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:3	833.042
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:4	833.042
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:5	833.042
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:6	833.042
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:7	833.042
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:2	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:3	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:4	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:5	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:6	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:7	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:8	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:9	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:10	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:11	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:12	382.671
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:13	382.671
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4857280	64.691

Name	MKI
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4857380	88.619
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4859725	33.159
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4859725:2	33.159
Floor:43_FL_vloerbedekking FF13_6.5 mm Granite 2904:4860075	28.825
Floor:43_FL_vloerbedekking FF15_6.5 mm Grezzo AB64 8927:4860207	28.598
Floor:43_FL_vloerbedekking FF15_6.5 mm Grezzo AB64 8927:4860207:2	28.598
Floor:43_FL_vloerbedekking FF15_6.5 mm Grezzo AB64 8927:4860207:3	28.598
Floor:43_FL_vloerbedekking FF17_6.5 mm Grezzo AB64 8913:4860820	18.332
Floor:43_FL_vloerbedekking FF17_6.5 mm Grezzo AB64 8913:4860820:2	18.332
Floor:43_FL_vloerbedekking FF18_6.5 mm Grezzo AB64 7923:4860928	46.062
Floor:43_FL_vloerbedekking FF18_6.5 mm Grezzo AB64 7923:4860928:2	46.062
Floor:43_FL_vloerbedekking FF18_6.5 mm Grezzo AB64 7923:4860928:3	46.062
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4860994	60.726
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:2	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:3	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:4	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:5	38.937
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:6	38.937
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:4981088	116.212
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:4981088:2	116.212
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:4981088:3	116.212

Excluded objects

Name

F.2 Calculation results traditional bitumen carpet tiles

(Multiple pages)

IFC file: DIEW30_B000_BV3_R20_detached-big-2.ifc - Database: http://localhost:8080

Calculation Data

Phase	ADPc	ADPf	GWP	ODP	POCP	AP	EP	HTP	FAETP	MAETP	TETP	SUM
Production	0.558	6652.887	278958.086	3.111	6916.055	56002.152	23685.121	124583.734	0.009	9526.682	241.272	506569.667
Transport	0.000	1195.835	27.369	0.000	-1.874	9.032	5.116	0.000	0.000	0.000	0.000	1235.479
Building	0.009	5372.838	844.769	0.016	18.316	296.854	209.376	0.000	0.000	0.000	0.000	6742.179
Waste_Transport	0.000	22653.502	12158.362	0.000	21.475	671.605	373.751	0.000	0.000	0.000	0.000	35878.695
Waste_Processing	0.000	38233.048	823.716	0.000	9.832	175.165	412.595	0.000	0.000	0.000	0.000	39654.355
Waste_Disposal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Beyond_Scope	-0.004	-21.475	-4868.608	0.000	-25.580	-604.234	-153.480	0.000	0.000	0.000	0.000	-5673.380
SUM	0.564	74086.636	287943.694	3.126	6938.224	56550.573	24532.479	124583.734	0.009	9526.682	241.272	584406.995

Included objects

Name	MKI
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925	264.022

Name	MKI
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:2	264.022
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:3	264.022
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:4	264.022
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:5	264.022
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:6	264.022
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:774925:7	264.022
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:782663	1823.110
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425	9114.588
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:2	9114.588
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:3	9114.588
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:4	9114.588
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4863425:5	9114.588
Floor:43_FL_vloerbedekking FF03_6.5 mm Arable 2915:4867093	596.267
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4867250	763.185
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4867250:2	763.185
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4867941	712.383
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4867941:2	712.383
Floor:43_FL_vloerbedekking FF06_6.5 mm Desso & EX for Home AA08 4311-640:4868156	369.211
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:2	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:3	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:4	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:5	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:6	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:7	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:8	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:9	3453.640
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4868230:10	3453.640
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4869032	774.908

Name	MKI
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4869128	1656.275
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4869128:2	1656.275
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4869128:3	1656.275
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4869468	508.140
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4869468:2	508.140
Floor:43_FL_vloerbedekking FF12_6.5 mm Granite 9004:4869745	559.500
Floor:43_FL_vloerbedekking FF13_6.5 mm Granite 2904:4869804	385.197
Floor:43_FL_vloerbedekking FF14_6.5 mm Desso & EX for Home AA08 9512-642:4869850	468.984
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907	798.074
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:2	798.074
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:3	798.074
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:4	798.074
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:5	798.074
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:6	798.074
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4869907:7	798.074
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4871398	1105.948
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4871398:2	1105.948
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5057287	1392.062
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5057287:2	1392.062
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5057287:3	1392.062
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:2	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:3	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:4	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:5	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:6	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:7	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:8	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:9	268.248

Name	MKI
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:10	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:11	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:12	268.248
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:853834:13	268.248
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:853971	4489.314
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698	11945.651
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:2	11945.651
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:3	11945.651
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:4	11945.651
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:5	11945.651
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4935698:6	11945.651
Floor:43_FL_vloerbedekking FF03_6.5 mm Arable 2915:4939160	2044.411
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614	1537.739
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614:2	1537.739
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614:3	1537.739
Floor:43_FL_vloerbedekking FF04_6.5 mm Arable custum color:4939614:4	1537.739
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998	1038.507
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998:2	1038.507
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998:3	1038.507
Floor:43_FL_vloerbedekking FF05_6.5 mm Arable 5031:4939998:4	1038.507
Floor:43_FL_vloerbedekking FF06_6.5 mm Desso & EX for Home AA08 4311-640:4940207	369.211
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:2	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:3	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:4	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:5	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:6	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:7	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:8	6805.411

Name	MKI
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:9	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:10	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:11	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:12	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:13	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:14	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:15	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:16	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:17	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:18	6805.411
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4940254:19	6805.411
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4941945	1646.952
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4941945:2	1646.952
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4942244	1654.268
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4942244:2	1654.268
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4942244:3	1654.268
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4944886	508.142
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4944886:2	508.142
Floor:43_FL_vloerbedekking FF12_6.5 mm Granite 9004:4944924	559.500
Floor:43_FL_vloerbedekking FF13_6.5 mm Granite 2904:4944968	385.197
Floor:43_FL_vloerbedekking FF14_6.5 mm Desso & EX for Home AA08 9512-642:4945016	457.359
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:2	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:3	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:4	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:5	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4945086:6	466.418
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4945671	727.414
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5041391	1392.062

Name	MKI
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5041391:2	1392.062
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:5041391:3	1392.062
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169	11010.974
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169:2	11010.974
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169:3	11010.974
Floor:43_FL_vloerbedekking (grijs)_6.5 mm Desso Field:1482169:4	11010.974
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:2	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:3	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:4	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:5	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:6	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:7	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:8	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:9	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:10	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:11	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:12	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:13	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:14	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:15	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:16	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:17	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:18	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:19	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:20	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:21	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:22	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:23	1587.965

Name	MKI
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:24	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:25	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:26	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:27	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:28	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:29	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:30	1587.965
Floor:43_FL_vloerbedekking (Beige)_6.5 mm Desso Field:1489122:31	1587.965
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178	9978.702
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:2	9978.702
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:3	9978.702
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:4	9978.702
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:5	9978.702
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:6	9978.702
Floor:43_FL_vloerbedekking FF01_6.5 mm Iconic 9517:4831178:7	9978.702
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:2	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:3	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:4	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:5	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:6	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:7	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:8	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:9	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:10	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:11	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:12	4583.874
Floor:43_FL_vloerbedekking FF07_6.5 mm Metallic Shade AA68 2017:4856412:13	4583.874
Floor:43_FL_vloerbedekking FF08_6.5 mm Metallic Shade AA68 2031:4857280	774.908

Name	MKI
Floor:43_FL_vloerbedekking FF10_6.5 mm Airmaster Earth 1051:4857380	1061.538
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4859725	397.202
Floor:43_FL_vloerbedekking FF11_6.5 mm Wave,9532:4859725:2	397.202
Floor:43_FL_vloerbedekking FF13_6.5 mm Granite 2904:4860075	345.282
Floor:43_FL_vloerbedekking FF15_6.5 mm Grezzo AB64 8927:4860207	342.563
Floor:43_FL_vloerbedekking FF15_6.5 mm Grezzo AB64 8927:4860207:2	342.563
Floor:43_FL_vloerbedekking FF15_6.5 mm Grezzo AB64 8927:4860207:3	342.563
Floor:43_FL_vloerbedekking FF17_6.5 mm Grezzo AB64 8913:4860820	219.593
Floor:43_FL_vloerbedekking FF17_6.5 mm Grezzo AB64 8913:4860820:2	219.593
Floor:43_FL_vloerbedekking FF18_6.5 mm Grezzo AB64 7923:4860928	551.757
Floor:43_FL_vloerbedekking FF18_6.5 mm Grezzo AB64 7923:4860928:2	551.757
Floor:43_FL_vloerbedekking FF18_6.5 mm Grezzo AB64 7923:4860928:3	551.757
Floor:43_FL_vloerbedekking FF19_6.5 mm Metalilic Shades AA57 2083:4860994	727.414
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:2	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:3	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:4	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:5	466.418
Floor:43_FL_vloerbedekking FF16_6.5 mm Veneto Sicuro R10-Veneto Periwinkel 761:4978726:6	466.418
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:4981088	1392.062
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:4981088:2	1392.062
Floor:43_FL_vloerbedekking FF21_6.5 mm Veneto-Veneto Pewter 685:4981088:3	1392.062

Excluded objects

Name

Appendix G

BEE Calculation- Walltiles

G.1 Calculation results reuse of existing walltiles

(Multiple pages)

IFC file: DIEW30_B000_BV3_R20_detached-big-2-t10.ifc - Database: http://localhost:8080

Calculation Data

Phase	ADPc	ADPf	GWP	ODP	POCP	AP	EP	HTP	FAETP	MAETP	TETP	SUM
Production	0.006	1174.293	233.700	0.021	12.876	37.856	0.000	0.000	0.003	0.000	1.518	1460.273
Transport	0.000	1901.531	38.950	0.005	0.005	8.962	0.000	0.000	0.000	0.000	0.286	1949.739
Building	0.000	164.813	225.330	0.000	0.000	0.845	0.000	0.000	0.000	0.000	0.022	391.011
Waste_Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Waste_Processing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Waste_Disposal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Beyond_Scope	-0.000	-193.655	-4.507	-0.000	0.000	-2.627	0.000	0.000	-0.000	-0.000	-0.119	-200.908
SUM	0.007	3046.982	493.474	0.026	12.881	45.035	0.000	0.000	0.003	0.000	1.708	3600.116

Included objects

Name	MKI
Basic Wall:41_WA_tegels_150x150:1902007	79.538

Name	**MKI**
Basic Wall:41_WA_tegels_150x150:1902008	30.092
Basic Wall:41_WA_tegels_150x150:1902009	48.428
Basic Wall:41_WA_tegels_150x150:1902010	24.405
Basic Wall:41_WA_tegels_150x150:1902011	24.405
Basic Wall:41_WA_tegels_150x150:1902015	4.341
Basic Wall:41_WA_tegels_150x150:1902016	8.881
Basic Wall:41_WA_tegels_150x150:1902027	25.434
Basic Wall:41_WA_tegels_150x150:1902028	35.141
Basic Wall:41_WA_tegels_150x150:1902029	1.321
Basic Wall:41_WA_tegels_150x150:1902030	11.248
Basic Wall:41_WA_tegels_150x150:1902031	3.567
Basic Wall:41_WA_tegels_150x150:1902032	7.640
Basic Wall:41_WA_tegels_150x150:1902033	38.123
Basic Wall:41_WA_tegels_150x150:1902034	22.496
Basic Wall:41_WA_tegels_150x150:1902035	6.945
Basic Wall:41_WA_tegels_150x150:1902036	1.095
Basic Wall:41_WA_tegels_150x150:1902403	1.095
Basic Wall:41_WA_tegels_150x150:1902439	6.945
Basic Wall:41_WA_tegels_150x150:1902514	18.337
Basic Wall:41_WA_tegels_150x150:1902561	49.602
Basic Wall:41_WA_tegels_150x150:1907734	22.594
Basic Wall:41_WA_tegels_150x150:1907757	0.730
Basic Wall:41_WA_tegels_150x150:1907833	0.705
Basic Wall:41_WA_tegels_150x150:2548030	7.105
Basic Wall:41_WA_tegels_150x150:2548031	8.367
Basic Wall:41_WA_tegels_150x150:2548032	1.972
Basic Wall:41_WA_tegels_150x150:2548033	8.334
Basic Wall:41_WA_tegels_150x150:2548054	7.105
Basic Wall:41_WA_tegels_150x150:2548055	8.367

Name	MKI
Basic Wall:41_WA_tegels_150x150:2548056	1.972
Basic Wall:41_WA_tegels_150x150:2548057	8.334
Basic Wall:41_WA_tegels_150x150:2548078	7.105
Basic Wall:41_WA_tegels_150x150:2548079	8.367
Basic Wall:41_WA_tegels_150x150:2548080	1.972
Basic Wall:41_WA_tegels_150x150:2548081	8.334
Basic Wall:41_WA_tegels_150x150:2548102	4.017
Basic Wall:41_WA_tegels_150x150:2548103	0.498
Basic Wall:41_WA_tegels_150x150:2548104	3.984
Basic Wall:41_WA_tegels_150x150:2548105	12.119
Basic Wall:41_WA_tegels_150x150:2548106	14.210
Basic Wall:41_WA_tegels_150x150:2548107	6.913
Basic Wall:41_WA_tegels_150x150:2548108	14.210
Basic Wall:41_WA_tegels_150x150:2548109	3.519
Basic Wall:41_WA_tegels_150x150:2565222	0.822
Basic Wall:41_WA_tegels_150x150:2565278	0.822
Floor:41_FL_tegels_150x150:2565377	0.511
Basic Wall:41_WA_tegels_150x150:2566205	0.822
Basic Wall:41_WA_tegels_150x150:2566206	0.822
Floor:41_FL_tegels_150x150:2566209	0.511
Basic Wall:41_WA_tegels_150x150:2566269	0.851
Basic Wall:41_WA_tegels_150x150:2566270	0.822
Floor:41_FL_tegels_150x150:2566273	0.511
Basic Wall:41_WA_tegels_150x150:2566295	0.822
Basic Wall:41_WA_tegels_150x150:2566296	0.822
Floor:41_FL_tegels_150x150:2566299	0.511
Basic Wall:41_WA_tegels_150x150:2568961	7.105
Basic Wall:41_WA_tegels_150x150:2568962	8.367
Basic Wall:41_WA_tegels_150x150:2568963	1.972

Name	MKI
Basic Wall:41_WA_tegels_150x150:2568964	8.334
Basic Wall:41_WA_tegels_150x150:2568985	7.105
Basic Wall:41_WA_tegels_150x150:2568986	8.367
Basic Wall:41_WA_tegels_150x150:2568987	1.972
Basic Wall:41_WA_tegels_150x150:2568988	8.334
Basic Wall:41_WA_tegels_150x150:2569009	7.105
Basic Wall:41_WA_tegels_150x150:2569010	8.367
Basic Wall:41_WA_tegels_150x150:2569011	1.972
Basic Wall:41_WA_tegels_150x150:2569012	8.334
Basic Wall:41_WA_tegels_150x150:2569033	4.017
Basic Wall:41_WA_tegels_150x150:2569034	0.498
Basic Wall:41_WA_tegels_150x150:2569035	3.984
Basic Wall:41_WA_tegels_150x150:2569036	12.119
Basic Wall:41_WA_tegels_150x150:2569037	14.210
Basic Wall:41_WA_tegels_150x150:2569038	6.913
Basic Wall:41_WA_tegels_150x150:2569039	14.210
Basic Wall:41_WA_tegels_150x150:2569040	3.519
Basic Wall:41_WA_tegels_150x150:2569238	2.302
Basic Wall:41_WA_tegels_150x150:2569266	4.529
Basic Wall:41_WA_tegels_150x150:2569275	0.566
Basic Wall:41_WA_tegels_150x150:2569315	4.529
Basic Wall:41_WA_tegels_150x150:2569360	4.831
Basic Wall:41_WA_tegels_150x150:2569412	16.231
Basic Wall:41_WA_tegels_150x150:2569450	6.747
Basic Wall:41_WA_tegels_150x150:2569506	16.193
Basic Wall:41_WA_tegels_150x150:2569585	9.537
Basic Wall:41_WA_tegels_150x150:2569623	1.872
Basic Wall:41_WA_tegels_150x150:2569655	9.500
Basic Wall:41_WA_tegels_150x150:2569704	6.945

Name	**MKI**
Basic Wall:41_WA_tegels_150x150:2570562	9.537
Basic Wall:41_WA_tegels_150x150:2570563	1.872
Basic Wall:41_WA_tegels_150x150:2570564	9.500
Basic Wall:41_WA_tegels_150x150:2570565	6.945
Basic Wall:41_WA_tegels_150x150:2570597	9.537
Basic Wall:41_WA_tegels_150x150:2570598	1.872
Basic Wall:41_WA_tegels_150x150:2570599	9.500
Basic Wall:41_WA_tegels_150x150:2570600	6.945
Basic Wall:41_WA_tegels_150x150:2570632	9.537
Basic Wall:41_WA_tegels_150x150:2570633	1.872
Basic Wall:41_WA_tegels_150x150:2570634	9.500
Basic Wall:41_WA_tegels_150x150:2570635	6.945
Basic Wall:41_WA_tegels_150x150:2570667	9.537
Basic Wall:41_WA_tegels_150x150:2570668	1.872
Basic Wall:41_WA_tegels_150x150:2570669	9.500
Basic Wall:41_WA_tegels_150x150:2570670	6.945
Basic Wall:41_WA_tegels_150x150:2641413	9.187
Basic Wall:41_WA_tegels_150x150:2641414	1.872
Basic Wall:41_WA_tegels_150x150:2641415	9.150
Basic Wall:41_WA_tegels_150x150:2641416	6.945
Basic Wall:41_WA_tegels_150x150:2641469	9.187
Basic Wall:41_WA_tegels_150x150:2641470	1.872
Basic Wall:41_WA_tegels_150x150:2641471	9.150
Basic Wall:41_WA_tegels_150x150:2641472	6.945
Basic Wall:41_WA_tegels_150x150:2641496	9.187
Basic Wall:41_WA_tegels_150x150:2641497	1.872
Basic Wall:41_WA_tegels_150x150:2641498	9.150
Basic Wall:41_WA_tegels_150x150:2641499	6.945
Basic Wall:41_WA_tegels_150x150:2641523	9.187

Name	MKI
Basic Wall:41_WA_tegels_150x150:2641524	1.872
Basic Wall:41_WA_tegels_150x150:2641525	9.150
Basic Wall:41_WA_tegels_150x150:2641526	6.945
Basic Wall:41_WA_tegels_150x150:2641550	12.101
Basic Wall:41_WA_tegels_150x150:2641551	1.622
Basic Wall:41_WA_tegels_150x150:2641552	4.517
Basic Wall:41_WA_tegels_150x150:2641553	6.039
Basic Wall:41_WA_tegels_150x150:2641554	16.581
Basic Wall:41_WA_tegels_150x150:2641555	4.272
Basic Wall:41_WA_tegels_150x150:2641960	12.101
Basic Wall:41_WA_tegels_150x150:2641961	1.622
Basic Wall:41_WA_tegels_150x150:2641962	4.517
Basic Wall:41_WA_tegels_150x150:2641963	6.039
Basic Wall:41_WA_tegels_150x150:2641964	16.581
Basic Wall:41_WA_tegels_150x150:2641965	4.272
Basic Wall:41_WA_tegels_150x150:2642065	4.347
Basic Wall:41_WA_tegels_150x150:2642117	16.193
Basic Wall:41_WA_tegels_150x150:2642118	16.231
Basic Wall:41_WA_tegels_150x150:2642119	15.211
Basic Wall:41_WA_tegels_150x150:2644992	11.413
Basic Wall:41_WA_tegels_150x150:2644993	13.812
Basic Wall:41_WA_tegels_150x150:2644994	21.627
Basic Wall:41_WA_tegels_150x150:2644995	13.194
Basic Wall:41_WA_tegels_150x150:2645133	2.181
Basic Wall:41_WA_BKS+GPS FR30:2870816	34.376
Basic Wall:41_WA_BKS+GPS FR30:2870925	29.922
Basic Wall:41_WA_tegels_150x150:3758575	9.512
Basic Wall:41_WA_tegels_150x150:3758576	2.928
Basic Wall:41_WA_tegels_150x150:3758577	9.550

Name	MKI
Basic Wall:41_WA_tegels_150x150:3758578	8.002
Basic Wall:41_WA_tegels_150x150:3759213	9.512
Basic Wall:41_WA_tegels_150x150:3759214	2.928
Basic Wall:41_WA_tegels_150x150:3759215	9.550
Basic Wall:41_WA_tegels_150x150:3759216	8.002
Basic Wall:41_WA_tegels_150x150:3759260	9.512
Basic Wall:41_WA_tegels_150x150:3759261	2.928
Basic Wall:41_WA_tegels_150x150:3759262	9.550
Basic Wall:41_WA_tegels_150x150:3759263	8.002
Basic Wall:41_WA_tegels_150x150:3759324	9.512
Basic Wall:41_WA_tegels_150x150:3759325	2.928
Basic Wall:41_WA_tegels_150x150:3759326	9.550
Basic Wall:41_WA_tegels_150x150:3759327	8.002
Basic Wall:41_WA_tegels_150x150:3759408	9.512
Basic Wall:41_WA_tegels_150x150:3759409	2.928
Basic Wall:41_WA_tegels_150x150:3759410	9.550
Basic Wall:41_WA_tegels_150x150:3759411	8.002
Basic Wall:41_WA_tegels_150x150:3759455	9.512
Basic Wall:41_WA_tegels_150x150:3759456	2.928
Basic Wall:41_WA_tegels_150x150:3759457	9.550
Basic Wall:41_WA_tegels_150x150:3759458	8.002
Basic Wall:41_WA_tegels_150x150:3761831	16.193
Basic Wall:41_WA_tegels_150x150:3761852	5.280
Basic Wall:41_WA_tegels_150x150:3761869	4.529
Basic Wall:41_WA_tegels_150x150:3761890	0.604
Basic Wall:41_WA_tegels_150x150:3761909	4.529
Basic Wall:41_WA_tegels_150x150:3761932	13.739
Basic Wall:41_WA_tegels_150x150:3761947	16.193
Basic Wall:41_WA_tegels_150x150:3761973	9.880

Name	MKI
Basic Wall:41_WA_tegels_150x150:3763043	16.193
Basic Wall:41_WA_tegels_150x150:3763044	5.280
Basic Wall:41_WA_tegels_150x150:3763045	4.529
Basic Wall:41_WA_tegels_150x150:3763046	0.604
Basic Wall:41_WA_tegels_150x150:3763047	4.529
Basic Wall:41_WA_tegels_150x150:3763048	13.739
Basic Wall:41_WA_tegels_150x150:3763049	16.193
Basic Wall:41_WA_tegels_150x150:3763050	9.880
Basic Wall:41_WA_tegels_150x150:1763026	6.530
Basic Wall:41_WA_tegels_150x150:1763027	8.040
Basic Wall:41_WA_tegels_150x150:1763028	1.397
Basic Wall:41_WA_tegels_150x150:1763029	8.006
Basic Wall:41_WA_tegels_150x150:1763050	6.530
Basic Wall:41_WA_tegels_150x150:1763051	8.040
Basic Wall:41_WA_tegels_150x150:1763052	1.397
Basic Wall:41_WA_tegels_150x150:1763053	8.006
Basic Wall:41_WA_tegels_150x150:1763074	6.530
Basic Wall:41_WA_tegels_150x150:1763075	8.040
Basic Wall:41_WA_tegels_150x150:1763076	1.397
Basic Wall:41_WA_tegels_150x150:1763077	8.006
Basic Wall:41_WA_tegels_150x150:1763098	2.424
Basic Wall:41_WA_tegels_150x150:1763099	0.631
Basic Wall:41_WA_tegels_150x150:1763100	3.984
Basic Wall:41_WA_tegels_150x150:1763101	9.662
Basic Wall:41_WA_tegels_150x150:1763102	13.912
Basic Wall:41_WA_tegels_150x150:1763103	5.585
Basic Wall:41_WA_tegels_150x150:1763104	12.318
Basic Wall:41_WA_tegels_150x150:1763105	4.515
Basic Wall:41_WA_tegels_150x150:1763520	6.530

Name	MKI
Basic Wall:41_WA_tegels_150x150:1763521	8.040
Basic Wall:41_WA_tegels_150x150:1763522	1.397
Basic Wall:41_WA_tegels_150x150:1763523	8.006
Basic Wall:41_WA_tegels_150x150:1763544	6.530
Basic Wall:41_WA_tegels_150x150:1763545	8.040
Basic Wall:41_WA_tegels_150x150:1763546	1.397
Basic Wall:41_WA_tegels_150x150:1763547	8.006
Basic Wall:41_WA_tegels_150x150:1763568	6.530
Basic Wall:41_WA_tegels_150x150:1763569	8.040
Basic Wall:41_WA_tegels_150x150:1763570	1.397
Basic Wall:41_WA_tegels_150x150:1763571	8.006
Basic Wall:41_WA_tegels_150x150:1763592	2.424
Basic Wall:41_WA_tegels_150x150:1763593	0.631
Basic Wall:41_WA_tegels_150x150:1763594	3.984
Basic Wall:41_WA_tegels_150x150:1763595	9.662
Basic Wall:41_WA_tegels_150x150:1763596	13.912
Basic Wall:41_WA_tegels_150x150:1763597	5.585
Basic Wall:41_WA_tegels_150x150:1763598	12.318
Basic Wall:41_WA_tegels_150x150:1763599	4.515
Basic Wall:41_WA_tegels_150x150:1764213	6.530
Basic Wall:41_WA_tegels_150x150:1764214	8.040
Basic Wall:41_WA_tegels_150x150:1764215	1.397
Basic Wall:41_WA_tegels_150x150:1764216	8.006
Basic Wall:41_WA_tegels_150x150:1764237	6.530
Basic Wall:41_WA_tegels_150x150:1764238	8.040
Basic Wall:41_WA_tegels_150x150:1764239	1.397
Basic Wall:41_WA_tegels_150x150:1764240	8.006
Basic Wall:41_WA_tegels_150x150:1764261	6.530
Basic Wall:41_WA_tegels_150x150:1764262	8.040

Name	MKI
Basic Wall:41_WA_tegels_150x150:1764263	1.397
Basic Wall:41_WA_tegels_150x150:1764264	8.006
Basic Wall:41_WA_tegels_150x150:1764285	2.424
Basic Wall:41_WA_tegels_150x150:1764286	0.631
Basic Wall:41_WA_tegels_150x150:1764287	3.984
Basic Wall:41_WA_tegels_150x150:1764288	9.662
Basic Wall:41_WA_tegels_150x150:1764289	13.912
Basic Wall:41_WA_tegels_150x150:1764290	5.585
Basic Wall:41_WA_tegels_150x150:1764291	12.318
Basic Wall:41_WA_tegels_150x150:1764292	4.515
Basic Wall:41_WA_tegels_150x150:1764446	6.530
Basic Wall:41_WA_tegels_150x150:1764447	8.040
Basic Wall:41_WA_tegels_150x150:1764448	1.397
Basic Wall:41_WA_tegels_150x150:1764449	8.006
Basic Wall:41_WA_tegels_150x150:1764470	6.530
Basic Wall:41_WA_tegels_150x150:1764471	8.040
Basic Wall:41_WA_tegels_150x150:1764472	1.397
Basic Wall:41_WA_tegels_150x150:1764473	8.006
Basic Wall:41_WA_tegels_150x150:1764494	6.530
Basic Wall:41_WA_tegels_150x150:1764495	8.040
Basic Wall:41_WA_tegels_150x150:1764496	1.397
Basic Wall:41_WA_tegels_150x150:1764497	8.006
Basic Wall:41_WA_tegels_150x150:1764518	2.424
Basic Wall:41_WA_tegels_150x150:1764519	0.631
Basic Wall:41_WA_tegels_150x150:1764520	3.984
Basic Wall:41_WA_tegels_150x150:1764521	9.662
Basic Wall:41_WA_tegels_150x150:1764522	13.912
Basic Wall:41_WA_tegels_150x150:1764523	5.585
Basic Wall:41_WA_tegels_150x150:1764524	12.318

Name	**MKI**
Basic Wall:41_WA_tegels_150x150:1764525	4.515
Basic Wall:41_WA_tegels_150x150:1764801	6.530
Basic Wall:41_WA_tegels_150x150:1764802	8.040
Basic Wall:41_WA_tegels_150x150:1764803	1.397
Basic Wall:41_WA_tegels_150x150:1764804	8.006
Basic Wall:41_WA_tegels_150x150:1764825	6.530
Basic Wall:41_WA_tegels_150x150:1764826	8.040
Basic Wall:41_WA_tegels_150x150:1764827	1.397
Basic Wall:41_WA_tegels_150x150:1764828	8.006
Basic Wall:41_WA_tegels_150x150:1764849	6.530
Basic Wall:41_WA_tegels_150x150:1764850	8.040
Basic Wall:41_WA_tegels_150x150:1764851	1.397
Basic Wall:41_WA_tegels_150x150:1764852	8.006
Basic Wall:41_WA_tegels_150x150:1764873	2.424
Basic Wall:41_WA_tegels_150x150:1764874	0.631
Basic Wall:41_WA_tegels_150x150:1764875	3.984
Basic Wall:41_WA_tegels_150x150:1764876	9.662
Basic Wall:41_WA_tegels_150x150:1764877	13.912
Basic Wall:41_WA_tegels_150x150:1764878	5.585
Basic Wall:41_WA_tegels_150x150:1764879	12.318
Basic Wall:41_WA_tegels_150x150:1764880	4.515
Basic Wall:41_WA_tegels_150x150:1765682	6.530
Basic Wall:41_WA_tegels_150x150:1765683	8.040
Basic Wall:41_WA_tegels_150x150:1765684	1.397
Basic Wall:41_WA_tegels_150x150:1765685	8.006
Basic Wall:41_WA_tegels_150x150:1765706	6.530
Basic Wall:41_WA_tegels_150x150:1765707	8.040
Basic Wall:41_WA_tegels_150x150:1765708	1.397
Basic Wall:41_WA_tegels_150x150:1765709	8.006

Name	MKI
Basic Wall:41_WA_tegels_150x150:1765730	6.530
Basic Wall:41_WA_tegels_150x150:1765731	8.040
Basic Wall:41_WA_tegels_150x150:1765732	1.397
Basic Wall:41_WA_tegels_150x150:1765733	8.006
Basic Wall:41_WA_tegels_150x150:1765754	2.424
Basic Wall:41_WA_tegels_150x150:1765755	0.631
Basic Wall:41_WA_tegels_150x150:1765756	3.984
Basic Wall:41_WA_tegels_150x150:1765757	9.662
Basic Wall:41_WA_tegels_150x150:1765758	13.912
Basic Wall:41_WA_tegels_150x150:1765759	5.585
Basic Wall:41_WA_tegels_150x150:1765760	12.318
Basic Wall:41_WA_tegels_150x150:1765761	4.515
Basic Wall:41_WA_tegels_150x150:1766346	6.530
Basic Wall:41_WA_tegels_150x150:1766347	8.040
Basic Wall:41_WA_tegels_150x150:1766348	1.397
Basic Wall:41_WA_tegels_150x150:1766349	8.006
Basic Wall:41_WA_tegels_150x150:1766370	6.530
Basic Wall:41_WA_tegels_150x150:1766371	8.040
Basic Wall:41_WA_tegels_150x150:1766372	1.397
Basic Wall:41_WA_tegels_150x150:1766373	8.006
Basic Wall:41_WA_tegels_150x150:1766394	6.530
Basic Wall:41_WA_tegels_150x150:1766395	8.040
Basic Wall:41_WA_tegels_150x150:1766396	1.397
Basic Wall:41_WA_tegels_150x150:1766397	8.006
Basic Wall:41_WA_tegels_150x150:1766418	2.424
Basic Wall:41_WA_tegels_150x150:1766419	0.631
Basic Wall:41_WA_tegels_150x150:1766420	3.984
Basic Wall:41_WA_tegels_150x150:1766421	9.662
Basic Wall:41_WA_tegels_150x150:1766422	13.912

Name	MKI
Basic Wall:41_WA_tegels_150x150:1766423	5.970
Basic Wall:41_WA_tegels_150x150:1766424	12.318
Basic Wall:41_WA_tegels_150x150:1766425	4.515
Basic Wall:41_WA_tegels_150x150:1766574	6.530
Basic Wall:41_WA_tegels_150x150:1766575	8.040
Basic Wall:41_WA_tegels_150x150:1766576	1.397
Basic Wall:41_WA_tegels_150x150:1766577	8.006
Basic Wall:41_WA_tegels_150x150:1766598	6.530
Basic Wall:41_WA_tegels_150x150:1766599	8.040
Basic Wall:41_WA_tegels_150x150:1766600	1.397
Basic Wall:41_WA_tegels_150x150:1766601	8.006
Basic Wall:41_WA_tegels_150x150:1766622	6.530
Basic Wall:41_WA_tegels_150x150:1766623	8.040
Basic Wall:41_WA_tegels_150x150:1766624	1.397
Basic Wall:41_WA_tegels_150x150:1766625	8.006
Basic Wall:41_WA_tegels_150x150:1766646	2.424
Basic Wall:41_WA_tegels_150x150:1766647	0.631
Basic Wall:41_WA_tegels_150x150:1766648	3.984
Basic Wall:41_WA_tegels_150x150:1766649	9.662
Basic Wall:41_WA_tegels_150x150:1766650	13.912
Basic Wall:41_WA_tegels_150x150:1766651	5.585
Basic Wall:41_WA_tegels_150x150:1766652	12.318
Basic Wall:41_WA_tegels_150x150:1766653	4.515
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3452904	54.389
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3453139	81.997
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3477190	1.371
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3477213	1.130
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3662029	23.718
Basic Wall:41_WA_tegels_150x150:1765250	6.530

Name	**MKI**
Basic Wall:41_WA_tegels_150x150:1765251	8.040
Basic Wall:41_WA_tegels_150x150:1765252	1.397
Basic Wall:41_WA_tegels_150x150:1765253	8.006
Basic Wall:41_WA_tegels_150x150:1765274	6.530
Basic Wall:41_WA_tegels_150x150:1765275	8.040
Basic Wall:41_WA_tegels_150x150:1765276	1.397
Basic Wall:41_WA_tegels_150x150:1765277	8.006
Basic Wall:41_WA_tegels_150x150:1765298	6.530
Basic Wall:41_WA_tegels_150x150:1765299	8.040
Basic Wall:41_WA_tegels_150x150:1765300	1.397
Basic Wall:41_WA_tegels_150x150:1765301	8.006
Basic Wall:41_WA_tegels_150x150:1765322	2.424
Basic Wall:41_WA_tegels_150x150:1765323	0.631
Basic Wall:41_WA_tegels_150x150:1765324	3.984
Basic Wall:41_WA_tegels_150x150:1765325	9.662
Basic Wall:41_WA_tegels_150x150:1765326	13.912
Basic Wall:41_WA_tegels_150x150:1765327	5.585
Basic Wall:41_WA_tegels_150x150:1765328	12.318
Basic Wall:41_WA_tegels_150x150:1765329	4.515
Basic Wall:41_WA_tegels_150x150:1766798	6.530
Basic Wall:41_WA_tegels_150x150:1766799	8.040
Basic Wall:41_WA_tegels_150x150:1766800	1.397
Basic Wall:41_WA_tegels_150x150:1766801	8.006
Basic Wall:41_WA_tegels_150x150:1766822	6.530
Basic Wall:41_WA_tegels_150x150:1766823	8.040
Basic Wall:41_WA_tegels_150x150:1766824	1.397
Basic Wall:41_WA_tegels_150x150:1766825	8.006
Basic Wall:41_WA_tegels_150x150:1766846	6.530
Basic Wall:41_WA_tegels_150x150:1766847	8.040

Name	MKI
Basic Wall:41_WA_tegels_150x150:1766848	1.397
Basic Wall:41_WA_tegels_150x150:1766849	8.006
Basic Wall:41_WA_tegels_150x150:1766870	2.424
Basic Wall:41_WA_tegels_150x150:1766871	0.631
Basic Wall:41_WA_tegels_150x150:1766872	3.984
Basic Wall:41_WA_tegels_150x150:1766873	9.662
Basic Wall:41_WA_tegels_150x150:1766874	13.912
Basic Wall:41_WA_tegels_150x150:1766875	5.585
Basic Wall:41_WA_tegels_150x150:1766876	12.318
Basic Wall:41_WA_tegels_150x150:1766877	4.515
Basic Wall:41_WA_tegels_150x150:1767467	6.530
Basic Wall:41_WA_tegels_150x150:1767468	8.040
Basic Wall:41_WA_tegels_150x150:1767469	1.397
Basic Wall:41_WA_tegels_150x150:1767470	8.006
Basic Wall:41_WA_tegels_150x150:1767491	6.530
Basic Wall:41_WA_tegels_150x150:1767492	8.040
Basic Wall:41_WA_tegels_150x150:1767493	1.397
Basic Wall:41_WA_tegels_150x150:1767494	8.006
Basic Wall:41_WA_tegels_150x150:1767515	6.530
Basic Wall:41_WA_tegels_150x150:1767516	8.040
Basic Wall:41_WA_tegels_150x150:1767517	1.397
Basic Wall:41_WA_tegels_150x150:1767518	8.006
Basic Wall:41_WA_tegels_150x150:1767539	2.424
Basic Wall:41_WA_tegels_150x150:1767540	0.631
Basic Wall:41_WA_tegels_150x150:1767541	3.984
Basic Wall:41_WA_tegels_150x150:1767542	9.662
Basic Wall:41_WA_tegels_150x150:1767543	13.912
Basic Wall:41_WA_tegels_150x150:1767544	5.585
Basic Wall:41_WA_tegels_150x150:1767545	12.318

Name	MKI
Basic Wall:41_WA_tegels_150x150:1767546	4.515
Basic Wall:41_WA_tegels_150x150:3198658	6.530
Basic Wall:41_WA_tegels_150x150:3198659	8.040
Basic Wall:41_WA_tegels_150x150:3198660	1.397
Basic Wall:41_WA_tegels_150x150:3198661	8.006
Basic Wall:41_WA_tegels_150x150:3198682	6.530
Basic Wall:41_WA_tegels_150x150:3198683	8.040
Basic Wall:41_WA_tegels_150x150:3198684	1.397
Basic Wall:41_WA_tegels_150x150:3198685	8.006
Basic Wall:41_WA_tegels_150x150:3198706	6.530
Basic Wall:41_WA_tegels_150x150:3198707	8.040
Basic Wall:41_WA_tegels_150x150:3198708	1.397
Basic Wall:41_WA_tegels_150x150:3198709	8.006
Basic Wall:41_WA_tegels_150x150:3198730	2.424
Basic Wall:41_WA_tegels_150x150:3198731	0.631
Basic Wall:41_WA_tegels_150x150:3198732	3.984
Basic Wall:41_WA_tegels_150x150:3198733	9.662
Basic Wall:41_WA_tegels_150x150:3198734	13.912
Basic Wall:41_WA_tegels_150x150:3198735	5.585
Basic Wall:41_WA_tegels_150x150:3198736	12.318
Basic Wall:41_WA_tegels_150x150:3198737	4.515
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3453708	7.606
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3454067	15.321
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3454399	54.374
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3454496	81.997
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3663015	1.371
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3663061	1.130
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3663205	23.718

Name	MKI
Basic Wall:41_WA_sauswerk_kleur wit:5092816	102.421

Excluded objects

Name

G.2 Calculation results in case of all new walltiles

(Multiple pages)

IFC file: DIEW30_B000_BV3_R20_detached-big-2.ifc - Database: http://localhost:8080

Calculation Data

Phase	ADPc	ADPf	GWP	ODP	POCP	AP	EP	HTP	FAETP	MAETP	TETP	SUM
Production	0.012	2179.989	433.846	0.039	23.903	70.276	0.000	0.000	0.005	0.000	2.818	2710.889
Transport	0.001	3530.052	72.308	0.010	0.009	16.637	0.000	0.000	0.001	0.000	0.531	3619.547
Building	0.000	305.963	418.309	0.001	0.000	1.568	0.000	0.000	0.000	0.000	0.042	725.883
Waste_Transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Waste_Processing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Waste_Disposal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Beyond_Scope	-0.000	-359.507	-8.366	-0.001	0.000	-4.876	0.000	0.000	-0.000	-0.000	-0.220	-372.971
SUM	0.012	5656.497	916.097	0.049	23.912	83.604	0.000	0.000	0.006	0.000	3.170	6683.349

Included objects

Name	MKI
Basic Wall:41_WA_tegels_150x150:1902007	159.077

Name	MKI
Basic Wall:41_WA_tegels_150x150:1902008	60.184
Basic Wall:41_WA_tegels_150x150:1902009	96.857
Basic Wall:41_WA_tegels_150x150:1902010	48.811
Basic Wall:41_WA_tegels_150x150:1902011	48.811
Basic Wall:41_WA_tegels_150x150:1902015	8.682
Basic Wall:41_WA_tegels_150x150:1902016	17.763
Basic Wall:41_WA_tegels_150x150:1902027	50.867
Basic Wall:41_WA_tegels_150x150:1902028	70.283
Basic Wall:41_WA_tegels_150x150:1902029	2.642
Basic Wall:41_WA_tegels_150x150:1902030	22.496
Basic Wall:41_WA_tegels_150x150:1902031	7.134
Basic Wall:41_WA_tegels_150x150:1902032	15.280
Basic Wall:41_WA_tegels_150x150:1902033	76.246
Basic Wall:41_WA_tegels_150x150:1902034	44.993
Basic Wall:41_WA_tegels_150x150:1902035	13.890
Basic Wall:41_WA_tegels_150x150:1902036	2.189
Basic Wall:41_WA_tegels_150x150:1902403	2.189
Basic Wall:41_WA_tegels_150x150:1902439	13.890
Basic Wall:41_WA_tegels_150x150:1902514	36.674
Basic Wall:41_WA_tegels_150x150:1902561	99.204
Basic Wall:41_WA_tegels_150x150:1907734	45.189
Basic Wall:41_WA_tegels_150x150:1907757	1.460
Basic Wall:41_WA_tegels_150x150:1907833	1.409
Basic Wall:41_WA_tegels_150x150:2548030	14.211
Basic Wall:41_WA_tegels_150x150:2548031	16.735
Basic Wall:41_WA_tegels_150x150:2548032	3.945
Basic Wall:41_WA_tegels_150x150:2548033	16.668
Basic Wall:41_WA_tegels_150x150:2548054	14.211
Basic Wall:41_WA_tegels_150x150:2548055	16.735

Name	MKI
Basic Wall:41_WA_tegels_150x150:2548056	3.945
Basic Wall:41_WA_tegels_150x150:2548057	16.668
Basic Wall:41_WA_tegels_150x150:2548078	14.211
Basic Wall:41_WA_tegels_150x150:2548079	16.735
Basic Wall:41_WA_tegels_150x150:2548080	3.945
Basic Wall:41_WA_tegels_150x150:2548081	16.668
Basic Wall:41_WA_tegels_150x150:2548102	8.035
Basic Wall:41_WA_tegels_150x150:2548103	0.996
Basic Wall:41_WA_tegels_150x150:2548104	7.969
Basic Wall:41_WA_tegels_150x150:2548105	24.238
Basic Wall:41_WA_tegels_150x150:2548106	28.421
Basic Wall:41_WA_tegels_150x150:2548107	13.826
Basic Wall:41_WA_tegels_150x150:2548108	28.421
Basic Wall:41_WA_tegels_150x150:2548109	7.037
Basic Wall:41_WA_tegels_150x150:2565222	1.644
Basic Wall:41_WA_tegels_150x150:2565278	1.644
Floor:41_FL_tegels_150x150:2565377	0.511
Basic Wall:41_WA_tegels_150x150:2566205	1.644
Basic Wall:41_WA_tegels_150x150:2566206	1.644
Floor:41_FL_tegels_150x150:2566209	0.511
Basic Wall:41_WA_tegels_150x150:2566269	1.703
Basic Wall:41_WA_tegels_150x150:2566270	1.644
Floor:41_FL_tegels_150x150:2566273	0.511
Basic Wall:41_WA_tegels_150x150:2566295	1.644
Basic Wall:41_WA_tegels_150x150:2566296	1.644
Floor:41_FL_tegels_150x150:2566299	0.511
Basic Wall:41_WA_tegels_150x150:2568961	14.211
Basic Wall:41_WA_tegels_150x150:2568962	16.735
Basic Wall:41_WA_tegels_150x150:2568963	3.945

Name	MKI
Basic Wall:41_WA_tegels_150x150:2568964	16.668
Basic Wall:41_WA_tegels_150x150:2568985	14.211
Basic Wall:41_WA_tegels_150x150:2568986	16.735
Basic Wall:41_WA_tegels_150x150:2568987	3.945
Basic Wall:41_WA_tegels_150x150:2568988	16.668
Basic Wall:41_WA_tegels_150x150:2569009	14.211
Basic Wall:41_WA_tegels_150x150:2569010	16.735
Basic Wall:41_WA_tegels_150x150:2569011	3.945
Basic Wall:41_WA_tegels_150x150:2569012	16.668
Basic Wall:41_WA_tegels_150x150:2569033	8.035
Basic Wall:41_WA_tegels_150x150:2569034	0.996
Basic Wall:41_WA_tegels_150x150:2569035	7.969
Basic Wall:41_WA_tegels_150x150:2569036	24.238
Basic Wall:41_WA_tegels_150x150:2569037	28.421
Basic Wall:41_WA_tegels_150x150:2569038	13.826
Basic Wall:41_WA_tegels_150x150:2569039	28.421
Basic Wall:41_WA_tegels_150x150:2569040	7.037
Basic Wall:41_WA_tegels_150x150:2569238	4.603
Basic Wall:41_WA_tegels_150x150:2569266	9.059
Basic Wall:41_WA_tegels_150x150:2569275	1.132
Basic Wall:41_WA_tegels_150x150:2569315	9.059
Basic Wall:41_WA_tegels_150x150:2569360	9.663
Basic Wall:41_WA_tegels_150x150:2569412	32.461
Basic Wall:41_WA_tegels_150x150:2569450	13.494
Basic Wall:41_WA_tegels_150x150:2569506	32.386
Basic Wall:41_WA_tegels_150x150:2569585	19.075
Basic Wall:41_WA_tegels_150x150:2569623	3.743
Basic Wall:41_WA_tegels_150x150:2569655	18.999
Basic Wall:41_WA_tegels_150x150:2569704	13.890

Name	MKI
Basic Wall:41_WA_tegels_150x150:2570562	19.075
Basic Wall:41_WA_tegels_150x150:2570563	3.743
Basic Wall:41_WA_tegels_150x150:2570564	18.999
Basic Wall:41_WA_tegels_150x150:2570565	13.890
Basic Wall:41_WA_tegels_150x150:2570597	19.075
Basic Wall:41_WA_tegels_150x150:2570598	3.743
Basic Wall:41_WA_tegels_150x150:2570599	18.999
Basic Wall:41_WA_tegels_150x150:2570600	13.890
Basic Wall:41_WA_tegels_150x150:2570632	19.075
Basic Wall:41_WA_tegels_150x150:2570633	3.743
Basic Wall:41_WA_tegels_150x150:2570634	18.999
Basic Wall:41_WA_tegels_150x150:2570635	13.890
Basic Wall:41_WA_tegels_150x150:2570667	19.075
Basic Wall:41_WA_tegels_150x150:2570668	3.743
Basic Wall:41_WA_tegels_150x150:2570669	18.999
Basic Wall:41_WA_tegels_150x150:2570670	13.890
Basic Wall:41_WA_tegels_150x150:2641413	18.375
Basic Wall:41_WA_tegels_150x150:2641414	3.743
Basic Wall:41_WA_tegels_150x150:2641415	18.299
Basic Wall:41_WA_tegels_150x150:2641416	13.890
Basic Wall:41_WA_tegels_150x150:2641469	18.375
Basic Wall:41_WA_tegels_150x150:2641470	3.743
Basic Wall:41_WA_tegels_150x150:2641471	18.299
Basic Wall:41_WA_tegels_150x150:2641472	13.890
Basic Wall:41_WA_tegels_150x150:2641496	18.375
Basic Wall:41_WA_tegels_150x150:2641497	3.743
Basic Wall:41_WA_tegels_150x150:2641498	18.299
Basic Wall:41_WA_tegels_150x150:2641499	13.890
Basic Wall:41_WA_tegels_150x150:2641523	18.375

Name	MKI
Basic Wall:41_WA_tegels_150x150:2641524	3.743
Basic Wall:41_WA_tegels_150x150:2641525	18.299
Basic Wall:41_WA_tegels_150x150:2641526	13.890
Basic Wall:41_WA_tegels_150x150:2641550	24.203
Basic Wall:41_WA_tegels_150x150:2641551	3.245
Basic Wall:41_WA_tegels_150x150:2641552	9.034
Basic Wall:41_WA_tegels_150x150:2641553	12.079
Basic Wall:41_WA_tegels_150x150:2641554	33.162
Basic Wall:41_WA_tegels_150x150:2641555	8.543
Basic Wall:41_WA_tegels_150x150:2641960	24.203
Basic Wall:41_WA_tegels_150x150:2641961	3.245
Basic Wall:41_WA_tegels_150x150:2641962	9.034
Basic Wall:41_WA_tegels_150x150:2641963	12.079
Basic Wall:41_WA_tegels_150x150:2641964	33.162
Basic Wall:41_WA_tegels_150x150:2641965	8.543
Basic Wall:41_WA_tegels_150x150:2642065	8.694
Basic Wall:41_WA_tegels_150x150:2642117	32.386
Basic Wall:41_WA_tegels_150x150:2642118	32.461
Basic Wall:41_WA_tegels_150x150:2642119	30.422
Basic Wall:41_WA_tegels_150x150:2644992	22.827
Basic Wall:41_WA_tegels_150x150:2644993	27.624
Basic Wall:41_WA_tegels_150x150:2644994	43.254
Basic Wall:41_WA_tegels_150x150:2644995	26.388
Basic Wall:41_WA_tegels_150x150:2645133	4.362
Basic Wall:41_WA_BKS+GPS FR30:2870816	34.376
Basic Wall:41_WA_BKS+GPS FR30:2870925	29.922
Basic Wall:41_WA_tegels_150x150:3758575	19.024
Basic Wall:41_WA_tegels_150x150:3758576	5.857
Basic Wall:41_WA_tegels_150x150:3758577	19.099

Name	MKI
Basic Wall:41_WA_tegels_150x150:3758578	16.004
Basic Wall:41_WA_tegels_150x150:3759213	19.024
Basic Wall:41_WA_tegels_150x150:3759214	5.857
Basic Wall:41_WA_tegels_150x150:3759215	19.099
Basic Wall:41_WA_tegels_150x150:3759216	16.004
Basic Wall:41_WA_tegels_150x150:3759260	19.024
Basic Wall:41_WA_tegels_150x150:3759261	5.857
Basic Wall:41_WA_tegels_150x150:3759262	19.099
Basic Wall:41_WA_tegels_150x150:3759263	16.004
Basic Wall:41_WA_tegels_150x150:3759324	19.024
Basic Wall:41_WA_tegels_150x150:3759325	5.857
Basic Wall:41_WA_tegels_150x150:3759326	19.099
Basic Wall:41_WA_tegels_150x150:3759327	16.004
Basic Wall:41_WA_tegels_150x150:3759408	19.024
Basic Wall:41_WA_tegels_150x150:3759409	5.857
Basic Wall:41_WA_tegels_150x150:3759410	19.099
Basic Wall:41_WA_tegels_150x150:3759411	16.004
Basic Wall:41_WA_tegels_150x150:3759455	19.024
Basic Wall:41_WA_tegels_150x150:3759456	5.857
Basic Wall:41_WA_tegels_150x150:3759457	19.099
Basic Wall:41_WA_tegels_150x150:3759458	16.004
Basic Wall:41_WA_tegels_150x150:3761831	32.386
Basic Wall:41_WA_tegels_150x150:3761852	10.560
Basic Wall:41_WA_tegels_150x150:3761869	9.059
Basic Wall:41_WA_tegels_150x150:3761890	1.208
Basic Wall:41_WA_tegels_150x150:3761909	9.059
Basic Wall:41_WA_tegels_150x150:3761932	27.479
Basic Wall:41_WA_tegels_150x150:3761947	32.386
Basic Wall:41_WA_tegels_150x150:3761973	19.760

Name	MKI
Basic Wall:41_WA_tegels_150x150:3763043	32.386
Basic Wall:41_WA_tegels_150x150:3763044	10.560
Basic Wall:41_WA_tegels_150x150:3763045	9.059
Basic Wall:41_WA_tegels_150x150:3763046	1.208
Basic Wall:41_WA_tegels_150x150:3763047	9.059
Basic Wall:41_WA_tegels_150x150:3763048	27.479
Basic Wall:41_WA_tegels_150x150:3763049	32.386
Basic Wall:41_WA_tegels_150x150:3763050	19.760
Basic Wall:41_WA_tegels_150x150:1763026	13.060
Basic Wall:41_WA_tegels_150x150:1763027	16.079
Basic Wall:41_WA_tegels_150x150:1763028	2.794
Basic Wall:41_WA_tegels_150x150:1763029	16.013
Basic Wall:41_WA_tegels_150x150:1763050	13.060
Basic Wall:41_WA_tegels_150x150:1763051	16.079
Basic Wall:41_WA_tegels_150x150:1763052	2.794
Basic Wall:41_WA_tegels_150x150:1763053	16.013
Basic Wall:41_WA_tegels_150x150:1763074	13.060
Basic Wall:41_WA_tegels_150x150:1763075	16.079
Basic Wall:41_WA_tegels_150x150:1763076	2.794
Basic Wall:41_WA_tegels_150x150:1763077	16.013
Basic Wall:41_WA_tegels_150x150:1763098	4.848
Basic Wall:41_WA_tegels_150x150:1763099	1.262
Basic Wall:41_WA_tegels_150x150:1763100	7.969
Basic Wall:41_WA_tegels_150x150:1763101	19.324
Basic Wall:41_WA_tegels_150x150:1763102	27.824
Basic Wall:41_WA_tegels_150x150:1763103	11.170
Basic Wall:41_WA_tegels_150x150:1763104	24.636
Basic Wall:41_WA_tegels_150x150:1763105	9.030
Basic Wall:41_WA_tegels_150x150:1763520	13.060

Name	**MKI**
Basic Wall:41_WA_tegels_150x150:1763521	16.079
Basic Wall:41_WA_tegels_150x150:1763522	2.794
Basic Wall:41_WA_tegels_150x150:1763523	16.013
Basic Wall:41_WA_tegels_150x150:1763544	13.060
Basic Wall:41_WA_tegels_150x150:1763545	16.079
Basic Wall:41_WA_tegels_150x150:1763546	2.794
Basic Wall:41_WA_tegels_150x150:1763547	16.013
Basic Wall:41_WA_tegels_150x150:1763568	13.060
Basic Wall:41_WA_tegels_150x150:1763569	16.079
Basic Wall:41_WA_tegels_150x150:1763570	2.794
Basic Wall:41_WA_tegels_150x150:1763571	16.013
Basic Wall:41_WA_tegels_150x150:1763592	4.848
Basic Wall:41_WA_tegels_150x150:1763593	1.262
Basic Wall:41_WA_tegels_150x150:1763594	7.969
Basic Wall:41_WA_tegels_150x150:1763595	19.324
Basic Wall:41_WA_tegels_150x150:1763596	27.824
Basic Wall:41_WA_tegels_150x150:1763597	11.170
Basic Wall:41_WA_tegels_150x150:1763598	24.636
Basic Wall:41_WA_tegels_150x150:1763599	9.030
Basic Wall:41_WA_tegels_150x150:1764213	13.060
Basic Wall:41_WA_tegels_150x150:1764214	16.079
Basic Wall:41_WA_tegels_150x150:1764215	2.794
Basic Wall:41_WA_tegels_150x150:1764216	16.013
Basic Wall:41_WA_tegels_150x150:1764237	13.060
Basic Wall:41_WA_tegels_150x150:1764238	16.079
Basic Wall:41_WA_tegels_150x150:1764239	2.794
Basic Wall:41_WA_tegels_150x150:1764240	16.013
Basic Wall:41_WA_tegels_150x150:1764261	13.060
Basic Wall:41_WA_tegels_150x150:1764262	16.079

Name	MKI
Basic Wall:41_WA_tegels_150x150:1764263	2.794
Basic Wall:41_WA_tegels_150x150:1764264	16.013
Basic Wall:41_WA_tegels_150x150:1764285	4.848
Basic Wall:41_WA_tegels_150x150:1764286	1.262
Basic Wall:41_WA_tegels_150x150:1764287	7.969
Basic Wall:41_WA_tegels_150x150:1764288	19.324
Basic Wall:41_WA_tegels_150x150:1764289	27.824
Basic Wall:41_WA_tegels_150x150:1764290	11.170
Basic Wall:41_WA_tegels_150x150:1764291	24.636
Basic Wall:41_WA_tegels_150x150:1764292	9.030
Basic Wall:41_WA_tegels_150x150:1764446	13.060
Basic Wall:41_WA_tegels_150x150:1764447	16.079
Basic Wall:41_WA_tegels_150x150:1764448	2.794
Basic Wall:41_WA_tegels_150x150:1764449	16.013
Basic Wall:41_WA_tegels_150x150:1764470	13.060
Basic Wall:41_WA_tegels_150x150:1764471	16.079
Basic Wall:41_WA_tegels_150x150:1764472	2.794
Basic Wall:41_WA_tegels_150x150:1764473	16.013
Basic Wall:41_WA_tegels_150x150:1764494	13.060
Basic Wall:41_WA_tegels_150x150:1764495	16.079
Basic Wall:41_WA_tegels_150x150:1764496	2.794
Basic Wall:41_WA_tegels_150x150:1764497	16.013
Basic Wall:41_WA_tegels_150x150:1764518	4.848
Basic Wall:41_WA_tegels_150x150:1764519	1.262
Basic Wall:41_WA_tegels_150x150:1764520	7.969
Basic Wall:41_WA_tegels_150x150:1764521	19.324
Basic Wall:41_WA_tegels_150x150:1764522	27.824
Basic Wall:41_WA_tegels_150x150:1764523	11.170
Basic Wall:41_WA_tegels_150x150:1764524	24.636

Name	MKI
Basic Wall:41_WA_tegels_150x150:1764525	9.030
Basic Wall:41_WA_tegels_150x150:1764801	13.060
Basic Wall:41_WA_tegels_150x150:1764802	16.079
Basic Wall:41_WA_tegels_150x150:1764803	2.794
Basic Wall:41_WA_tegels_150x150:1764804	16.013
Basic Wall:41_WA_tegels_150x150:1764825	13.060
Basic Wall:41_WA_tegels_150x150:1764826	16.079
Basic Wall:41_WA_tegels_150x150:1764827	2.794
Basic Wall:41_WA_tegels_150x150:1764828	16.013
Basic Wall:41_WA_tegels_150x150:1764849	13.060
Basic Wall:41_WA_tegels_150x150:1764850	16.079
Basic Wall:41_WA_tegels_150x150:1764851	2.794
Basic Wall:41_WA_tegels_150x150:1764852	16.013
Basic Wall:41_WA_tegels_150x150:1764873	4.848
Basic Wall:41_WA_tegels_150x150:1764874	1.262
Basic Wall:41_WA_tegels_150x150:1764875	7.969
Basic Wall:41_WA_tegels_150x150:1764876	19.324
Basic Wall:41_WA_tegels_150x150:1764877	27.824
Basic Wall:41_WA_tegels_150x150:1764878	11.170
Basic Wall:41_WA_tegels_150x150:1764879	24.636
Basic Wall:41_WA_tegels_150x150:1764880	9.030
Basic Wall:41_WA_tegels_150x150:1765682	13.060
Basic Wall:41_WA_tegels_150x150:1765683	16.079
Basic Wall:41_WA_tegels_150x150:1765684	2.794
Basic Wall:41_WA_tegels_150x150:1765685	16.013
Basic Wall:41_WA_tegels_150x150:1765706	13.060
Basic Wall:41_WA_tegels_150x150:1765707	16.079
Basic Wall:41_WA_tegels_150x150:1765708	2.794
Basic Wall:41_WA_tegels_150x150:1765709	16.013

Name	MKI
Basic Wall:41_WA_tegels_150x150:1765730	13.060
Basic Wall:41_WA_tegels_150x150:1765731	16.079
Basic Wall:41_WA_tegels_150x150:1765732	2.794
Basic Wall:41_WA_tegels_150x150:1765733	16.013
Basic Wall:41_WA_tegels_150x150:1765754	4.848
Basic Wall:41_WA_tegels_150x150:1765755	1.262
Basic Wall:41_WA_tegels_150x150:1765756	7.969
Basic Wall:41_WA_tegels_150x150:1765757	19.324
Basic Wall:41_WA_tegels_150x150:1765758	27.824
Basic Wall:41_WA_tegels_150x150:1765759	11.170
Basic Wall:41_WA_tegels_150x150:1765760	24.636
Basic Wall:41_WA_tegels_150x150:1765761	9.030
Basic Wall:41_WA_tegels_150x150:1766346	13.060
Basic Wall:41_WA_tegels_150x150:1766347	16.079
Basic Wall:41_WA_tegels_150x150:1766348	2.794
Basic Wall:41_WA_tegels_150x150:1766349	16.013
Basic Wall:41_WA_tegels_150x150:1766370	13.060
Basic Wall:41_WA_tegels_150x150:1766371	16.079
Basic Wall:41_WA_tegels_150x150:1766372	2.794
Basic Wall:41_WA_tegels_150x150:1766373	16.013
Basic Wall:41_WA_tegels_150x150:1766394	13.060
Basic Wall:41_WA_tegels_150x150:1766395	16.079
Basic Wall:41_WA_tegels_150x150:1766396	2.794
Basic Wall:41_WA_tegels_150x150:1766397	16.013
Basic Wall:41_WA_tegels_150x150:1766418	4.848
Basic Wall:41_WA_tegels_150x150:1766419	1.262
Basic Wall:41_WA_tegels_150x150:1766420	7.969
Basic Wall:41_WA_tegels_150x150:1766421	19.324
Basic Wall:41_WA_tegels_150x150:1766422	27.824

Name	MKI
Basic Wall:41_WA_tegels_150x150:1766423	11.940
Basic Wall:41_WA_tegels_150x150:1766424	24.636
Basic Wall:41_WA_tegels_150x150:1766425	9.030
Basic Wall:41_WA_tegels_150x150:1766574	13.060
Basic Wall:41_WA_tegels_150x150:1766575	16.079
Basic Wall:41_WA_tegels_150x150:1766576	2.794
Basic Wall:41_WA_tegels_150x150:1766577	16.013
Basic Wall:41_WA_tegels_150x150:1766598	13.060
Basic Wall:41_WA_tegels_150x150:1766599	16.079
Basic Wall:41_WA_tegels_150x150:1766600	2.794
Basic Wall:41_WA_tegels_150x150:1766601	16.013
Basic Wall:41_WA_tegels_150x150:1766622	13.060
Basic Wall:41_WA_tegels_150x150:1766623	16.079
Basic Wall:41_WA_tegels_150x150:1766624	2.794
Basic Wall:41_WA_tegels_150x150:1766625	16.013
Basic Wall:41_WA_tegels_150x150:1766646	4.848
Basic Wall:41_WA_tegels_150x150:1766647	1.262
Basic Wall:41_WA_tegels_150x150:1766648	7.969
Basic Wall:41_WA_tegels_150x150:1766649	19.324
Basic Wall:41_WA_tegels_150x150:1766650	27.824
Basic Wall:41_WA_tegels_150x150:1766651	11.170
Basic Wall:41_WA_tegels_150x150:1766652	24.636
Basic Wall:41_WA_tegels_150x150:1766653	9.030
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3452904	54.389
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3453139	81.997
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3477190	1.371
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3477213	1.130
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3662029	23.718
Basic Wall:41_WA_tegels_150x150:1765250	13.060

Name	MKI
Basic Wall:41_WA_tegels_150x150:1765251	16.079
Basic Wall:41_WA_tegels_150x150:1765252	2.794
Basic Wall:41_WA_tegels_150x150:1765253	16.013
Basic Wall:41_WA_tegels_150x150:1765274	13.060
Basic Wall:41_WA_tegels_150x150:1765275	16.079
Basic Wall:41_WA_tegels_150x150:1765276	2.794
Basic Wall:41_WA_tegels_150x150:1765277	16.013
Basic Wall:41_WA_tegels_150x150:1765298	13.060
Basic Wall:41_WA_tegels_150x150:1765299	16.079
Basic Wall:41_WA_tegels_150x150:1765300	2.794
Basic Wall:41_WA_tegels_150x150:1765301	16.013
Basic Wall:41_WA_tegels_150x150:1765322	4.848
Basic Wall:41_WA_tegels_150x150:1765323	1.262
Basic Wall:41_WA_tegels_150x150:1765324	7.969
Basic Wall:41_WA_tegels_150x150:1765325	19.324
Basic Wall:41_WA_tegels_150x150:1765326	27.824
Basic Wall:41_WA_tegels_150x150:1765327	11.170
Basic Wall:41_WA_tegels_150x150:1765328	24.636
Basic Wall:41_WA_tegels_150x150:1765329	9.030
Basic Wall:41_WA_tegels_150x150:1766798	13.060
Basic Wall:41_WA_tegels_150x150:1766799	16.079
Basic Wall:41_WA_tegels_150x150:1766800	2.794
Basic Wall:41_WA_tegels_150x150:1766801	16.013
Basic Wall:41_WA_tegels_150x150:1766822	13.060
Basic Wall:41_WA_tegels_150x150:1766823	16.079
Basic Wall:41_WA_tegels_150x150:1766824	2.794
Basic Wall:41_WA_tegels_150x150:1766825	16.013
Basic Wall:41_WA_tegels_150x150:1766846	13.060
Basic Wall:41_WA_tegels_150x150:1766847	16.079

Name	MKI
Basic Wall:41_WA_tegels_150x150:1766848	2.794
Basic Wall:41_WA_tegels_150x150:1766849	16.013
Basic Wall:41_WA_tegels_150x150:1766870	4.848
Basic Wall:41_WA_tegels_150x150:1766871	1.262
Basic Wall:41_WA_tegels_150x150:1766872	7.969
Basic Wall:41_WA_tegels_150x150:1766873	19.324
Basic Wall:41_WA_tegels_150x150:1766874	27.824
Basic Wall:41_WA_tegels_150x150:1766875	11.170
Basic Wall:41_WA_tegels_150x150:1766876	24.636
Basic Wall:41_WA_tegels_150x150:1766877	9.030
Basic Wall:41_WA_tegels_150x150:1767467	13.060
Basic Wall:41_WA_tegels_150x150:1767468	16.079
Basic Wall:41_WA_tegels_150x150:1767469	2.794
Basic Wall:41_WA_tegels_150x150:1767470	16.013
Basic Wall:41_WA_tegels_150x150:1767491	13.060
Basic Wall:41_WA_tegels_150x150:1767492	16.079
Basic Wall:41_WA_tegels_150x150:1767493	2.794
Basic Wall:41_WA_tegels_150x150:1767494	16.013
Basic Wall:41_WA_tegels_150x150:1767515	13.060
Basic Wall:41_WA_tegels_150x150:1767516	16.079
Basic Wall:41_WA_tegels_150x150:1767517	2.794
Basic Wall:41_WA_tegels_150x150:1767518	16.013
Basic Wall:41_WA_tegels_150x150:1767539	4.848
Basic Wall:41_WA_tegels_150x150:1767540	1.262
Basic Wall:41_WA_tegels_150x150:1767541	7.969
Basic Wall:41_WA_tegels_150x150:1767542	19.324
Basic Wall:41_WA_tegels_150x150:1767543	27.824
Basic Wall:41_WA_tegels_150x150:1767544	11.170
Basic Wall:41_WA_tegels_150x150:1767545	24.636

Name	MKI
Basic Wall:41_WA_tegels_150x150:1767546	9.030
Basic Wall:41_WA_tegels_150x150:3198658	13.060
Basic Wall:41_WA_tegels_150x150:3198659	16.079
Basic Wall:41_WA_tegels_150x150:3198660	2.794
Basic Wall:41_WA_tegels_150x150:3198661	16.013
Basic Wall:41_WA_tegels_150x150:3198682	13.060
Basic Wall:41_WA_tegels_150x150:3198683	16.079
Basic Wall:41_WA_tegels_150x150:3198684	2.794
Basic Wall:41_WA_tegels_150x150:3198685	16.013
Basic Wall:41_WA_tegels_150x150:3198706	13.060
Basic Wall:41_WA_tegels_150x150:3198707	16.079
Basic Wall:41_WA_tegels_150x150:3198708	2.794
Basic Wall:41_WA_tegels_150x150:3198709	16.013
Basic Wall:41_WA_tegels_150x150:3198730	4.848
Basic Wall:41_WA_tegels_150x150:3198731	1.262
Basic Wall:41_WA_tegels_150x150:3198732	7.969
Basic Wall:41_WA_tegels_150x150:3198733	19.324
Basic Wall:41_WA_tegels_150x150:3198734	27.824
Basic Wall:41_WA_tegels_150x150:3198735	11.170
Basic Wall:41_WA_tegels_150x150:3198736	24.636
Basic Wall:41_WA_tegels_150x150:3198737	9.030
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3453708	7.606
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3454067	15.321
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3454399	54.374
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3454496	81.997
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3663015	1.371
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3663061	1.130
Basic Wall:41_WA_sauswerk_NSC S3030-R90B (licht blauw):3663205	23.718

Name	MKI
Basic Wall:41_WA_sauswerk_kleur wit:5092816	102.421

Excluded objects

Name