TOWARDS VALUE INCREASE IN URBAN REGENERATION

“A study of how Value Engineering could be used in order to increase the value of urban regeneration projects”

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Acknowledgements

Dear reader, for you this might be the first part to read. For me however, it is the end of ten tough months. Now that this journey almost comes to an end, I often browse through the document and note that I am very pleased with the result.

With this thesis I finish the Master study Construction Management and Engineering at Delft University of Technology. The research is performed at the municipality of Rotterdam, who offered me the possibility to conduct my thesis. For that my gratitude, especially to those who provided valuable support and interest in my research and me as a person. In particular, thanks go out to Leon Dijk and Peter de Graag. Leon, for your interest in my research and valuable feedback from a theoretical point of view. Peter, for your help in developing the life cycle cost estimation model. Furthermore, I would like to thank my thesis committee – Jan Anne Annema, Peter de Jong and Bert van Wee – for their critical and inspiring feedback on intermediate versions of the report. I would like to thank both Jan Anne and Peter in particular. Jan Anne, for keeping me motivated throughout the process. I really appreciate his confidence in me. Peter, for providing valuable literatures and keeping me sharp. Without your support, finishing the thesis would have become much more difficult.

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Michell Hogeveen,
July 2014
Executive Summary

The research presented in this thesis contains a part of the ongoing effort to improve the situation of the decision-making process at municipalities with regard to urban regeneration.

By the means of urban regeneration, municipalities aim to increase the current value of an urban area. This so called ‘value improvement’ is obtained when extra performances achieved by urban regeneration outrun the life cycle costs for it. This implies that if both parameters are quantified the decision making process becomes more transparent. Nevertheless, practice at municipalities show differently. On the one hand, decisions regarding urban regeneration are based solely on investment costs. On the other hand, extra performances obtained by urban regeneration are described in qualitative manners. It is hypothesized that both shortcomings result in sub-optimal decision making.

More optimal decision making is believed to be achieved by applying Value Engineering (VE) during the earlier stages of the design process. Herein, it aims to improve the value of a design by providing modifications that either eliminate costs that do not contribute much to the performance of a project, or adding extra performances for relatively low costs. Most successful implementations showed the use of VE in the product industry. However, very little is known about the insights it might provide, and how to be applied in the fields of urban regeneration. This leads to the main question of this research:

“How could Value Engineering be used in the earlier stages of project development in order to improve the value of urban regeneration projects?”

In this research a methodology is developed to apply VE in the fields of urban regeneration. The figure on the next page shows the developed methodology, which consists of five different phases. The urban regeneration of the Coolsingel at Rotterdam is used as case study to provide an educational enrichment on the practical applicability of the developed methodology.

To come to the presented overview on the next page the research takes a design approach. First of all, several literatures regarding the topic VE are studied. From this it is concluded that with regard to urban regeneration projects, value in VE is defined as the ratio between performance and life cycle costs. The approach thus uses a preference system that bases the preference of an alternative on the highest ratio between those parameters, or in other words on cost-effectiveness. Hence, options are identified to monetize the performance as well as the life cycle costs of urban regeneration projects. Information with regard to the life cycle costs of such projects is collected at the municipality of Rotterdam and assembled into a life cycle cost estimation model. The model and identified options to monetize the performance of urban regeneration projects are used in order to apply VE on the real time case study – the urban regeneration of the Coolsingel. Herein the methodology is used to develop modifications on the preferred alternative, which are evaluated on cost-effectiveness. The situation that provides the highest cost-effectiveness is suggested to be realized.
Application VE in the fields of urban regeneration  

*Phase A: Characterization of the intended functions of the urban regeneration project and the life cycle costs of the physical solutions proposed in the preferred design.*

In the first phase, different functions of a project are identified by conducting a function analysis with experts (step 1). This analysis is seen as one of the most important pillars of VE. It is a process in which the project team distances itself from provided physical solutions, which for example are suggested in the preferred alternative. Herein main questions are: what should the project do? And how is this achieved with the preferred alternative? Due to this process project teams are not constrained by the physical measures suggested in designs. This allows them to be more creative during phase C – the development of modifications.

The identified functions of a project are graphically presented in a FAST (Function Analysis System Technique) diagram. In a FAST diagram functions are organized by asking ‘how’ questions from left to right. And check with ‘why’ questions, from right to left.

Besides conducting a function analysis, the life cycle costs of the preferred alternative are estimated during the first phase of VE (step 2). To do so, a deterministic life cycle cost estimating model (LCC model) is developed with regard to urban regeneration projects. With this model it is not only possible to estimate realization costs of such projects, but also recurring costs such as costs for maintenance, operational and removal activities. Data provided in the model are based on real-world data and are gathered at the municipality of Rotterdam.

To use the model, practitioners are in need of the design quantities of an alternative (e.g. x square meter natural stone, x amount of trees, etc.). Furthermore, a discount rate and period of analysis need to be selected. The first, to convert future costs into their time-equivalent value of the present. The latter, to decide whether decisions should be based on the short or long-term.

Based on the Coolsingel case the following conclusions are formulated with regard to carrying out a function analysis and estimating the life cycle costs with the LCC model:

- Setting up a FAST diagram can be time consuming. First of all, because there is no ideal diagram to represent functions. Secondly, because practitioners can be caught up in displaying too much details. To prevent the latter, it is necessary to divine the level of detail beforehand.
- By focusing on functions rather than on physical solutions, it was easier to come up with modifications on the preferred alternative.
- The LCC model is a useful model to give decision makers insight into the life cycle costs of urban regeneration projects. However, some data in the model is solely based on real-world data obtained from the Coolsingel case. Therefore, the model cannot yet be used for estimating the life cycle costs of other urban regeneration projects. Nevertheless, it should be remarked that the model can serve as a stepping stone for the development of a generic life cycle cost estimation model. In the development of such a model it is advised to gather data from different kinds of projects regarding maintenance and operational costs.
- Project alternatives with high social benefits and low recurring costs, realized by high capital costs up-front, are financially more attractive when low discount rates and long periods of analysis are applied. Therefore, it is advised to assess project alternatives with a discount rate of 2.5% over a period of 60 years or more. Results indicate that high discount rates and short
periods of analysis often result in the preference of the alternative that bears the lowest costs up-front.

**Phase B: Selection of functions that are realized sub-optimal by the preferred alternative.**

During phase B of VE functions are selected that are realized sub-optimal by the preferred alternative. This selection process can be facilitated by performing a sensitivity analysis on the estimated life cycle costs of the preferred alternative (step 3 and 4). This analysis explores what happens if we change the value of an input variable to the life cycle costs of the preferred alternative. Variables that, if changed, highly affect the life cycle costs are found interesting to modify.

Results from the Coolsingel case point out that two functions are realized sub-optimal by the preferred alternative. These functions are ‘widen sidewalks’ and ‘provide high quality pavements’.

The first function is realized by relocating the two-stroke car lane at the Coolsingel from the west side of the tram track to the east side of the tram track. On the one hand this results in a four-stroke car lane, on the other it offers room to develop a wide boulevard. Negative side effects are that sidewalks at the east will shrink and cross sections ‘Hofplein’ and ‘Churchillplein’ need to be redeveloped. From the sensitivity analysis it is concluded that this latter effect highly affects the life cycle costs of the project.

The second function, ‘provide high quality pavements’, is achieved by proposing natural stone as pavement material. The LCC model does not only shows that this material type is expensive to purchase, but also to maintain. Therefore, it is not surprisingly that the sensitivity analysis indicates that if this material type is interchanged with a cheaper variant, the total costs of the project will decrease tremendously.

This research divined for each of the two upper stated functions a modification, with the purpose to enhance the total value of the preferred alternative. This process is conducted in the next phase of the proposed VE methodology.

**Phase C: Development of modifications**

For each of the sub-optimal selected functions, modifications are designed that might improve the total value of the preferred alternative (step 5). As described earlier, the functions selected for the Coolsingel case are: ‘widen sidewalks’ and ‘provide high quality pavements’.

To widen the sidewalks it is proposed to remove the two-stroke traffic lane on the west side of the tram track, instead of relocating them to the east side of the track (modification 1). In this case both sides of the Coolsingel can be provided with wide sidewalks, which allows room for mixed vegetation on either sides. Furthermore, it is not necessary anymore to make excessive changes to the cross sections ‘Hofplein’ and ‘Churchillplein’. A major disadvantage of the modification is that the current traffic intensity at the Coolsingel cannot be handled by a two-stroke traffic lane. Therefore, this modification will result in congestion at the Coolsingel.
As an alternative for the natural stone pavements, concrete pavements are used (modification 2). This will reduce both costs and attractiveness of the public area.

**Phase D: Evaluation of modifications**

In this phase the proposed modifications are evaluated with respect to the preferred alternative (step 6). For this process VE uses a preference system that bases the preference of an alternative on the highest ratio between life cycle costs and performances (P/LCC ratio). This implies that both parameters need to be quantified.

The life cycle costs can be quantified by using the LCC estimating model. The performance of a modification can be quantified by estimating the performance of the preferred alternative (fixed part) and adding this amount with the increased or decreased performance achieved with the modification (variable part). In this case the preferred alternative acts as a reference point on the basis of which it is determined whether proposed modifications enhance the value of preferred alternative or not. Modifications that offer a value improvement are preferred to be implemented.

The results of the Coolsingel case are provided in the table hereunder. To come to these values a discount rate of 2.5% is used, and a time period of 60 years. Furthermore, the variable part is defined by using values that reflect the ‘Willingness to Pay’ (WTP) for certain improvements. From practise it is concluded that the WTP is not always easy to define. Especially, for improving features for which no market prices exist (i.e. air quality, safety, etc.). In this research the effects of some measures are monetized. However, this list is not limited and should be supplemented.

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From the table the following conclusions are formulated:

- The performance of the reference point is equal to the life cycle costs of the preferred alternative. Hence, the value (P/LCC ratio) of the preferred alternative is equal to 1.
- Both modifications do not enhance the value of the preferred alternative.

Interestingly, when implementing the alternatives at different points in time, results indicate that the P/LCC ratio might change. The table below shows the results of the P/LCC ratio when the different alternatives are implemented in the year 2025.

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From the table the following is concluded:

- The value of an alternative depends at which given point in time it is implemented.
- When modification 1 is realized 10 years later (in the year 2025), value improvement of the preferred alternative is obtained.
- Taking into account the implementation time of an alternative is important. Neglecting the fact can lead to sub-optimal decision making.

Since the implementation of modification 1 in the year 2025 results in a value improvement of the preferred alternative, it is interesting to find the given point in time at which modification 1 has a value of 1. This moment is graphically presented in the right figure (b) below. The figure (a) to the left graphically presents the P/LCC ratios of the alternatives when they are implemented at the year 2015.

From the graphs the following is concluded:

- It is recommended to develop modification 1 gradually over time and start with removing the two stroke traffic lane at the Coolsingel in the year 2018.

Phase E: Presentation of the results

In the final phase of the proposed VE methodology, the results of the study are documented and included in the decision making document (step 7). This has several advantages for decision makers. First of all, decision makers are directly provided with information about value enhancing opportunities. Secondly, this insight could help in conveying the idea that the cheapest design is not always the best design and that adding performance could matter. Last but not least, decision makers are provided insight in when it is best to implement the value enhancing ideas.
Conclusions and recommendations

In this study, a methodology is developed to apply VE in the fields of urban regeneration. By the means of a case study it is shown that the methodology can be used to provide insight into value enhancing ideas during the decision making process. The results point out that it is a better solution to develop the public space at the Coolsingel gradually over time and make excessive interventions from the year 2018. Herein a public space provided with a two-stroke traffic lane is preferred over a four-stroke traffic lane.

The developed methodology can be further developed by setting up a database in which the effects of measures with regard to urban regeneration are monetized. This database allows the project team to formulate better underpinnings in the decision making document, without being too time consuming. Hence, it is believed to be less likely that the alternative preferred by decision makers will differ from the one that is preferred in the decision making document. If in any cases this document is also provided with possible modifications that show value improvements, we believe decision makers are less likely to make sub-optimal decisions.

Various organizations are working on tools that can provide indications of monetized performances in urban regeneration projects. A most recent example is the tool TEEB-stad. Data used in this tool are however based on studies conducted in various kinds of cities. Since many performances of urban regeneration projects are bound to location-specific characteristics, the tool lacks depth and the list of quantified performances is limited. Still it is believed that the tool could serve as a good starting point for the development of a database on city level. To gather proper data for the database, the municipality of Rotterdam should conduct various types of stated and revealed preference surveys in different parts of the city. We believe that the department ‘Milieu Ruimte Ondergrond (MRO)’, within the municipality of Rotterdam, should facilitate this process as they already made good progress in quantifying sustainability measures.

Furthermore, it is suggested to supplement the developed LCC model with missing cost indicators. This process might be time consuming, but will facilitate the development of a generic life cycle cost estimating model. We believe that this job should be conducted by the clusters ‘Stadsbeheer’ and ‘Stadsontwikkeling’.

In the end it is important that life cycle costs and quantified performances are taken into account during the decision making process. Therefore, we believe that decision making documents should provide insights on both parameters when prescribing the preferred alternative. Since decision making documents are set-up by the department ‘Project Management Bureau (PMB)’, they should be informed about what information becomes available and how this information can be used to underpin the selection of the preferred alternative. We believe that by making VE studies obligatory in the decision making documents for large urban regeneration projects, life cycle costs and performances will be more often monetized during the decision making process.
Dutch management summary

In dit proefschrift is er onderzoek gedaan om de situatie omtrent het besluitvormingsproces van stadsvernieuwingsprojecten te verbeteren.

Gemeenten trachten door middel van herontwikkeling van de publieke ruimte de waarde van een bepaald gebied te verhogen. In het algemeen geldt dat de waarde van een gebied kan worden verhoogd wanneer de baten van de herontwikkeling de kosten (over de gehele levensduur) hiervan overtreffen. Beter inzicht hierin kan worden bereikt wanneer zowel de baten als de levenscycluskosten kwantitatief inzichtelijk worden gemaakt. In de praktijk verloopt de besluitvorming van een herontwikkelingsproject echter vaak anders. Enerzijds worden besluiten met betrekking tot herontwikkelingsprojecten vaak gebaseerd op de investeringssom. Anderzijds worden de te verwachte baten vaak niet uitgedrukt in cijfers, maar in woorden. Hierdoor kunnen de kosten en baten niet goed tegen elkaar worden afgewogen, wat kan leiden tot suboptimale besluitvorming.

De toepassing van Value Engineering (VE) in het beginstadium van het ontwerpproces kan mogelijk leiden tot een betere besluitvorming. Deze methode heeft tot doel om op een systematische manier alle kosten te elimineren die niet tot baten in het project leiden. VE is ontwikkeld in de product industrie. De toepassing van deze methode in de context van stadsvernieuwingsprojecten is hierdoor nog weinig bekend. Dit leidt dan ook tot de volgende onderzoeksvraag voor dit onderzoek:

“Hoe kan Value Engineering gebruikt worden tijdens de beginstadia van stadsvernieuwingsprojecten en leiden tot waardevermeerdering binnen dit soort projecten?”

In dit onderzoek is een kader ontwikkeld om VE toe passen in de context van stadsvernieuwingsprojecten. Dit kader is weergegeven op de volgende bladzijde en bestaat uit vijf fases. Het ontwikkelde kader is getoetst, door het toe te passen op de herontwikkeling van de publieke ruimte van de Coolsingel. Dit herontwikkelingsproject is dan ook gebruikt als case studie om te zien in hoeverre de methode praktisch toepasbaar is.

Om tot het ontwikkelde kader te komen hanteert het onderzoek een ontwerpende benadering. Allereerst, wordt kennis opgedaan omtrent de theorie VE. Hieruit is geconcludeerd dat met betrekking tot stadsvernieuwingsprojecten, het begrip ‘Waarde’ kan worden gedefinieerd als de verhouding tussen de levenscycluskosten en baten van een project. In VE wordt de voorkeur dus bepaald met een voorkeursysteem dat evalueert op basis van de hoogst behaalde ratio tussen deze parameters. MET ander woorden, de voorkeur wordt bepaald op basis van kosteneffectiviteit. Om dit te kunnen doen zullen beiden parameters in kwantitatieve termen moeten worden uitgedrukt. Data met betrekking tot de levenscycluskosten van stadsontwikkelingsprojecten zijn verzameld binnen de gemeente Rotterdam en samengevoegd in een LCC model waar deze geraamd mee kunnen worden. Verder zijn er verschillende mogelijkenheden onderzocht om de baten van een project te kwantificeren. Vervolgens is deze kennis gebruikt om VE toe te kunnen passen op de casus Coolsingel. Hierin is een voorkeursalternatief als uitgangspunt genomen. Op dit alternatief zijn met behulp van VE wijzigingen bedacht die vervolgens zijn geëvalueerd op kosteneffectiviteit (waarde). De oplossing met de hoogste kosteneffectiviteit wordt aanbevolen tot verdere ontwikkeling.
Toepassing VE binnen de context van stadsvernieuwingsprojecten

**Fase A: Het karakteriseren van functies die de gemeente wil bereiken met het project en het ramen van de levenscycluskosten van het voorkeursalternatief.**

Tijdens deze fase dient het projectteam verschillende functies van het project te achterhalen. Hiervoor zal een functieanalyse moeten worden uitgevoerd *(stap 1)*. De functieanalyse is één van de belangrijkste pijlers binnen VE. Het is een bewustwordingstraject, waarin afstand wordt genomen van een fysieke oplossing (abstraheren), die bijvoorbeeld wordt voorgesteld in het voorkeursalternatief. Kernvragen hierin zijn: Wat moet het project doen? En hoe wordt dit in het voorkeursalternatief opgenomen? Het abstraheren biedt tijdens de fase ‘het ontwikkelen van de wijzigingen’ (fase C in de figuur) gemakkelijker inzichten tot nieuwe ideeën.

In de functie analyse wordt gebruik gemaakt van het zogenaamde FAST (Function Analysis System Technique) diagram. In dit diagram worden de functies die men wilt bereiken met het project geordend in ‘hoe relaties’ (van links naar rechts) en ‘waarom relaties’ (van rechts naar links).

Verder worden tijdens deze fase de levenscycluskosten van het voorkeursalternatief geraamd *(stap 2)*. Hiervoor is een deterministisch LCC model ontwikkeld waarmee niet alleen de investeringssom, maar ook toekomstige kosten zoals onderhoud, gebruik en sloop kunnen worden geraamd. De data in het model zijn gebaseerd op verzamelde data binnen de gemeente Rotterdam.

Om het LCC model te kunnen gebruiken zal men inzicht moeten hebben in de te realiseren hoeveelheden (bijv. x aantal m² natuursteen, x aantal bomen, etc.). Verder zal men een discontovoet moeten vaststellen om de toekomstige kosten terug te rekenen naar de waarde op het moment van de beslissing. Daarnaast zal besloten moeten worden of men de kosten analyseert op korte of op langere termijn.

Op basis van de case studie zijn de volgende conclusies geformuleerd met betrekking tot het maken van een FAST diagram en het ramen van de levenscycluskosten met het ontwikkelde LCC model:

- Het ontwikkelen van een FAST diagram is niet eenvoudig. Allereerst omdat er niet één juist diagram bestaat. Ten tweede kan men zich verliezen in het detail niveau van het diagram. Om dit te voorkomen zal men voorafgaand eerst het detail niveau moeten vast stellen.
- Het diagram maakt het gemakkelijker wijzigingen te bedenken op het voorkeursalternatief.
- Het LCC model is bruikbaar om de levenscycluskosten van een alternatief te ramen. Enkele data in het model zijn gebaseerd op de Coolsingel case. Dit houdt in dat er een eerste aanzet is gemaakt voor een generiek model. Het is dan ook nodig om het model verder te ontwikkelen om deze ook toe te kunnen passen in andere projecten.
- Om alternatieven die veel ‘zachte baten’ (bijv. reductie van CO₂, PM₁₀, etc.) en lage terugkerende kosten genereren financieel aantrekkelijk te maken, adviseren wij een discontovoet van 2.5% te hanteren en een doorlooptijd van minstens 60 jaar in het LCC model. Resultaten tonen aan dat wanneer dit niet wordt gedaan, de uitkomst het alternatief met de laagste investeringssom zal zijn.
Fase B: Het selecteren van functies die momenteel door het voorkeursalternatief suboptimaal worden gerealiseerd.

In deze fase zal er onderzocht moeten worden welke functies momenteel suboptimaal worden gerealiseerd. Dit proces kan worden gefaciliteerd door een gevoeligheidsanalyse uit te voeren op de levenscycluskosten van het voorkeursalternatief (stap 3 en 4). Deze analyse brengt in kaart wat het effect is in de uitkomst van de kosten indien een verandering van een activiteit plaatsvindt. Wanneer de kosten voor een bepaalde activiteit enorm blijken te veranderen is het interessant om juist deze activiteit te gaan wijzigen.

Uit de resultaten van de Coolsingel case is gebleken, dat twee functies mogelijk suboptimaal worden gerealiseerd door het voorkeursalternatief. Dit zijn de functies: ‘het verbreden van de voetpaden’ en ‘het realiseren van een aantrekkelijke bestrating’.

Binnen het alternatief wordt de eerste functie gerealiseerd door de twee rijstroken gelegen aan de west zijde van de trambaan te verplaatsen naar de oostzijde van de trambaan. Hierdoor kan een mooie boulevard worden gerealiseerd aan de westzijde. Dit heeft echter tot gevolg dat het voetpad gelegen aan de oostzijde (kant stadhuis) krimpt. Verder moeten er grootse aanpassing worden gedaan aan de kruispunten ‘Hofplein’ en ‘Churchillplein’. Uit de gevoeligheidsanalyse is gebleken dat juist deze kosten veel invloed hebben op de uiteindelijke kosten van het project.

Om de tweede functie te bereiken stelt het voorkeursalternatief voor om een natuurstenen bestrating toe te passen. Het LCC model toont echter aan dat dit type bestrating niet alleen duur is in aanschaf, maar ook in onderhoud. De gevoeligheidsanalyse laat dan ook zien, dat wanneer we inperken op de kosten hiervan de totale kosten van het project zullen dalen.

In het onderzoek zijn op de hierboven beschreven twee functies wijzigingen bedacht, met als doel de totale waarde van het voorkeursalternatief te verhogen.

Fase C: Het ontwikkelen van de modificaties op de geselecteerde functies.

Tijdens deze fase zijn er wijzigingen bedacht voor de functies die optimaler gerealiseerd kunnen worden (stap 5). Zoals hierboven is beschreven zijn dit voor de Coolsingel de functies: ‘het verbreden van de voetpaden’ en ‘het realiseren van een aantrekkelijke bestrating’.

Om bredere voetpaden te realiseren is er gekeken naar wat er gebeurt als de twee rijstroken worden verwijderd en niet worden teruggeplaatst ( modificatie 1). Dit heeft tot gevolg dat er aan beide kanten van de Coolsingel ruimte is voor brede voetpaden, die beide voorzien kunnen worden van gemixt groen (bomen, decoratief groen, etc.). Verder zijn grootschalige aanpassingen aan de kruisingen ‘Hofplein’ en ‘Churchillplein’ niet meer noodzakelijk. Een nadeel is echter dat mogelijk congestie zal ontstaan op het traject, doordat de twee rijstroken de huidige verkeersintensiteit mogelijk niet aan kunnen.

Voor de tweede functie is gekeken naar de mogelijkheid om de natuurstenen bestrating te vervangen door een betonstenen bestrating ( modificatie 2). Dit zal aan de ene kant de kosten drukken en aan de andere kant de kwaliteit van de ruimte verlagen.
Fase D: Het evalueren van de modificaties

In deze fase dienen voorgestelde wijzigingen te worden geëvalueerd ten opzichte van het voorkeursalternatief (stap 6). Om de voorkeur te bepalen werkt VE met een voorkeurssysteem dat evalueert op basis van de hoogst behaalde ratio tussen baten en levenscycluskosten. Binnen VE wordt de ratio gezien als de waarde van het project. Om deze te bepalen is het dus noodzakelijk om beide parameters kwantitatief inzichtelijk te maken. De levenscycluskosten kunnen onderzocht worden met het ontwikkelde LCC model. De baten van een wijziging kunnen worden gekwantificeerd door een schatting te maken van de baten die worden gegeven door het voorkeursalternatief en hierbij de vermeerderde of verminderde baten verkregen door de wijziging bij op te tellen. Het voorkeursalternatief fungeert dus als referentiepunt op basis waarvan beoordeeld kan worden of het wijzigen van het voorkeursalternatief wel of niet leidt tot een verhoging van de waarde. Waarde verhogende wijzigingen van het voorkeursalternatief hebben de voorkeur om geïmplementeerd te worden.

De resultaten van de toepassing van deze fase op de Coolsingel case zijn gegeven in de tabel hieronder. Om tot de waardes in de tabel te komen is een discontovoet van 2.5% toegepast en is gerekend met een tijdsperiode van 60 jaar. Verder zijn de variabele baten bepaald op basis van de ‘Willingness to Pay’ (WTP). Gebleken is dat de WTP niet eenvoudig te bepalen is. Dit geldt met name voor de vraag hoeveel men bereid is te betalen voor bijvoorbeeld een betere luchtkwaliteit, meer groen of meer veiligheid. De beantwoording hiervan is veelal subjectief. In dit onderzoek zijn enkele baten gemonetariseerd. Echter, de lijst is niet limitatief en zal moeten worden aangevuld.

### Tabel: Resultaten Coolsingel Case

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Voorkeursalternatief</td>
<td>92.5</td>
<td>0</td>
<td>92.5</td>
<td>92.5</td>
<td>1</td>
</tr>
<tr>
<td>Modificatie 1</td>
<td>96.7</td>
<td>-2.7</td>
<td>92.5</td>
<td>89.8</td>
<td>0.93</td>
</tr>
<tr>
<td>Modificatie 2</td>
<td>73.3</td>
<td>-36.2</td>
<td>92.5</td>
<td>56.3</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Uit de tabel kunnen de volgende conclusies worden geformuleerd:

- De baten die gerealiseerd worden door het voorkeursalternatief zijn gelijk gesteld aan de levenscycluskosten om dit alternatief te realiseren. Hierdoor is de waarde van het voorkeursalternatief gelijk aan 1.
- Beide wijzigingen leiden niet tot een waardevermeerdering van het voorkeursalternatief.

Wanneer de verkregen ratio’s worden uitgezet tegen het tijdstip waarop de wijzigingen worden geïmplementeerd, is de uitkomst anders. De onderstaande tabel geeft de waarde van de verschillende alternatieven aan wanneer deze geïmplementeerd zouden worden in het jaar 2025.

### Tabel: Resultaten Coolsingel Case Tijdstip 2025

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Voorkeursalternatief</td>
<td>92.5</td>
<td>0</td>
<td>92.5</td>
<td>92.5</td>
<td>1</td>
</tr>
<tr>
<td>Modificatie 1</td>
<td>96.7</td>
<td>+15.1</td>
<td>92.5</td>
<td>107.6</td>
<td>1.11</td>
</tr>
<tr>
<td>Modificatie 2</td>
<td>73.3</td>
<td>-36.2</td>
<td>92.5</td>
<td>56.3</td>
<td>0.77</td>
</tr>
</tbody>
</table>
Hieruit concluderen wij het volgende:

- De waarde van een alternatief is afhankelijk van het tijdstip waarop deze wordt geïmplementeerd.
- In het jaar 2025 biedt modificatie 1 een hogere waarde dan het voorkeursalternatief.
- Wanneer er geen rekening gehouden wordt met de implementatietijd van een alternatief kan er nog steeds suboptimale besluitvorming plaatsvinden.

Omdat het implementeren van modificatie 1 in het jaar 2025 leidt tot een hogere waardevermeerdering van de Coolsingel, zijn wij op zoek gegaan naar het tijdstip waarop de waarde van deze gelijk is aan de waarde van het voorkeursalternatief. Dit moment wordt gegeven in de rechter onderstaande grafiek (b). De linker grafiek (a) geeft de waarde van de verschillende alternatieven aan wanneer deze geïmplementeerd worden in het jaar 2015.

Uit de grafiek is het volgende geconcludeerd:

- Het is een betere strategie om de Coolsingel organisch te ontwikkelen en in het jaar 2018 te starten met het implementeren van modificatie 1.

_Fase E: Het opnemen van de resultaten in het beslisdocument_

In de laatste fase worden de resultaten gedocumenteerd en opgenomen in het beslisdocument (stap 7). Dit biedt besluitnemers verschillende voordelen. Allereerst geeft het direct inzicht in waarde verhogende mogelijkheden. Ten tweede blijkt uit dit document dat niet altijd het goedkoopste ontwerp, het beste ontwerp is en dat het toevoegen van baten van belang kan zijn om waardevermeerdering te krijgen. Verder wordt er inzicht gegeven in welk alternatief op welk tijdstip het beste geïmplementeerd kan worden.

_Resume_

In dit onderzoek is een methode ontwikkeld om VE toe te kunnen passen in de project industrie. Verder is aangetoond met behulp van een casus dat de methode inzicht geeft in waarde verhogende ontwerpvarianten. De resultaten tonen aan dat het verstandiger is om de publieke ruimte van de Coolsingel organisch te ontwikkelen. Het voorkeursalternatief waarin een vierbaansweg wordt voorgesteld is de beste oplossing wanneer men het hele gebied direct zal gaan ontwikkelen. Echter, wanneer men een aantal jaar wacht blijkt een Coolsingel met twee rijstroken een beter alternatief te zijn.
De ontwikkelde methode kan verder ontwikkeld worden door een database op te stellen waarin baten met betrekking tot herontwikkelingsprojecten zijn gemonetariseerd. Met behulp van de database kan het projectteam in korte tijd een betere onderbouwing formuleren in het beslisdocument. De uiteindelijke beslissing die gemaakt wordt door besluitnemers zal dan ook minder snel afwijken van het geen dat wordt voorgeschreven in het beslisdocument. Wanneer dit document dan ook nog voorzien wordt van mogelijke wijzigingen op verschillende alternatieven is de kans op suboptimale besluitvorming nog minder aanwezig.

Verschillende organisaties zijn bezig geweest met het ontwikkelen van modellen die de baten van projecten uit kunnen drukken in geld. Een meest recente ontwikkeling is de TEEB-stad tool. Data dat deze tool gebruikt zijn gebaseerd op verschillende studies uitgevoerd in verschillende steden. Aangezien veel baten van stadsvernieuwingsprojecten gebonden zijn aan locatie specifieke eigenschappen, mist de tool diepgang en ontbreken er veel baten. Toch biedt de tool een mooie basis voor het ontwikkelen van een database met gemonetariseerde baten voor de stad Rotterdam. Om dit te bewerkstellen adviseren wij verschillende stated en revealed preference onderzoeken te verrichten in verschillende delen van de stad. Dit kan het beste worden opgepakt door de afdeling ‘Milieu Ruimte Ondergrond (MRO)’ aangezien zij al een goede stap hebben gemaakt in het monetariseren van baten met betrekking tot duurzaamheid.

Verder wordt het aanbevolen om het LCC model uit te breiden met kostenkengetallen die momenteel ontbreken. Het opstellen hiervan is tijdintensief, maar zal uiteindelijk leiden tot een generiek model dat de levenscycluskosten van een project kan ramen. Hier heeft men dan in de toekomst profijt van aangezien het denken op de lange termijn steeds vaker als verplichting wordt voorgeschreven bij het nemen van projectbeslissingen. Het uitbreiden van het model zou opgepakt kunnen worden door de clusters stadsbeheer (SB) en stadsontwikkeling (SO).

Van belang is dat deze kennis uiteindelijk wordt meegenomen in het beslisdocument. Het is daarom belangrijk dat het projectmanagement bureau (PMB) op de hoogte wordt gesteld van deze ontwikkelingen. Zij zullen immers het kwantificeren van de baten van project alternatieven als verplichte eis moeten gaan nemen in het beslisdocument. Daarnaast is het ook van belang dat de alternatieven worden doorgerekend op basis van levenscycluskosten. Beiden dienen verricht te worden bij het uitvoeren van een VE studie. Gelet daarop pleiten wij ervoor om VE als verplicht onderdeel toe te voegen aan het beslisdocument.
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Terms, definitions and abbreviations
For the purpose of reading this document, the following terms, definitions and abbreviations are applied.

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<th>Term</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Asset</td>
<td>Services that we use on a daily basis, such as: roads, buildings, water distribution systems, etc.</td>
</tr>
<tr>
<td>Cost of capital</td>
<td>The minimum required rate of return demanded by investors on an investment to meet a profitable project (Brealey et al., 2009, a).</td>
</tr>
<tr>
<td>Cost-effectiveness</td>
<td>The relationship between money spent (monetary inputs) and outcomes generated (effects). In other words, it reflects value for money (WebFinance, 2014).</td>
</tr>
<tr>
<td>Cost indicators</td>
<td>Unit price of an activity.</td>
</tr>
<tr>
<td>Discount rate</td>
<td>Is the rate at which value of money in the future is brought back to the present.</td>
</tr>
<tr>
<td>Eco-burden</td>
<td>The environmental burden of a project to its society in the form of emissions and material depletion (Vogtlander, 2013b).</td>
</tr>
<tr>
<td>Eco-costs</td>
<td>Prevention based single cost indicators that express the ecological impact of a product or process in terms of money.</td>
</tr>
<tr>
<td>Eco tax</td>
<td>Taxes/incentives on products or processes that have a negative impact on the environment and are intended to promote ecologically sustainable activities (Wikipedia, 2014).</td>
</tr>
<tr>
<td>Life Cycle Costing [LCC]</td>
<td>A methodology for systematic economic evaluation of life-cycle costs over a period of analysis, as defined in the agreed scope.</td>
</tr>
<tr>
<td>Life cycle costs</td>
<td>The costs in order to realize a measure and all of its associated future expected expenses.</td>
</tr>
<tr>
<td>Monetization</td>
<td>The process of converting something into money.</td>
</tr>
<tr>
<td>Net present value [NPV]</td>
<td>A method that sums up the discounted future cash flows (income + costs).</td>
</tr>
<tr>
<td>P/LCC model</td>
<td>Performance life cycle costs model.</td>
</tr>
<tr>
<td>Performance</td>
<td>The desired requirements of a project, collectively defined by stakeholders and described in quantitative terms.</td>
</tr>
<tr>
<td>Preferred alternative</td>
<td>A preliminary design selected at the end of the study phase, which is further developed during the development phase towards a definitive design.</td>
</tr>
<tr>
<td>SSK</td>
<td>A method that forms a uniform framework for cost estimations throughout the life cycle of a project [Dutch: Standaard Systematiek Kostenramingen].</td>
</tr>
<tr>
<td>Stakeholder(s)</td>
<td>Are individuals, groups or entities that have an interest in the project.</td>
</tr>
<tr>
<td>V/t,i model</td>
<td>Value time of implementation model.</td>
</tr>
<tr>
<td>Value Engineering [VE]</td>
<td>An organized team effort aimed at analysing functions and qualities of projects in order to generate practical cost-effective alternatives that meet customer requirements.</td>
</tr>
<tr>
<td>Willingness to Pay [WTP]</td>
<td>The amount of money an individual is willing to spend for certain performances.</td>
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Section 1. Introduction
This section of the research provides an introduction to the subject. It contains the research problem, objective and questions. Furthermore, it elaborates on the research methodology and scope.
1. Introduction to the subject

This thesis is motivated by the experience nowadays with the decision-making process regarding regeneration projects for urban areas in Dutch cities. The aim of urban regeneration is to increase the current value of the area, which is obtained when performances outrun the costs for regeneration. Performances in this context are seen as the desired requirements of an urban area, collectively defined by stakeholders, and expressed in quantitative terms. For example, an urban area is intended to be safe, attractive, maintainable, etc. Costs, on the other hand reflect the price to be paid in order to obtain the intended performances.

From practice it is however observed that on the one hand intended performances are often described in words, rather than in numbers. This makes it difficult for decision makers to see the actual effects of money invested, on the performances that investment will generate. On the other hand, decisions are often based on investment costs and far too little attention is paid on making future recurring costs transparent. With future recurring costs we mean costs such as maintaining and operating the urban area.

Value engineers believe that the balance between costs and performances reflects the value of a project. That’s why they developed the approach Value Engineering (VE) to seek out the value of a project by making the balance between those two parameters transparent (Kelly et al., 2004; NEN-EN 12973, 2000). The aim is to improve the value of an alternative during the earlier stages of project development by either eliminating costs that do not contribute much to the intended performances, or adding extra performances for relatively low costs (Bouma et al., 2006).

The approach however originates from the product industry and is relatively new to project-orientated industries. This thesis believes however that VE might be beneficial for improving the value of design proposals regarding urban regeneration projects. To validate this believe, it will yield insight into the practical application of VE during the decision-making process of urban regeneration.

The research starts with discussing several problems that might lead to suboptimal decision-making when evaluating different project alternatives for urban regeneration. Then it is discussed whether VE could be used in order to facilitate this process. Afterwards, we elaborate on the research questions, followed by the scope and research methodology.
1.1. Risks for suboptimal decision-making when evaluating project alternatives

It is widely known that when realized, urban areas provide long-term benefits, not only for its owners (most often municipalities), but more importantly for its users. Therefore, municipalities aim to develop urban areas that are characterized by high values for its users. A major problem however is that municipalities cannot randomly invest their money in value enhancing ideas. First of all because nowadays municipalities face budget deficits (Omroep West, 2012). Secondly, because money invested is indirectly financed by taxpayers’ money. As a consequence municipalities are morally obligated to underpin their decisions carefully. Current practice shows however that municipalities have a hard time in doing so.

First of all, performances of projects are expressed in qualitative terms (1). Since costs are reflected in quantitative terms, the mutual relationship between both factors cannot be mapped. We believe that this could lead to sub-optimal decision-making, since decision makers are not able to see the actual effects of money invested on the performances this investment might generate.

This problem is illustrated by the means of a fictitious situation, in which one could choose between two options; realizing a project that costs 80 million euro, or realizing a cheaper variant of 40 million. For the simplicity of this example it is assumed that performances are measured by the increased attractiveness of the urban area. When evaluating both projects, experts believe that the value of project 1 is much higher than the value of project 2. Therefore, they advised decision-makers to realise that project. However, in this case decision-makers should place trust in the knowledge of experts, since they do not have any insights in the effects of extra money invested on the attractiveness of the area. This is more clearly depicted in the equations below.

\[
\text{Value}_{\text{project 1}} = \frac{\text{Attractiveness}}{80 \text{ M€}}, \text{ or } \text{Value}_{\text{project 2}} = \frac{\text{Attractiveness}}{40 \text{ M€}}
\]

If the effects can however be monetised, different project alternatives are easier comparable, since the comparison is based on comparable units (euros). For example, if project 1 offers a performance of 90 million euro and project 2 a performance of 50 million euro, project 2 should be selected as it generates more value for money. This situation is shown in the equations hereunder.

\[
\text{Value}_{\text{project 1}} = \frac{90}{80 \text{ M€}} = 1.125, \text{ or } \text{Value}_{\text{project 2}} = \frac{50}{40 \text{ M€}} = 1.25
\]

Please note that this fictitious example illustrates suboptimal decision making due to the fact that performances are non-quantified.

Secondly, suboptimal decision-making might be at risk due to the fact that decisions are often based on investment costs (2). Assessments purely based on investment costs provide unrealistic insights in the actual costs of urban regeneration projects. Simply because urban regeneration is often focussed on the long-term which implies that if realised, areas not change rapidly and thus needed to be maintained and operated for years. This raises the importance of making maintenance, operational and removal costs of alternatives transparent when making the assessment. In various literatures (BRI, 2008; ISO 15686-5, 2008) these costs are
appointed as life cycle costs. It should be remarked that lately the importance of estimating life cycle costs has been given much attention. This even led to the developments of methodologies to estimate such. Most well-known is Life Cycle Costing (LCC). From attended meetings at the municipality of Rotterdam, it is however observed that these methodologies are not yet applied when evaluating project alternatives for urban regeneration plans.

1.2. Problem statement
The previous parts lead to the following problem statement for this research:

"Suboptimal decision making in urban regeneration projects might be at risk, as decision makers at public entities do not quantify project performances, and do not take into account future recurring costs when making assessments."

We believe that decision-making could be improved by providing decision makers insights into opportunities to enhance the value of design proposals, during the earlier stages of project development.

1.3. Could Value Engineering (VE) help to improve decision-making?
Current literature provides several methodologies to assess project alternatives on performances and costs (Faber & Mulders, 2012). Most successful implementations showed the use of Social Cost Benefit analysis (SCBA). It should however be remarked that such techniques are applied at the end of project stages and therefore do not stimulate the creation of value enhancing ideas during project development. Furthermore, from several attended assessment meetings at the municipality of Rotterdam it is observed that SCBA’s are regarded as too ‘heavy instruments’ for the assessment in urban regeneration.

Value Engineering (VE) might offer an alternative method to assess project alternatives. As shortly discussed in the introduction of the thesis, it seeks out the value of a project by making the balance between costs and performances transparent. Furthermore, during project development it aims to improve the value of a design proposal by providing insights into modifications that either eliminating costs that do not contribute much to the performance of a project, or adding extra performances for relatively low costs. In both cases the value of a project increases. These main principals of VE are illustrated in the equations below.

\[ P_x + P_y + P_z + P_r + P_e = V_{\text{total}} \]

\[ \frac{P_x + P_y + P_z}{C_x + C_y + C_z} = V_{\text{total}} \]

\[ \frac{P_x + P_y + P_z + P_r + P_e}{C_x + C_y + C_z + C_r} = V_{\text{total}} \]

\( P_{x,y,z} \) indicate the performances of an alternative, \( C_{x,y,z} \) the associated costs to realize the performances and \( V_{\text{total}} \) the total value generated. Note from the equation that in the VE approach value resembles the cost-effectiveness of an alternative.

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1 Is a tool that underpins decisions concerning project investments, by providing insights in not only the financial effects (i.e. investment costs, direct benefits, etc.), but also social effects (i.e. pollution, safety, etc.) of a project (OIE, 2000)

2 Urban regeneration projects often are characterized by the following project stages: initiative phase, study phase, plan development, execution, hand-over and end-of-life. For large infrastructure projects SCBA are conducted at the end of the plan development stage

3 The relationship between money spent (monetary inputs) and outcomes generated (effects). In other words, it reflects value for money
A recent study (Arenas, 2011) indicates that the highest potential of VE is generated during the earlier stages of project development. This is illustrated by Figure 1.

![Figure 1](image_url)

Figure 1: Product development stages against the potential of VE (Arenas, 2011, p. 50)

From the figure it could be concluded that costs for design changes increase over time. Due to this fact resistance by decision makers against design changes increase even more rapid. This implies that the highest potential to change in order to improve the value of designs is gained during the earlier stages of project development (initiative and project development). For that reason it is argued that VE should be applied during those stages of a project in order to be beneficial.

Since the VE approach provides insights into value enhancing modifications, it is believed that it could improve decision making. Compared to SCBA’s, VE studies are conducted simultaneously to the development process. They do not only provide a format to evaluate different project alternatives, but also provide tools to come up prematurely with value enhancing ideas. When the aim is to increase the value of project alternatives, we believe that not only the evaluation process should be facilitated, but also the design process of alternatives. The latter is not considered in SCBA’s. Therefore VE might be a more suitable method than SCBA’s, to reach the aim of value increase in urban regeneration.

1.4. Formulation of the research objective

In the upper stated parts we argued that Value Engineering (VE) might be a useful method to enhance the value of design proposals, during the earlier stages of project development. This last phrase indicates research boundaries. Choosing the earlier stages of project development as research boundaries has practical and theoretical reasons. Practical reasons because of the selected case study (see part 1.8). Theoretical ones because it is argued that during those stages, VE has the highest potential (see Figure 1). With this thesis we aim to enrich the practical knowledge of the method in the fields of urban regeneration.

From this the main objective can be formulated as follows:

“Facilitate decision-making regarding regeneration projects for urban areas by making value improvements of design modifications transparent during the earlier stages of project development”
The objective is achieved by:

- Reviewing literature regarding Value Engineering (VE), Life Cycle Costing (LCC) and cost estimating;
- Defining methods to monetize the performance of urban regeneration projects;
- Developing a life cycle cost estimating model that estimates the life cycle costs of urban regeneration projects, and can be used by practitioners;
- Applying VE on a case that is currently in the earlier stages of project development.

1.5. Research questions

In order to find answer to the problem formulated above, the following main research question is formulated for this research:

“How could Value Engineering be used in the earlier stages of project development in order to improve the value of urban regeneration projects?”

How could Value Engineering be used... means that this research wants to provide recommendations for how public entities, mainly municipalities, could use VE as a methodology to improve the value of design proposals intended for urban regeneration plans.

...in the earlier stages of project development... means that the research recommendations are based upon a practical application of VE in the earlier stages of project development. To be more specific, the research focusses on the initiative and plan development stage of urban regeneration projects.

...in order to improve the value of urban regeneration projects means that the research yields insight into the question whether the value of design proposals for urban regeneration plans can be improved when municipalities use VE.

The main research question is broken down into five key questions:

- **Key question 1:** “In what way can performances and life cycle costs of project alternatives be expressed in monetary terms?”
  This question focuses on how to monetize the two parameters; performance and life cycle costs, which form the basis for project evaluation in VE.

- **Key question 2:** “What are the requirements of a life cycle cost estimation model for publicly funded urban regeneration projects?”
  This question focuses on providing requirements for the development of a life cycle cost estimation model.

- **Key question 3:** “How can the life cycle costs of urban regeneration projects be modelled?”
  Here the requirements are processed into a model that can estimate the life cycle costs project alternatives. The focus is on developing a life cycle cost estimating model for urban regeneration projects.
Key question 4: “What can be learned from the practical application of Value Engineering in the fields of urban regeneration?”
We want to know and learn from a practical application of VE, if it might improve decision-making by providing insights into value enhancing design modifications.

Key question 5: “Which steps need to be considered in order to apply Value Engineering in the fields of urban regeneration?”
This question focuses on providing the necessary steps in order to conduct VE in the fields of urban regeneration.

1.6. Research scope
The research scope is concerned with defining the project boundaries in order to create a solution space. Therefore, the research scope is used to determine what to take into account and what to neglect. This is important to note, since it provides direction to the outcome of the research.

The research takes place within the boundaries of assessing different design proposals (nearly the end of the study phase) and modifications on the proposal that is preferred (end of developing phase). The scope is depicted in Figure 2 below.

Figure 2: Research scope
This research scope is easily explained since it is believed that here the highest potentials of Value Engineering (VE) can be obtained (please note Figure 1).

More specific and projected on the assessment of different design proposals at the end of the study phase (see Figure 2), the research neglects to apply VE for the selection of the preferred alternative. Otherwise we have to develop several modifications that might improve the value of each different alternative. We believe that this insight will not be more beneficial in answering the main question of this research. Nevertheless, it should be remarked that for properly selecting the preferred alternative (in figure: A), both performances and life cycle costs of all proposed designs (in figure: A, B and C) should be made transparent. Due to time constraints, expressing the performances of proposed designs is not included in the thesis. The selection will be based on life cycle costs and expected performances based on knowledge given by experts (not-quantitative).

The focus point of the thesis is the development of the preferred design into a definitive design. In Figure 2 this is indicated by the development of A into A’. In the thesis it is researched whether this process can be facilitated when a VE approach is applied.
The focus of the research is given in Figure 3.

As depicted in green in the figure, the primary focus of the thesis is improving the value of the preferred alternative during the development phase.

Furthermore, the following general boundaries are set for conducting the research:

- To develop the life cycle cost model, data is used that is provided by the municipality of Rotterdam;
- The research is focused on a single case study, which is considered as representative in part 1.8;
- The research is not intended as a consulting report for the Coolsingel project specific;
- The benefits of applying VE during the study phase of project development are discarded.

1.7. Research methodology

The main theorem that serves as the backbone of this research is Value Engineering (VE). In VE project solutions are assessed on two parameters: performances and costs. Remember that urban regeneration projects are often long lasting and for that reason costs should also contain future recurring costs. That's why we emphasized to estimate the life cycle costs of project alternatives to make proper assessments. For this several literatures on Life Cycle Costing (LCC) are studied. In addition, conversations are held with experts within the municipality of Rotterdam to define cost indicators with regard to urban regeneration. These cost indicators can be multiplied with corresponding design quantities in order to estimate the life cycle costs of proposed designs. To monetize performances also literature research is conducted. The literature study on how to define the performances and life cycle costs of urban regeneration projects are combined and form the theoretical framework of the thesis.

Having established the framework, a mathematical model is developed to estimate the life cycle costs of design proposals. Then a practical application of VE is provided by applying it to a single case study. From this it is concluded how VE could be used in order to improve the value of urban regeneration projects. Then recommendations for further research and further improvements on the model are provided. At last in the epilogue a reflection is provided on the research.

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4 Unit price for a specific activity, e.g. the construction of concrete pavements
The upper stated is summarized in the research model below shown in Figure 4.

Figure 4: Research model

1.8. Research framework: a single-case
Case studies have been widely used around the world in all different fields of sciences. Alexander George and Andrew Bennett (2005) for instance proclaim that in recent years roughly half of all articles in the top political science journals have used case studies. Actually, it can even be said that much of what we know has been produced by case study research (Flyvbjerg, 2011). Case studies are used to obtain the general picture of a specific subject. It is regarded as an intensive way of working, which offers a more in-depth research approach instead of a broad one, especially using a single-case.

The results of single case studies, such as proposed for this research, lack however comparison possibilities with other existing projects. It is therefore not surprisingly that it is often argued that a single case study cannot provide reliable information for the broader class. This issue has been a controversial and a much disputed subject in the field of case-study research. Flyvbjerg (2006) and Nock et al. (2008) however argue that; the opinion that one cannot generalize on the basis of a single case and therefore the findings do not contribute to scientific development, is one of great misunderstandings in case study research. Although Flyvbjerg recognizes the lack of comparison possibilities in single case study research, he claims that such studies are not always performed for scientific underpinning but also can serve the fields of social sciences. It is therefore not without reason that he quote’s Anthony Giddens in his article, who states that single case studies can also provide an educational form of enrichment (Flyvbjerg, 2011).

This study acknowledges the upper stated reasoning and uses a single case study in order to learn whether Value Engineering (VE) could be used as a technique to improve the value of preferred alternatives. This implies that the educational enrichment is obtained by the practical application of VE.

1.9. Research roadmap
The structure of the research is – in line with the upper stated methodology – as follows.

After this section, section 2 will provide the theoretical framework that serves as the backbone of this research. It elaborates on the theorems Value Engineering (VE) and Life Cycle Costs (LCC). In addition, it discusses how projects can be evaluated on value by monetizing performances and costs. Answer will be given on the first and second key questions.
The third key question is answered in section 3. The section provides a model for estimating the life cycle costs of urban regeneration projects. Bases for the model are the requirements formulated in the conclusions of section 2.

In section 4 VE will be applied on a single case study – a regeneration project for the public space of the Coolsingel, which is located in the city Rotterdam. This answers the fourth key question of the research.

Based on the case study conclusions and recommendations are drawn that are used in providing answer to the main research question of the research; “How could Value Engineering be used in the earlier stages of project development in order to improve the value of urban regeneration projects?” This is done in section 5 of the research.

In the end section 6, provides an epilogue on the thesis. It provides not only insights into the benefits of this research, but also discusses the limitations of it.

The roadmap of the research is visually presented in Figure 5 below.

![Research roadmap](image)

Figure 5: Research roadmap

At the start of each new section the roadmap will be used to indicate the position of that section in the total research.
Section 2. Theoretical Framework

This section of the thesis provides the theoretical framework, which serves as the backbone of the thesis. It will answer two research questions. The first question to be answered is “In what way can performances and life cycle costs of project alternatives be expressed in monetary terms?” The second question is “What are the requirements of a life cycle cost estimation model for publicly funded urban regeneration projects?”

To answer the first question, chapter 2 elaborates on the theory Value Engineering (VE). The chapter ends with introducing the performance life cycle cost model (P/LCC model). Note that this model consists of two parameters; performance and life cycle costs.

Methods to monetise the performances of design modifications are discussed in chapter 3.

Its counterpart, the life cycle costs of urban regeneration projects, are discussed in chapter 4. The backbone of this chapter is formed by the theory Life Cycle Costing (LCC). The chapter ends with providing the requirements for a life cycle estimating model, which can be used for the development of such. By this answer is given to the second research question.

By combining the findings of chapter 3 and chapter 4, several methods are introduced that can be used to express the P/LCC ratio. Hereby, answer is given to the first research question.
2. Value Engineering (VE)

Value Engineering (VE) provides the backbone of this thesis. This chapter provides an overview of what VE is and how it can be applied in practice.

2.1. Broader context of VE

In the literature a wide variety of terms can be found that are related to Value Engineering (VE). Hereunder a list of the terms is shown that are commonly used throughout literatures.

- VM* – Value Management
- VM – Value Methodology
- VE – Value Engineering
- VA – Value Analysis

The terms are often found to be controversial. Wikipedia (2007) for example states that Value Engineering is also referred to as Value Management, Value Methodology or Value Analysis. This however, is not the case. By different authors, (DACE, 2014; Kelly et al., 2004; SAVE International, 2007) Value Management (VM*) is seen as an all-embracing procedure in which Value Engineering (VE) and Value Analysis (VA) are sub-processes, and Value Methodology (VM) the systematic process applied in both processes. The difference between VE and VA however is that the Value Methodology in VE studies is applied on conceptual projects, while in VA studies the methodology is applied retrospectively (on realized projects), in order to achieve value improvement (SAVE International, 2007). In line with this statement, Kelly et al. (2004, p. 31) define VE as “a subset of the value management process, where the focus is on improving the value of a technical project during the design and construction stages”. In Figure 6 the difference between VE and VA is presented schematically.

![Figure 6: Difference between VE and VA, based upon (DACE, 2014; SAVE International, 2007)](image)

From Figure 6 it can be observed that besides VE and VA, also other techniques can be attributed as sub-processes of Value Management. Examples are Quality Function deployment (QFD) or Failure Modes & Effects analyses (FMEA) (DACE, 2014). These however will not be further discussed throughout this research. The same applies for VA studies, since the scope of this research is focused on improving the value of an alternative during project development.

2.2. The global development of Value Engineering

The global developments of Value Engineering (VE) started during World War II at the company called General Electric Company (GEC). Because of the war, resources like steel, copper, bronze, electrical resistors and capacitors were exceptionally scarce. At that time Lawrence Miles was a purchase engineer within the GEC. GEC wished to expand its production and Miles was appointed to purchase the materials in order to ensure this. He often experienced problems obtaining the specified material or component by the designer so he reasoned, "If I
cannot obtain the specified product I must obtain an alternative which performs the same function’. Together with a team he creatively generates alternatives to the existing solution which also provide the required function. During this process, Miles found out that some of the substitutes were providing equal or better performance at lower costs. This functional approach was called by Miles ‘Value Analysis (VA)’ and he describes it as follows “An organized approach to providing the necessary functions at the lowest cost” (Kelly et al., 2004, p. 12). Because of his revolutionary philosophy, Miles is regarded in several literature as the founding father of the VE methodology (Kelly et al., 2004; Miles, 1989; SAVE International, 2007; Stewart, 2005).

Since 1954, VA widely spread among Federal agencies in the USA. The first government organization to implement the program of VA was at the US Department of Defence’s Bureau of Ships. At this time the term VE came into being because engineers were considered to be most appropriate to conduct this program. This resulted in 1959 in the formation of the Society of American Value Engineers whom established the term VE as the most commonly used term in the USA today.

Retained for many years in the manufacturing industry, VE migrated to the construction industry in the late 1960’s and spread globally (Kelly et al., 2004). From North American manufacturing, VE was introduced in North American construction through the US Navy. Through organizations with North America head offices and UK research activities, VE spread largely to the UK and a similar process occurred in Australia and Europe. During the mid to late 1990s a number of guidance documents were produced to guide the VE process.

2.3. The transition of Value Engineering to the construction industry

Since the VE approach originates from the product industry, many literatures on VE define ‘value’ as the ratio between the functionality and costs of a product (Kelly et al., 2004; NEN-EN 12973, 2000; SAVE International, 2007).

However, Ramadhin (2009) suggests using the term performance as an interchangeable term for functionality, when applying VE in the construction industry. In that case, ‘performance’ is defined as “the desired requirements of a project, collectively defined by stakeholders and described in quantitative terms”. ‘Costs’ are defined as “the price to be paid to realise the performances”. To prevent future confusions regarding the terminology, the thesis uses the definition of the terms provided by Ramadhin (2009). This implies that ‘value’ is defined as a ratio between performance and costs of a project, and is expressed by the following equation:

\[
\text{Value} = \frac{\text{Performance}}{\text{Costs}}
\]

Note that in the VE approach value thus resembles the cost-effectiveness of a project. However, in the Value-Price-Cost model and Cost-Benefit analysis, value is expressed differently. For more information on how value is expressed in those theories, see Appendix A.
2.4. The process of VE

SAVE International’s Value standard and Body of Knowledge lists three stages that need to be processed in order to conduct a proper VE study. These are: Pre-Workshop, Value Workshop (Six phased process) and a Post-Workshop. Together they form the Job plan and provide structure to the VE study (SAVE International, 2007). An overview of the Job plan is provided in Figure 7 hereunder.

The Pre-Workshop stage addresses the planning and organization involved in the VE study. Indicative techniques that could be used during this stage are (Kelly et al., 2004, p. 108):

- Interviews
- Stakeholder mapping
- Document analysis
- Questionnaires
- Post occupancy evaluation of a similar facility or of the facility under discussion in the case of refurbishment and adaptation projects
- Site Tour

The aim of this stage is to gather information about the project and get familiar with the key stakeholders involved.

The Workshop stage entails the actual execution of the Job Plan. According to SAVE Value standard and Body of Knowledge this stage consists of the following phases:

1. Information phase: Data collected in the ‘Pre-Workshop’ stage will be more in-depth analysed in the information phase of the Workshop stage. The aim of this stage is to define the performance criteria of a project. These criteria are necessary in order to evaluate the performance of a project alternative.

2. Function analysis phase: In this phase the project functions are defined using a two-word active verb and a measurable noun context. The aim is to clearly capture what performances are intended to be delivered by the project. By this, physical measures proposed as a solution

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Theoretical Framework 38
for the project are eliminated from our thinking, which allows us to explore alternative solutions (or so called modifications) more easily. A commonly proposed technique to identify the functions of a project is the Function Analysis System Technique (FAST). The output of the technique is a graphical representation of functions, which is called a FAST diagram. Since this phase is regarded as one of the most important pillars of VE, it is further discussed in part 2.5.

3. **Creative phase:** The objective of this phase is to find alternative solutions for functions that are currently not realized optimally by measures proposed in a design. To stimulate this process van Geffen and Hendriksen (2005) suggest several techniques that might be useful, such as; brainstorming, brain writing, metaphors, wildest idea, Nominal Group Technique, Mind Mapping, etc. Please note that there does not exist one singular method for the generation of ideas.

4. **Evaluation phase:** In this phase proposed alternative solutions are evaluated on the ratio between costs and performances. The ratio reflects the value of the solution. The solution with the highest ratio should be selected. The evaluation process is further discussed in part 2.6.

5. **Development phase:** During this phase the selected ideas are investigated in considerable detail for their technical feasibility and economic viability. Assessments are performed for low, medium and high-risk scenarios.

6. **Presentation phase:** The output of the Work plan is presented to the client and decision makers.

Finally, the Post-Workshop stage is regarded as a reflection stage. People involved in the valuation have to reflect on the process in order to learn and improve their skills. Please note that the application of the development and presentation phase will not be discussed in this thesis due to the boundaries of the research.

2.5. **Function analysis phase in VE**

Too many times, project teams jump into problem solving activities without fully defining what it is they really need to solve. During the function analysis phase, individuals or teams try to solve the upper stated dilemma.

The general idea behind a function analysis is that the project team distances itself from the suggested physical solutions in the preferred alternative and provides insight into the core functions it needs to perform. To do so several techniques can be used, like for example Means-Ends analysis, Objective analysis and FAST diagramming. The last mentioned technique is most often applied in VE studies and therefore will be explained in more detail below (Borza, 2011; Johnson, 2012; ten Hagen et al., 2011).

FAST diagrams provide a graphical representation of how functions are linked or work together in a project, in order to deliver the intended performances. By focusing on functions, teams and individuals can focus on what is really important and not be constrained by the physical features of the project (Borza, 2011). In addition, van Geffen and Hendriksen (2005) proclaim that FAST diagramming will provide insight in the following:

(1) Relations between functions
Furthermore, they state that there is no ideal diagram to represent the functions. This means that if one will ask different project teams to develop a FAST diagram for the same project, the produced diagrams will slightly differ from each other.

In short, functions in FAST diagrams are described in a two word format – an active verb + measurable noun. Figure 8 illustrates how the FAST diagram is organised. In short, one should start by asking himself “what does the project needs to perform?” and then brainstorm functions. Then the model is build up by asking “how” questions from left to right. And check with “why” questions, from right to left. Downwards are functions that occur at the same time or are caused by the upper stated function. These are derived by asking “when” questions. In Appendix B, the development of a FAST diagram is illustrated by the means of an example for a pencil.

Figure 8: FAST Diagram (Borza, 2011)

Then the physical measures proposed by a project design are linked to the functions provided in the diagram. Proposed measures that realize their intended functions sub-optimal are selected and modified in order to increase the total value of the design. This is illustrated in Figure 9 below. It should be remarked that the modification still needs to realize the function that is preferred.

Figure 9: Modification of a measure
Please note that $P_T$ in the figure indicates the total performance of the design and $C_T$ the total costs. The ratio between the two expresses the total value of the design and is indicated as $V_T$. Whether a modification actually increases the total value of a design is evaluated by expressing its effects on the ratio between costs and performances. This evaluation process is discussed in the next part.

2.6. Value assessment in VE: The P/LCC ratio

As discussed in previous parts of the thesis, modifications should be evaluated on their effects on the ratio between costs and performances of a project. Note that the ratio could be increased when modifications eliminate costs that do not contribute much to the performance of a project. Conversely, modifications can also add extra performances to a project for relatively low costs. This implies that the basis for the evaluation consists of two parameters; performance ($P$) and costs ($C$). Regarding the evaluation of modifications in urban regeneration projects, the latter parameter requires some more explanation.

Urban regeneration projects do not only cost money in order to be realized. It should be emphasized that these projects are often long lasting and for that reason generate costs on the long-term due to maintenance and operational activities. The costs of those activities are defined in various literatures as ‘life cycle costs’ (see i.e. BRI, 2008; Dale, 1993; Davis Langdon, 2006). This indicates that in this thesis the basis for the evaluation consists of the parameters; performance ($P$) and life cycle costs ($LCC$). The two parameters can be graphically plotted as depicted in Figure 10.

![Figure 10: P/LCC evaluation model, based upon (Ramadhin, 2009)](image)

The diagonal line in the figure represents the collections of points for which performances and life cycle costs are exactly in balance. Alternatives above the line (i.e. point A) are economically rational. While alternatives below the line (i.e. point B) are not. Furthermore, it indicates that not necessarily the cheapest alternative (see point B) should be selected, since it could be noticed that point A delivers a higher $P/LCC$ ratio. In reality, the model is bound by several constraints that will prevent the development of unrealistic alternatives. These constraints are discussed in part 2.7 below.
2.7. Constraints of the P/LCC model: Defining the solution space for alternatives

There are several boundaries that put constraints on evaluating the P/LCC ratio of project alternatives.

First of all, public entities often have a maximum budget to spend on their infrastructures. The maximum budget in this model consists of a maximum budget available for the realisation costs and yearly expenditures to keep the infrastructure operational. This boundary is given in Figure 11a below.

Furthermore, municipalities will have minimum requirements, to which the alternative must comply in order to be accepted. In the model the minimum requirements are presented by the minimum acceptable performance of the infrastructure project. This minimum performance constraint is presented in the P/LCC model as illustrated in Figure 11b.

This concludes that the solution space for urban regeneration project alternatives are bound by a maximum budget and a minimum acceptable level of performance.

![Figure 11: The solution space for urban regeneration project alternatives](image)

2.8. Why P/LCC instead of P-LCC

From previous chapters it can be concluded that Value Engineering (VE) uses a preference system that bases the preference of an alternative on the highest ratio between performance and life cycle costs. Some however might argue that if an organization has unlimited resources, it is best to select the alternative which offers the highest net performance. This implies a preference system that bases the preference of an alternative on the highest difference between performance and life cycle costs. The difference between both preference systems can be best illustrated by presenting a fictitious situation assessed with both systems. The fictitious situation is depicted in Table 1. The table shows two alternatives, A and B. A generates a performance equal to 9 million euro for 3 million euro costs. While B generates a performance equal to 20 million euro for 10 million euro costs.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>LCC [M€]</th>
<th>P_ALTERNATIVE [M€]</th>
<th>P/LCC</th>
<th>P-LCC [M€]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>20</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

In the example of Table 1, alternative A would win if a ‘ratio’ preference system is used. However, it loses when a ‘difference’ preference system is used. The difference between the
two preference systems is immediately visible, when presenting the values of Table 1 in the P/LCC model. This is shown in Figure 12. Figure 12a graphically represents the preference based on the P/LCC preference system, while Figure 12b graphically presents the preference based on the P-LCC preference system.

Figure 12: Difference between the P/LCC (a) and P-LCC (b) preference system

The figure easily shows us that the type of preference system can lead to different rankings of alternatives. Throughout the literature no studies are found that clearly prescribe which preference system to use. Probably because both systems provide insight into economically rational alternatives. Then the question rises why some literatures (De Ridder & Vrijhoef, 2007, p. 884; Kelly et al., 2004) use ratio preference systems. We believe that the difference preference system has one major drawback: it promotes to spent larger amounts of money on an alternative. This could easily be concluded from Figure 12b, which shows us that it is relatively easy to get higher differences between performance and life cycle costs, if larger amounts of money are spent. So, when organizations have unlimited money to spent, selecting the alternative that offers the highest net performance should be preferred. However, municipalities finance their projects with taxpayers’ money. Hence, cost-effectiveness should be the selection principle. This allows money that is saved by selecting a cost-effective alternative to be used in other projects were that saved money might be of more use.

2.9. Expressing value in VE: How to define the P and LCC

This part provides a method to express the performance (P) and life cycle costs (LCC) of an alternative. The method is illustrated by the means of a virtual situation, in which an evaluation needs to be made between a proposed alternative and two modifications on that alternative. The virtual situation is presented in Table 2 below. The proposed alternative is presented as A_REF, while the modifications are presented by A_MOD1 and A_MOD2 respectively.

Table 2: Virtual situation of an assessment procedure

<table>
<thead>
<tr>
<th>Alternative</th>
<th>LCC [M€]</th>
<th>Increased or decreased performance [M€]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A_REF</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>A_MOD1</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>A_MOD2</td>
<td>70</td>
<td>-20</td>
</tr>
</tbody>
</table>

To evaluate the virtual modifications provided in Table 2 on a P/LCC ratio, it is necessary to make an assumption about the performance of the reference point (=performance proposal), since the total performance consists of that performance plus the increased or decreased performance due to modifications (variable performance). One could however argue that determining the actual performance of the reference point can be a difficult task. This is indeed
the case. But here we simply want to know whether a suggested modification will increase the ratio relative to the reference point. This implies that it is not necessarily needed to estimate the actual performance of the reference point. To indicate whether the ratio of modifications improves the ratio of an alternative, we could also assume that the performance of the reference point is equal to the life cycle costs needed in order to realize the reference point. In this case, the ratio of the proposed alternative is equal to 1.

Table 3 shows the results of the virtual alternatives presented in Table 2, when evaluated with the ratio system P/LCC. In this the total performance of the reference point is thus assumed to be 80.

Table 3: Virtual situation of the assessment procedure assessed with the ratio (P/LCC)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A_REF</td>
<td>80</td>
<td>0</td>
<td>80</td>
<td>80</td>
<td>1</td>
</tr>
<tr>
<td>A_MOD1</td>
<td>100</td>
<td>40</td>
<td>80</td>
<td>120</td>
<td>1.2</td>
</tr>
<tr>
<td>A_MOD2</td>
<td>70</td>
<td>-20</td>
<td>80</td>
<td>60</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Please note that in the table; $P_{VAR}$ indicates the variable amount of performance, $P_{REF}$ the performance of the reference point and $P_T$ the total performance of the alternative. The parameters are displayed graphically in Figure 13a below. Furthermore, the results of Table 3 are presented in the P/LCC model in Figure 13b.

Figure 13: Variable and fixed part of performance in the P/LCC model

By ranking the alternatives on their $P/LCC$ ratio, Figure 13b indicates that modification 1 should be preferred, followed by the proposed alternative and modification 2 respectively.

Concluding from the upper stated the P/LCC can be defined by the following formula:

$$Value_{alternative} = \frac{(P_{REF} + P_{VAR})}{LCC}$$, where

$P_{REF} + P_{VAR}$ = Total performance of an alternative ($P_T$)

$LCC$ = The life cycle costs of an alternative

There are several possibilities to express the total performance of an alternative. These will be discussed in chapter 3. Furthermore, how to calculate the life cycle costs of an alternative is explained in chapter 4.
3. Methods to monetise the performances of modifications

Two parameters are needed in order to express the total performance of a modification; the performance of the reference point; $P_{REF}$ and the increased or decreased performance due to modifications; $P_{VAR}$. This chapter discusses several methods to obtain both parameters.

3.1. Expressing the total performance of an alternative

Expressing the total performance of an alternative is difficult. However, as discussed earlier the total performance can be calculated by adding a fixed part (the performance of the reference point; $P_{REF}$) with a variable part (increased or decreased performance due to the modifications; $P_{VAR}$). This implies that the total performance of an alternative can be calculated by the following formula:

$$P_T = P_{REF} + P_{VAR}$$

Furthermore, we discussed that the performance of the reference point can be assumed equal to the amount of life cycle costs. Conversely, expressing the variable part is believed to be more difficult and therefore forms the focus point of the chapter. For that, two methods are distinguished, a direct and indirect method. Before the methods are discussed it is important to explain the concept ‘Willingness to Pay (WTP)’.

3.2. The Willingness to Pay (WTP)

The WTP for a certain performance can be described as the amount of money an individual is willing to spend for that performance. However, urban regeneration is developed for the broader class, rather than for individuals. Since multiple individuals have different perceptions of how the public area should perform, it might become difficult to define the WTP for redeveloping that public area.

To obtain the WTP for a certain modification, theoretically every person involved in the project should be asked what he is willing to spend for that modification. Then in the end all individual WTP’s can be combined into an average WTP. The average WTP then represents the amount of money people are willing to spend in order to realize the modification.

In this study, the increased or decreased performance can be monetized by the WTP for that increase or decrease. The next two parts discusses two different methods to define the WTP for measures regarding urban regeneration.

3.3. Expressing the variable performance; direct method

The direct method expresses the WTP for extra performance on a criterion directly. So, if the municipality of Rotterdam is able to express the WTP for extra performance (i.e. due to a modification) on a criterion, this extra performance can be expressed in money directly.

Throughout the literature two main methods are often used to obtain WTP values; stated preference and revealed preference (Kim, 2013; Boxall et al., 1996; Fujiwara & Campbell, 2011).

The first method, stated preference, uses constructed questionnaires to elicit estimates of people’s Willingness to Pay (WTP) for a particular situation. Herein two different questionnaire formats are possible; the contingent valuation format and the choice modelling format. To put it simple, the first format is based on directly asking people ‘how much they are willing to pay’ for the improvement of a situation. The second format provides respondents of different
choice sets (e.g. renders of different alternatives). Each time the respondent has to choose the preferred alternative.

Revealed preference observes the WTP of people by revealing their purchasing habits. Two methods are distinguished to derive the revealed preferences of people: the hedonic pricing method and the travel cost method. The first method derives the WTP through observations on real choices made in actual markets. Most common applications are found in housing and labour markets. In the former, the WTP can be derived by observing the price differential between identical houses located in other parts of the city. The second method, the travel cost method, derives the WTP by observing the time and travel cost expenses that people incur to visit a site. Herein the WTP to visit a site is estimated based on the number of trips that people make at different travel costs.

This research does not include stated or revealed preference analyses in order to derive the WTP for a particular situation. Conducting such analyses is time consuming and does not seem necessary in obtaining the goal of this research. As a replacement, various WTP’s are gathered from earlier conducted stated or revealed preference analyses in the fields of urban regeneration, which are assembled in Appendix N. These values are used in chapter 10 of the research to express the variable performance of modifications on an alternative in monetary terms. It should however be remarked that the list provided in Appendix N is not limited and should be supplemented. To do so, the municipality of Rotterdam can conduct various kinds of stated and revealed preference analyses in the fields of urban regeneration. For further information of how to conduct such analyses one could see Fujiwara and Campbell (2011).

By the means of a fictitious situation it is shown how the variable performance of a modification can be expressed in monetary terms. For instance, imagine the realization of trees at a street with no trees. From Appendix N it can be derived that the effect of this measure will increase the value of properties with 5% (Dutch: WOZ-waarde). Please note that in this case the WTP is reflected as a percentage. The extra performance obtained by the realization of trees can then be expressed in monetary terms by multiplying the average property value with 5%.

It should however be remarked that the direct method can only be used when the effects of a measure on a performance criterion can be expressed in the WTP for that measure. If there are several criteria for which the WTP is not present, the performance on these criteria should be grouped first, and then expressed in monetary terms. We call this the indirect method.

In the indirect method the performance of a modification on several criteria can be combined by the use of a Multi Criteria Evaluation (MCE). This will be discussed further in part 3.4.

3.4. Expressing the variable performance; indirect method

To combine dissimilar performances scored on different criteria into one parameter, the Multi Criteria Evaluation (MCE) can be used. In the context of evaluating different modifications, the output provides a score range, in which a higher score means a higher value. The scale of the scores can be depicted in various manners. Most commonly used are Likert scales (−−,−,0,+,++) or simply grades (2,4,6,8,10).

In the end, one could add the scores scored on each criterion to indicate if a modification generates a higher performance. So for instance imagine that one uses a Likert scale to score
the performances of a modification on the various criteria. If all stakeholders agreed on the scores, they can be combined into an overall performance of the modification by cancelling out the plusses and minus. Note that this process neglects the fact that some criteria might be of more importance than others. A performance criterion of minor importance should not get equal influence as one of major importance in the preference, or the other way around. Therefore a more sophisticated method is obtained by ranking the importance of the performance criteria by using the tool Pair Wise Comparison (PWC).

In PWC an individual expresses his preference between two mutually distinct criteria (Tamhane, 2012). For example, imagine the two criteria are a and b, the following pairwise comparisons are possible:

- An individual prefers a over b: “a > b” a, gets 1 point
- An individual prefers b over a: “b > a” b, gets 1 point
- An individual is indifferent between both alternatives: “a = b” both get 0.5 points

The pairwise comparisons are filled out in a matrix by multiple individuals, the scores per criteria are added and then divided by the amount of respondents. This results in a weight factor for each criterion. The criterion with the highest factor is regarded as most important. From the upper stated it could be concluded that the PWC method is based on ‘group intelligence’ in order to define the weight factors for the performance criteria. An example of a filled in PWC matrix is shown in Appendix C. Furthermore, Appendix D provides statistical experiments that demonstrate the wisdom of crowds.

So, the PWC method is used in order to define the weight factors of the performance criteria in order to conduct the MCE. The application of the MCE can be best illustrated by an example.

Therefore, imagine the following four performance criteria; quality of the surroundings, safety, sustainability and practicability, with weights of 30%, 40%, 10% and 20% respectively. The weights are determined by using PWC. The scoring of the modifications on an alternative are assessed on a scale using the grades 2, 4, 6, 8 and 10. Where 2 indicates the lowest value achieved and 10 the highest. In this example the maximum amount of points that can be scored is 1000, while the minimum amount is 200. This can also be noticed in Table 4, which provides a matrix for conducting the MCE for a fictitious alternative.

Table 4: MCE for a fictitious alternative

<table>
<thead>
<tr>
<th>Performance criteria</th>
<th>Score</th>
<th>Weight factor</th>
<th>Total score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of the surroundings</td>
<td>2 4 6 8 10</td>
<td>30</td>
<td>240</td>
</tr>
<tr>
<td>Safety</td>
<td>2 4 6 8 10</td>
<td>40</td>
<td>240</td>
</tr>
<tr>
<td>Sustainability</td>
<td>2 4 6 8 10</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Practicability</td>
<td>2 4 6 8 10</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td><strong>Total score</strong></td>
<td>100</td>
<td><strong>660</strong></td>
<td></td>
</tr>
</tbody>
</table>

The next step is to find a realistic monetary value for a given range of points scored by the presented fictitious alternative. For instance the following monetary values can be achieved:

- 200 < score < 400: 10 M€
- 400 < score < 600: 20 M€
- 600 < score < 800: 30 M€
The presented fictitious alternative in Table 4 scores 660 point in total and thus falls in the range of 600 to 800. This indicates that the fictitious alternative provides a ‘variable performance’ of 30 million euro. If we assume that also in this example the ‘performance of the reference point ($P_{REF}$)’ is equal to 80 million (see Table 3), than the total performance ($P_T$) of this fictitious alternative is 110 million euros. Please consider that it is important to ‘tweak’ the findings afterwards. As the resulting scores should reflect reality. Therefore, in some cases the obtained weights need to be tweaked in order to provide realistic outcomes.

The various possibilities to conduct the MCE are schematically presented in Figure 14 below. The possibilities are presented by the use of ‘AND’ and ‘OR’ gates. In OR gates decision makers should perform one of the options. Note that it is still possible to perform more than one option. In AND gates all sub-options are needed.

![Figure 14: Overview of options for conducting a MCE](image)

From several attended meetings we noticed that the practice of the MCE at the municipality of Rotterdam shows the use of a Likert scale ($-\ldots;0,+;++$) to score the performances of a project proposal. Furthermore, they simply cancelled out the plusses and minus in order to make their decision. The meetings are attached in Appendix E.

We believe however that this method might result in sub-optimal decision making, because some criteria might be of more importance than others. When simply summing up the scores decision makers neglect this fact. Hence, we believe in using weight factors to indicate the relative importance between the performance criteria and prevent sub-optimal decision making.

### 3.5. Overview of options to determine $P_T$

Summarized, the total performance of an alternative consists of the performance of the reference point ($P_{REF}$) plus the increased or decreased performance due to modifications on that alternative ($P_{VAR}$). In this thesis, $P_{REF}$ is assumed to be equal to the Net Present Value (NPV) of the life cycle costs of a proposed alternative. In this case the ratio between life cycle costs and performance is equal to 1. To express $P_{VAR}$ one could express the performance in money
per criterion (direct method), or, if that is not possible, the performance on several criteria can be grouped first into one performance score, and then expressed in money (indirect method). The several options to determine the total performance of an alternative are presented schematically in Figure 15 below.

Figure 15: Overview of estimating the total performance of an alternative

Please note that the use of the Multi Criteria Evaluation (MCE) is explained in part 3.4 previously.
Life Cycle Costing (LCC)

In recent years, there has been an increasing interest in calculating the life cycle costs of construction projects. This led to the development of a methodology to calculate such, which is called Life Cycle Costing (LCC).

In this chapter of the theoretical framework we will explain the LCC methodology. It contains some background information on the methodology, its application and how it can be linked with the currently cost estimation tools on the market.

4.1. Broader context of LCC

A considerable amount of literature has been published on Life-cycle costing (LCC) (Geerken & van Hoof, 2013; Soti & Habing, n.d.). These studies more or less define LCC as a process to evaluate the life-cycle costs of a project by analysing realisation costs and discounted future costs, such as operational, maintenance and end-of-life costs. Before we delve deeper into the concept of LCC, it is important to explain the place of LCC in its wider context.

Throughout the literature a variety of terms can be found that are related to LCC, which might create some confusion if not described properly. Most commonly used terms are listed below.

LCM – Life cycle management
LCA – Life cycle assessment
LCC – Life Cycle Costing

Life cycle management (LCM) is seen as an approach that assists management in managing the entire life cycle of products or services. The approach is supported by tools such as Life Cycle Costing (LCC) and life cycle assessment (LCA) (Rebitzer & Hunkeler, 2003; Swarr et al., 2011). LCM is thus the all-embracing procedure in which LCC and LCA act as facilitating tools.

LCA is a method for assessing the environmental aspects and potential impacts throughout the life cycle of a product, process or service. The term was first developed during a SETAC (Society of Environmental Toxicology and Chemistry) conference in 1990 in the United States (SETAC, 1997; Klopffer, 2006). Over the past years it developed and culminated in the codification of a series of International Standards, ISO 14040 (ISO 14040, 1997, 2006). Reasons for the developments of LCA studies stem from the awareness of certain human activities, which caused irreversible environmental impacts to the earth. Due to the environmental load imposed by the construction industry, there has been an urge to make the construction supply chain more sustainable (CIB, 1999). To do so, LCA has been adopted as a methodology to assess the environmental performances of urban regeneration projects.

The economic counterpart of LCA is known in several studies (Dale, 1993; Hunkeler et al., 2008; Rebitzer & Hunkeler, 2003; Swarr et al., 2011) as Life Cycle Costing (LCC). The International Standard on LCC (ISO 15686-5, 2008) provides a proper definition of the methodology. Herein LCC is defined as “a methodology for systematic economic evaluation of life-cycle costs over a period of analysis, as defined in the agreed scope”. Additionally, life-cycle cost is defined as “cost of an asset or its parts throughout its life cycle, while fulfilling the performance requirements”.

Theoretical Framework
Thus, related to the construction industry, LCC and LCA are methods to measure costs and environmental performances during the life cycle of public infrastructure respectively. Though both assessments make analysis from two different dimensions (economic and environmental), both are important to facilitate the decision making process regarding public infrastructure (see Figure 16).

Figure 16: The use of LCC and LCA for the decision-making process in public infrastructure, based upon (Davis Langdon, 2006)

4.2. Future expected changes in the cost balance sheets

In the previous part it is explained that Life Cycle Costing (LCC) provides insight in the future expected costs of projects or products, while Life Cycle Assessment (LCA) shows the environmental burden (or eco-burden) of such, for our society. As indicated recently (Ortiz et al., 2009), the latter becomes increasingly important in project development, since a lot of realized projects are responsible for high impacts on the environment. Despite this fact, high impacts are rarely made transparent by decision-makers. Simply because in many cases the benefits of eco-burden reducing measures are non-beneficial from a financial point of view. However, this paragraph tries to make clear that low eco-burden projects might be more attractive also from a financial point of view, than projects with high eco-burdens.

Vogtlander (2013c) demonstrates with his ‘three stakeholders’ model’ that; when people become more aware of the fact that certain activities cause irrecoverable damage to the earth and as a group decide to do something, governments will react by increasing the taxes on environmentally unsustainable activities. This will make such activities less attractive, also from a financial point of view. The three stakeholders’ model is shortly discussed below.

In the transition towards sustainability, three stakeholders can be distinguished (Vogtlander, 2013c): Citizens, Government and companies (see Figure 17 to the right).

Citizens are interacting with their governments via politics: they ask the government to take action in order to start the sustainable transition. Governments on their behalf take actions via regulations, taxes, subsidies etc. to force companies to react. Companies interact with consumers and check if their needs are satisfied. The circle in the middle of the model indicates the direction to trigger the transition towards sustainability.

When applied during project development, the model indicates that projects with high eco-burdens on the long term, have the possibility to become more expensive during their life time,
due to measures taken by the government (e.g. Eco tax). In this case, people that own the project need to pay money for the environmental burden they realize with it. So, where the eco-burden of a project nowadays is “paid” externally (by the society), it is believed that in the future these burdens will be paid internally (by the polluter). According to Vogtlander (2013b) it is not a question if but when this will happen.

The expected future shift on the cost balance sheet of public infrastructure is depicted in Figure 18 below.

Figure 18: Future expected shift on the cost balance sheet of projects. Left represents the current situation, while the right shows the expected future situation, based upon (Vogtlander, 2013b).

If the above sketched situation is acknowledged, it becomes necessary to convert the LCA impacts to costs. Furthermore, it is also believed that if we have reached the situation on the right (see Figure 18), the current scope of the LCC analysis will be extended. After all, a LCC analysis provides insight in all the internal costs of a project over its life cycle. This will be discussed in the next part.

4.3. Life Cycle Assessment (LCA) in Life Cycle Costing (LCC)

In order to estimate the total internal costs of urban regeneration projects in the future, outcomes of an LCA analysis need to be converted into costs. To do so, in 1999 the eco-costs system has been introduced on conferences and several articles have been published in the International Journal of LCA (Vogtlander & Bijma, 2000; Vogtlander et al., 2001).

Simply put, eco-costs are single cost indicators that express the ecological impact of a product or process in terms of money. The amount of money is based on the required costs of prevention measures, which have to be taken to make a product or process “in line with earth’s estimated carrying capacity” (Hendriks et al., 2004). Since our society is yet far from sustainable, the eco-costs are ‘virtual’. This means that they have been estimated on a ‘what if’ basis and are thus intangible costs. Therefore, when they are used in calculating the life cycle costs of a project it is important to separate them from tangible costs such as; maintenance, operation, realisation and disposal costs. This implies one classical LCC analysis and one ecological LCC analysis (LCCeco). The latter one can be used by decision makers to speculate the future expected total costs. Furthermore, they also indicate which project is from an ecological point of view the most attractive one, when assessing different project alternatives.

5 Classical LCC analysis include solely tangible costs such as realization, maintenance, operation and disposal costs.
In recent years, general databases with eco-cost indicators are developed at the Delft University of Technology. These indicators are defined as the sum of 3 direct (toxic emissions, energy and materials depletion) and 2 indirect elements (depreciation and labour). For further details on the calculations of these indicators see (Vogtlander & Bijma, 2000; Vogtlander et al., 2001). The databases are often used in product-oriented industries to calculate the total eco-costs of a product. However, none studies have been found that uses these databases to calculate the eco-costs of infrastructural projects. Therefore, this study will provide the first attempt in developing a model that can estimate the eco-costs of a project over its entire life cycle.

Summarized, Life Cycle Costing (LCC) is a methodology used to economically evaluate the life cycle costs of an alternative over a predefined period of analysis. Classic LCC analysis provide insights in the realisation costs and future expected operational, maintenance and disposal costs of a project.

It is strongly believed that public entities should be aware of the fact that our society will not continue to accept unsustainable situations caused by urban regeneration in the long term. It is therefore expected that the eco-burden of public infrastructure will ‘internalise’ in the future by means of measures taken by the government. When this happens the eco-burden of projects should be expressed in terms of money, and should become part of the LCC assessment. To convert the eco-burden of projects, eco-cost indicators can be used, which are based on the required costs of prevention measures to be taken, in order to make the eco-burden of projects in line with the carrying capacity of our earth.

Nevertheless, at the moment eco-costs are external costs. There is no party responsible for the eco-burden of urban regeneration projects. Hence, eco-costs should not be summed with internal costs like operational, maintenance and disposal costs.

4.4. The process of LCC
The process to conduct a LCC analysis is described below in several key steps. The steps are based on several literatures, such as (BRI, 2008; Dale, 1993; Davis Langdon, 2006; Davis Langdon, 2007b; Rijkswaterstaat DVS, 2012). The steps are summarized below.

1. **Setting the primary objectives of the LCC analysis:** This step is straightforward. For example, in this research the primary objective is to underpin strategic decisions during the earlier stages of project development.

2. **Define the boundaries of the LCC:** Here details about the project are discussed and its boundaries defined.

3. **Defining the key parameters for the analysis:** The most important parameters that need to be determined are: the cost to include, period of analysis, method of economic evaluation and which risk to include. The parameters depend on the objective (see step 1) and type of organization. This is explained by the fact that the parameters will depend on the project phase; i.e. early on in the process the level of detail is often of low granularity. Additionally, public entities have different opinions than private parties, which probably will reflect in different choices of economic evaluation or selected period of analysis. As the input parameters require some more explanation, they are further discussed in part 4.5.
4. **Selecting data:** Often LCC analysis are carried out during the earlier stages of project development. Hence, it might be possible that a lot of data such as cost data or project information is lacking. In these cases assumptions need to be made which could for example be based on benchmark projects.

5. **Conducting the LCC analysis:** During this step the LCC analysis is carried out.

6. **Reporting the results:** This is the final step of the LCC analysis. During this step different project alternatives are compared and one will be selected.

4.5. **Description of the key parameters in LCC**

In this part a more detailed description is provided of the key parameters to include in Life Cycle Costing (LCC). An overview of the key parameters is provided in Appendix F.

Cost to include

In line with the scope of the LCC analysis it is important to clarify which costs are to be included and how to express them before attempting to undertake the LCC study. Usually it is necessary to include all relevant costs relating to the construction, maintenance, operation and disposal of a project. However, economic or legal interests in the project might differ between private and public parties. Therefore, they may decide to omit certain costs that will be borne by others. This thesis focuses on the following cost items: *realisation costs, operational costs, maintenance costs, disposal costs and eco-costs*.

To calculate the cost items a distinction is made between *direct* and *indirect costs*. Direct costs are costs that the contractor relates to the realisation of a single object (*price* * quantity). For example, he calculates the direct costs of 100 m² asphalt by multiplying it with the unit price for realizing a square metre of asphalt. In addition to the direct costs, the contractor adds indirect costs. Indirect costs are costs that could not be related to a single object. This thesis distinguishes four types of indirect costs: *execution costs, one-off costs, overhead costs and profit & risks*. The municipality of Rotterdam reflects these costs by multiplying the direct costs with a fixed percentage. Background information on direct and indirect costs is provided in Appendix G. Below the different cost items are summarized. Please note that the costs are in line with the costs that are involved in urban regeneration projects. Other infrastructure projects could have different costs. This implies that the formulas shown below can only be applied when calculating the life cycle costs for urban regeneration projects.

**Realisation costs** (*C*) can be calculated by the following formula:

\[ C_r = (C_{REM} + C_c + C_{ADD}) \times (P_{indirect} + 1) \]

- \( C_{REM} \) = Removal costs of the current situation
- \( C_c \) = Construction costs of an alternative
- \( C_{ADD} \) = Additional costs
- \( P_{indirect} \) = Fixed percentage for execution costs, one-off costs, overhead costs and profit & risks

6 Cost, which cannot be translated into price*quantity. The costs are based on rough estimations.
Long-term costs, such as operational costs only include overhead costs. Maintenance costs include costs for corrective maintenance, routine inspections and also overhead. These last costs are included as percentages in the cost indicators for maintenance developed by the municipality of Rotterdam (Gemeente Rotterdam, n.d.).

Then, disposal costs ($C_{DIS}$) can be calculated as follows:

$$C_{DIS} = C_{REMend} \times (P_{indirect} + 1),$$

where $C_{REMend} =$ Removal costs at the end of life
$P_{indirect} =$ Fixed percentage for execution costs, one-off costs, overhead costs and profit & risks

Finally, the eco-costs ($C_{ECO}$) are related to realisation, operational, maintenance and disposal activities. These are calculated as follows:

$$C_{ECO} = (C_{ECO_R} + C_{ECO_O} + C_{ECO_M} + C_{ECO_DIS}) \times (P_{indirect} + 1),$$

where
$C_{ECO_R} =$ Eco-costs for realisation activities
$C_{ECO_O} =$ Eco-costs for operational activities
$C_{ECO_M} =$ Eco-costs for maintenance activities
$C_{ECO_DIS} =$ Eco-costs for disposal activities
$P_{indirect} =$ Fixed percentage for execution costs, one-off costs, overhead costs and profit & risks

It should be remarked that the reduction of eco-cost can be achieved by realizing prevention measures. To do so it is assumed that a contractor is needed in order to realize such. Therefore, the last equation also takes into account indirect costs.

Period of analysis

The period of analysis is defined in the ISO 15686-5 (2008) as “the length of time over which an LCC assessment is analysed”. The period can have a fundamental impact on the outcome of the analysis. Therefore, it is important to understand the potential effects of a long or short period of analysis. A longer period of analysis introduces higher levels of uncertainties in the analysis. After all, impacts such as inflation, operation and maintenance activities become more difficult to predict over time. This does not imply that LCC analyses should not be carried out over long periods of time. The increased risks however should adequately be understood.

Furthermore, practitioners should also be aware of the impact of the chosen discount rate when applying different analysis periods. A longer time period, results in a greater impact of the discount rate on the future costs. In contrast, a shorter period will result in smaller effects of the discount rate on the outcome of the analysis. Further on this is explained in more detail.

For strategic decisions, public entities often select a long time period (50 to 100 years). This period often reflects the ‘physical life’ of a project, which is characterised as the moment of construction to demolition or replacement (Davis Langdon, 2007a). Rijkswaterstaat for example uses a time period of 100 years to evaluate different project alternatives (Rijkswaterstaat DVS, 2012). In the private sector often shorter time periods are selected, since
clients in these sectors are more focused on generating short term investment returns (Davis Langdon, 2007b).

Method of economic evaluation
There are several methods available to make economic assessments in LCC analysis. The three most commonly used in project-orientated industries are (Dale, 1993):

1. **Simple payback**: defined as the time taken for the return on an investment to repay the investment.
2. **Net present value (NPV)**: defined as the sum of money that needs to be invested today to meet all future financial requirements as they arise throughout the life of the investment.
3. **Internal rate of return (IRR)**: defined as the percentage earned on the amount of capital invested in each year of the life of the project after allowing for the repayment of the sum originally invested.

All three methods are systems to determine the financial worth of an investment. In the construction industry we generally wish to know if additional money spent on a project is worth the savings that will be made by a subsequent reduction in operating or maintenance costs. For example, investments in sustainable solutions may be expensive but might save future expected eco- or operational costs.

When evaluating urban regeneration alternatives both the simple payback and Internal Rate of Return (IRR) method seemed less suitable then the Net Present Value (NPV) method. Dale (1993) argues that the simple payback method does not make allowance for the variables: inflation, interest (payable or received), cash flow and taxation. Conversely, the NPV method does.

The IRR, is more often used by private parties to calculate the necessary ‘cost of capital’ to obtain a NPV of zero. This may lead to shortcomings, such as; the selection of a less productive alternative or non-unique solution. Since public parties compared to private parties are less interested in high rates of returns, but more interested in high society benefits, the IRR method also seems less suitable, compared to the NPV method.

Because of the limitations of the simple payback and IRR method, both methods will not further be discussed in this thesis. This thesis will use the NPV method to evaluate different project alternatives. The method evaluates alternatives by converting all their future expected costs to the worth of these costs in the present. In doing so, a fair assessment between the alternatives can be made.

Long term costs, such as operational, maintenance and disposal costs therefore need to be converted into their time-equivalent values of the present. In addition the same applies for eco-costs related to these activities. This implies the following formula for calculating the life cycle costs of an alternative at time zero:

\[ LCC (€) = C_r + \sum [PV (C_D) + PV (C_M)] + PV (C_{DIS}) \]

where

7 The minimum required rate of return demanded by investors on an investment to meet a profitable project (Brealey et al., 2009).
\[ C = \text{Realisation costs} \]
\[ PV(C_{O}) = \text{Present value of operational costs} \]
\[ PV(C_{M}) = \text{Present value of maintenance costs} \]
\[ PV(C_{DIS}) = \text{Present value of disposal costs} \]

Intangible costs\(^8\), such as eco-costs are strictly separated from tangible costs\(^9\). A key reason for this is that currently eco-costs are indirectly paid by the entire society. However, public entities are morally obligated to act from a societal perspective. Hence, eco-costs will be made transparent. To do so, the following formula is used, which calculates the life cycle eco-costs of an alternative at time zero:

\[
LCC\_ECO (\€) = C\_ECO \_R + \sum [PV(C\_ECO \_O) + PV(C\_ECO \_M)] + PV(C\_ECO \_DIS),
\]

where

- \( C\_ECO \_R \) = Eco-costs due to the realisation of an alternative
- \( PV(C\_ECO \_O) \) = Present value of eco-costs due to operational activities
- \( PV(C\_ECO \_M) \) = Present value of eco-costs due to maintenance activities
- \( PV(C\_ECO \_DIS) \) = Present value of eco-costs due to disposal activities

In the equations above, one could notice the ‘present value of costs’. This value is calculated by the means of an important concept within the NPV method called ‘discounting’. This concept is explained in more detail hereunder.

Discounting
Project costs that occur at different points in the life of an asset\(^10\) cannot be compared or summed directly due to the varying time value of money. It is based on the principle that a sum of money at the present time has a higher value than the same sum in the future, due to the earning power of that sum in the interim (Davis Langdon, 2007a). Hence, future costs needed to be converted into their time-equivalent value of the base date. For this process a ‘discount rate’ is used.

It is important not to confuse the discount rate with the inflation rate. The discount rate represents the time value of money. It reflects the opportunity cost of capital\(^11\) to an investor over time. The time value of money, expressed in a discount rate, depends on; inflation, opportunity costs of capital and personal preferences (Brealey et al., 2009).

Two types of discount rates can be distinguished: a ‘real’ and a ‘nominal’ rate. The real discount rate reflects the time value of money without taking into account inflation or deflation. While the nominal discount rate takes this into account. The consultancy firm Davis Langdon (2007a) argues that if inflation rates are approximately equal, inflation rates are most often excluded from the LCC analysis. However, if the analysis includes services subject to differing rates of

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\(^8\) Intangible costs do not physically exist. For example, eco-costs are intangible costs; at the moment there are no players that pay for these costs. Hence, they are also called ‘virtual costs’.

\(^9\) Tangible costs physically exist and need to be paid for, i.e. realization, operational, maintenance or disposal costs.

\(^10\) Services that we use on a daily basis, such as: roads, buildings, etc.

\(^11\) An investor could also invest the amount of money in shares and for example receives a rate of return equal to 8%.
inflation such as; energy prices and labour prices, inflation should be included. This implies using a nominal discount rate. Yet, most theories on LCC suggest using a real discount rate for assessing infrastructure projects (Davis Langdon, 2007a; Rijkswaterstaat DVS, 2012). Reasons for this are explained by the fact that inflation is difficult to predict, especially on the long-term. Therefore, this thesis will use the real discount rate to convert costs to their present values.

**Effects of the discount rate**

A discount rate equal to zero, disregards the earning power of money of future costs. In other words, the timing of cash flows does not matter; money in the future has the same value as money in the present. The higher the discount rate, the more importance is given to the near-present. The effects of the discount rate on the NPV of an alternative are illustrated in Figure 19 to the right.

From the figure it can be concluded that higher net benefits in the future, generated by greater savings on i.e. operational costs are less attractive, when one applies a high discount rate. Conversely, the attractiveness of future savings (and thus higher benefits) becomes greater when low discount factors are applied. This implies that a high discount rate will favour options with low capital costs (e.g. realisation costs) and high future costs, above options with high capital costs and low future costs. Provided that the period of the LCC analysis is rather short. In contrast, options with high capital costs and low future costs will be more favoured, if a long period of analysis is selected.

Thus, when a high discount rate and short period of analysis is selected, one is likely to favour options with low capital costs and high future costs, while a low discount rate and long period of analysis will favour the opposite.

**Selecting the discount rate**

The context of this thesis deals with publicly funded urban regeneration projects. Judgements should therefore be based on social benefits generated by the project, rather than on the rate of return on capital invested.

In many cases, social benefits bear no relation to the rate of return on capital invested (e.g. reduction of air pollution). Project alternatives with high social benefits, realised by high capital costs up-front, will be evaluated non-beneficial if high discount rates will be applied in the assessment. In contrast, they become financially more attractive if low discount rates will be applied.

Therefore, in the public sector (e.g. municipalities) discount rates often fall into a range of 3 to 5% (Davis Langdon, 2007b). Rijkswaterstaat for example, recommends to use a discount rate of 2.5% when assessing project alternatives. Furthermore, they advise to perform a robustness check with a rate of 5.5% (Rijkswaterstaat DVS, 2012). Including risks
Projects are consistently affected by risks and uncertainties, throughout their lifecycles. If these risks are not appropriately managed, additional costs will occur. Several studies recognise the incorporation of risk analysis in LCC analysis to identify the impacts caused by risks and uncertainties (CIBSE, 2008; Boassabaine & Kirkham, 2005). Since LCC analyses incorporate future costs, risks can be caused due to variations of price rates, quantities, life-time of components, etc. These risks can be assessed by applying a qualitative or quantitative approach. Qualitative approaches can be found in (CIBSE, 2008; Smith, 1999) and are not further discussed in this research.

In quantitative risk analyses, models are used that compute the risk impacts of project related activities. Techniques to quantify risks are either deterministic or probabilistic. In probabilistic approaches the risk of project is expressed by a probability distribution, while deterministic approaches use a fixed percentage to build in risks. The two methods are explained in more detail in part 4.6.

Often the input variables in the LCC analysis are evaluated by applying a sensitivity analysis. It evaluates the impact of change in a variable, e.g. the discount rate, on the NPV of a project. The results can be graphically presented in a ‘Tornado Diagram’.

Summary

In the context of this research, a LCC analysis is used to facilitate the assessment of multiple project alternatives during the earlier stages of urban regeneration development.

To do so, the realisation, operation, maintenance and disposal costs in each design need to be made transparent. Additionally, eco-costs related to the proposed activities in these cost items need to be taken into account. A subtle and conclusive reason for this is explained by the fact that public entities are morally obligated to act from a societal perspective. Especially, since urban regeneration projects are publicly funded. It should however be remarked that eco-costs are intangible costs and for that reason should not be summed up with the other costs (i.e. operational costs).

The costs mentioned above occur at different points in the life of urban regeneration. Due to the time value of money, future expected costs needed to be converted into their time-equivalent value of the present. This process is called discounting. To discount future cash flows a discount rate needs to be selected. This rate reflects the opportunity cost of capital to an investor over time. In the public sector discount rates often fall into a range of 3 to 5%. A key reason for this is to make social benefits, which do not affect the rate of return on invested capital, financially more attractive. However, it should be remarked that a higher discount rate can be applied to perform a feasibility check on a project alternative.

If the discount rate is 2.5% and the period of analysis is 60 years; the above indicates that public entities should use the following formula to assess the realisation ($C_r$), operation ($C_o$), maintenance ($C_m$) and disposal ($C_{Dis}$) costs of an alternative:

$$LCC (\text{€}) = C_r + \sum_{t=1}^{60} \left( \frac{C_{Dt}}{(1 + 0.025)^t} + \frac{C_{Mt}}{(1 + 0.025)^t} + \frac{C_{DIS_{65}}}{(1 + 0.025)^{6T}}, \right.$$
Theoretical Framework

It represents the year in which the costs might occur.

Eco-costs are not included in the upper stated formula, but are calculated separately by using the following equation:

$$LCC_{ECO} (€) = C_{ECO_R} + \sum_{t=1}^{60} \left[ \frac{C_{ECO_{Ot}}}{(1 + 0.025)^t} + \frac{C_{ECO_{Mt}}}{(1 + 0.025)^t} + \frac{C_{ECODIS_{t+1}}}{(1 + 0.025)^{61}} \right]$$

It should however be remarked that the output of the analysis can be affected by risks and uncertainties. Risks can be quantified deterministic or probabilistic. Both manners are discussed in the next chapter.

With a sensitivity analysis the impact of changing an input variable on the output of the analysis can be checked. Through this process, practitioners can identify variables that heavily affect the model outputs and determine break-even points that alter the ranking of project alternatives.

4.6. Estimating life cycle costs with current estimating tools

Recently there has been done a lot of research in order to improve cost estimations, also in the Netherlands (WRI, 1991; Cantarelli et al., 2010; Flyvbjerg et al., 2002). The results point out that in practice, project costs are continuously underestimated.

In order to achieve more reliable cost estimations, Rijkswaterstaat initiated a group called 'Werkgroep Ramingen Problematiek'. The results of this group were bundled in the report ‘Een raamwerk voor Ramingen’ (Bouwdienst RWS Werkgroep Ramingen Problematiek, 1991). Elven infrastructure projects were examined and recommendations were provided on basis of the results. These recommendations were implemented during the period 1992-1994 under the name ‘Project Ramingen Infrastructuur (PRI)’ (PRI, 1995). Results led to a couple of insights regarding the improvement of the quality of the cost estimates. The three main items focused on were: process, uniformity and risks of the cost estimations.

Cost estimation process

From initiative to realisation, various types of cost estimations are made for a project. The estimates differ in level of accuracy; the latter in the process the more accurate they become.

Prorail (2011) distinguishes five different cost estimations, which are related to the development stages of a project. This thesis will only discuss estimates that facilitate the assessment of; project alternatives (end of study phase) and modifications proposed for the preferred alternative (development phase). Related estimates are “Beslissing voorkeursalternatief” and “Beslissing voorkeursvariant”. Both estimates are based on cost indicators. Cost indicators reflect the unit price of a certain activity. For example, the unit price of excavating sand is 2.05 euro per cubic meter (Kortram et al., 2013). The indicators are often based on historical data derived from benchmarking projects.

12 A preliminary design selected at the end of the study phase, which is further developed during the development phase towards a definitive design
The difference between the two estimates is reflected in the level of accuracy. Estimates facilitating the selection of the preferred alternative are allowed to have a spread around the base estimate of 30%. While the other estimate allows a spread of 20%. For scope changes and realisation complexities both estimates allow the estimates to deviate with 10%.

For further details on the other estimates see (Prorail, 2011).

Uniform estimation framework
The PRI (1995) recommends to establish a uniform framework for cost estimations, since it has many advantages. First of all it provides transparency; different estimates throughout the cost estimations process could easily be compared, as they all make use of the same framework. Secondly, it facilitates communication between different parties involved; uniformity provides clarity and lacking information could therefore easily been noticed.

It is therefore to no surprise that clients and consultancy bureaus worked together to implement the recommendations given by the PRI. This resulted in the SSK (Standaard Systematiek Kostenramingen), which is a method that forms a uniform framework for cost estimations throughout the life cycle of a project (CROW, 2010). The method consists of the following budget structure (see Table 5). The terms provided in the table can also be found in Appendix G.

Importance should be given to the terms ‘Miscellaneous’ and ‘item unforeseen’. Both terms reflect the risks and uncertainties involved in the estimation. To quantify risks and uncertainties either a deterministic or probabilistic approach can be applied. These two methods are explained further hereunder.

Table 5: Budget structure cost estimates SSK

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>(1) Direct costs</td>
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<td>+</td>
</tr>
<tr>
<td>(2) Indirect costs</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>(3) Primary costs (1+2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Additional costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Miscellaneous (Dutch: nader te detailleren)</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>(6) Base estimate (3+4+5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) Unforeseen</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>(8) Subtotal (6+7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9) VAT (Dutch: BTW)</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>(10) Total cost estimate (8+9)</td>
<td></td>
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</tr>
</tbody>
</table>

Including risks and uncertainties
Throughout the literature, different methods are addressed in order to incorporate risks and uncertainties (Clark, 1985; Spackova et al., 2013; van der Meer, 2003). Two main methods can be distinguished; deterministic and probabilistic risk estimation methods.

Deterministic approach
In the deterministic approach estimated values are used to calculate the base estimate (see Table 5; 1+2+4). These values are based on the multiplication of cost indicators and associated quantities proposed in the design. In order to make the estimate more realistic the items
‘miscellaneous’ and ‘unforeseen’ are added. In the deterministic approach, the item ‘miscellaneous’ is calculated by adding a fixed margin on the estimated values 1, 2 and 4 (see Table 5). The item ‘unforeseen’ is calculated by adding a fixed percentage on the base estimated (PRI, 1995; van der Meer, 2003).

When applying a deterministic approach, the ideal situation of the development of an estimate is shown in Figure 20 on the left. The margin and percentage for calculating respectively the items ‘miscellaneous’ and ‘unforeseen’ are reduced with the subsequent project phases, as the level of detail will increase over time.

Flyvbjerg et al. (2002), who studied several case studies, found out that in many cases cost estimates deviate upward (see Figure 20 on the right). In other words, project costs are often underestimated. Several causes were provided for these underestimations. Most important ones are project risks, uncertainties and strategic misrepresentation. The latter one refers to intentionally biased forecasts in order to serve the interests of project promoters in getting projects started. As ‘lying’ is a difficult issue to incorporate in cost estimation methods, this study will not further analyse underestimations caused by strategic misrepresentation, but will focus on project risks and uncertainties.

Probabilistic approach
In the probabilistic method the margin is expressed in a standard deviation (σ) with the help of probabilistic calculations. Similar to the deterministic approach, the probabilistic approach also uses estimated values in order to calculate the direct, indirect and additional costs (price*quantity). The difference however lies in the fact that the margins on these values are expressed by a probability distribution. The total sum of the probability distributions provides a statistical underpinned spread around the base estimate. In addition, the cost item ‘unforeseen’ is also expressed by a probability distribution. This spread reflects the risks and uncertainties of scope changes or realisation complexities.

The spread can be calculated by two ways; Statistical or Bayesian. The first way uses historical data to estimate the distribution. If historical data is not sufficient, input from experts is used to calculate the uncertainty. This way is called the Bayesian approach. In the Bayesian approach a minimum, an average and a maximum price and quantity is given for each cost item. With this information one can use a triangular or normal distribution to calculate the standard deviations of the direct, indirect and additional cost items.
In contrast with the deterministic approach, the probabilistic approach provides in theory a cost estimation process as given in Figure 21. As could be noticed from this figure, the estimation is not supposed to be going upwards, as is the case in deterministic cost estimations. Still, the probabilistic cost estimation method is relatively new and effects of this method on the estimation process should be further analysed.

The most important difference between the deterministic and probabilistic approach is that probabilistic estimations provide an explicit representation of the margin. The margin is statistically underpinned and the effects of changes in the cost items on the margin could therefore be explained.

Besides the believed possible advantages of underpinning risks and uncertainties statistically, this research will not express the risks and uncertainties in such manner. But will incorporate risks and uncertainties by providing a maximum allowable deviation of the base estimate, which is expressed by a fixed percentage. Furthermore, unforeseen events such as scope changes or realisation complexities are incorporated by adding an extra fixed percentage on the base estimate. Thus, a deterministic approach will be used, rather than a probabilistic approach to incorporate risks and uncertainties in the cost estimation.

Main reasons are explained by the fact that the deterministic approach is easier to apply compared to the probabilistic approach. In addition, this research is less interested in improving the accuracy of currently used cost estimation methods. Rather, it is focused on facilitating the decision-making process by expressing the P/LCC ratio of modifications on a preferred design. It is believed that applying a probabilistic approach will not have great influence on achieving this objective. For more details on the probabilistic approach see (Janssen, 2003; van Bennekom, 2006; van der Meer, 2003).

Summary
This part provided an overview of how costs can be estimated. It is recommended to use the SSK methodology to estimate the life cycle costs of a project. The SSK provides a uniform framework for cost estimations throughout the life cycle of a project. It structures the total LCC estimate by dividing it into several cost parts, such as direct costs, indirect costs, etc. Direct costs are calculated by multiplying cost indicators with associated quantities proposed in an alternative. Indirect costs will be calculated by the multiplication of direct (specified) costs with a fixed percentage.

Importance should be placed when incorporating risks and uncertainties in the cost estimate. In the SSK, these risks and uncertainties are reflected in the cost items ‘miscellaneous’ and ‘unforeseen’. To calculate the items two estimating approach are distinguished: deterministic and probabilistic cost estimating. The first calculates the items by adding fixed percentages, while the latter expresses the items by probability distributions. Both methods have their
advantages. Where deterministic approaches are known for their simplicity, probabilistic approaches are well-known for their explicit underpinning of deviations in the estimates.

Because of its simplicity, this research will use a deterministic approach to estimate the life cycle costs of an alternative. It should however be remarked that in practice deterministic based cost estimations often deviate upwards with the subsequent project phases.

Since the LCC estimate is used to facilitate decision-making during the study and development phases of a project, a maximum deviation of 30 respectively 20% is allowed in the primary and additional costs of the project. For scope changes and realisation complexities (item unforeseen) a maximum deviation of 10% will be allowed.
5. Conclusions
This chapter provides the conclusions of section 2 of this thesis; the theoretical framework.

The section provides answer to the following two research questions:

- “In what way can performances and life cycle costs of project alternatives be expressed in monetary terms?”
- “What are the requirements of a life cycle cost estimation model for publicly funded urban regeneration projects?”

The first question is answered by presenting a schematic overview of possibilities in Figure 22.

The figure presents an overview of the possible methods to express the value of modifications on a preferred alternative. In this, value is defined as a ratio between the life cycle costs and performance of a project. It thus resembles the cost-effectiveness of a modification. Please consider that the performances of a project are ‘the desired requirements of a project, which are collectively defined by stakeholders and reflected in quantitative terms’.

From the figure it can be noticed that the total performance consists of the performance of the preferred alternative (reference point; $P_{REF}$) plus an increased or decreased amount of the performance due to modifications on that alternative (variable part; $P_{VAR}$). In this thesis $P_{REF}$ is assumed to be equal to the life cycle costs of the preferred alternative. In this case the total value will then be 1, since there does not exists a variable part. To calculate the variable part, one should define first the performance criteria of the project. After that $P_{VAR}$ can be obtained by expressing the performance in money per criterion (direct method), or, if that is not possible, the performance on several criteria can be grouped first into one performance score, and then expressed in money (indirect method). The latter option can use Multi Criteria Evaluation (MCE) as a technique to do so.

The counterpart of the performance of project, the life cycle costs, consist of all relevant costs related to the construction, maintenance, operation, disposal and ecological burden of a project. To estimate the life cycle costs several requirements are divined and are listed after Figure 22. Hereby the second research question is answered.
Figure 22: Complete overview of options to obtain the P/LCC ratio of project alternatives
The requirements presented below provide answer to the research question “What are the requirements of a life cycle cost estimation model for publicly funded urban regeneration projects?”

**Input requirements:**

**Cost to include:**
- Realisation costs of a design proposal
- Present value of its associated operational costs
- Present value of its maintenance costs
- Present value of its disposal costs
- Present value of the associated eco-costs

**Period of analysis and discount rate:**
- Public entities should select a long period of analysis. In this section it is proposed to select a period of analysis between 50 to 100 years
- For publicly funded projects, public entities should select a discount rate that falls within a range of 2.5 and 5.5%

**Risks:**
- To foster simplicity it is advised to use a deterministic cost approach to include risks and uncertainties.
- Risks are incorporated by adding 30% on the primary costs of an alternative
- Uncertainties are incorporated by adding 10% on the base estimate

**Format requirements:**
- The LCC estimation model should be in accordance with the budget structure of the ‘SSK methodology’ as shown in this section.

**Output requirements:**
- The model should be able to provide insight into the life cycle- and eco-costs of an alternative by performing the following calculations:

\[
LCC (\varepsilon) = C_r + \sum_{t=1}^{T} \left[ \frac{C_{O_t}}{(1 + r)^t} + \frac{C_{M_t}}{(1 + r)^t} + \frac{C_{DIST_T}}{(1 + r)^t} \right]
\]

\[
LCC_{ECO} (\varepsilon) = C_{ECO_R} + \sum_{t=1}^{T} \left[ \frac{C_{ECO_{O_t}}}{(1 + r)^t} + \frac{C_{ECO_{M_t}}}{(1 + r)^t} + \frac{C_{ECO_{DIST_T}}}{(1 + r)^t} \right], \text{where}
\]

T represents the chosen period of analysis, r the discount rate and t the year at which future costs occur.
Section 3. A model for estimating the LCC of urban regeneration projects

This section presents the answer to the research question “How can the LCC of urban regeneration projects be modelled?” by presenting a LCC estimating model. First we elaborate on the design of the estimation model. Then an overview is provided of the main elements with regard to urban regeneration projects, followed by a description of the cost sheets in the model. Afterwards, the cost indicators used in the model are discussed. The section ends with providing conclusions regarding the developed LCC estimation model.
6. The LCC estimating model

For estimating the life cycle costs of urban regeneration projects a deterministic cost model is developed in Microsoft Excel. Bases for the model are the requirements formulated in the conclusions of the previous section.

First this chapter elaborates on the design of the model. Then the main elements of urban regeneration projects are discussed followed by a description of the cost sheets in the model. Then the data sheets are discussed. Here we specifically focus on how the cost indicators are developed.

6.1. Design

The model is divided into four main parts; a spreadsheet to enter the project description, several cost sheets, two output sheets and additional sheets for the backup of data. The model is graphically presented in Figure 23.

![Figure 23: Schematic overview of the LCC cost estimation model](image)

The data sheets contain the cost indicators that are used in order to calculate the life cycle costs. In part 6.4 it is discussed how these cost indicators are obtained and developed. Furthermore, part 6.2 elaborates on the main elements regarding urban regeneration projects.

Inputs

For practitioners there are three main input sheets in the model; two to enter the quantities of a design proposal and one to enter the discount rate, period of analysis and starting year of realization.

The quantities that need to be entered are the removal quantities of all current elements in the public space and the construction quantities of a proposed design. In order to include risks and uncertainties, one could fill in fixed percentages for the items ‘miscellaneous’ and
‘unforeseen’. Afterwards, the model will automatically calculate the associated operational, maintenance, disposal (end-of-life) and eco-costs.

The discount rate, period of analysis and starting year of realization are filled in on the NPV sheet. Important to note is that the maximum period of analysis can be set on 100 years. The NPV sheet is show in Appendix I.

Output
The whole point of the LCC estimation model is to calculate the life cycle costs of a proposal with regard to urban regeneration projects. For that reason the model generates the following insights:

- Total costs of realization
- Total operational costs
- Total maintenance costs
- Total costs of disposal
- Total eco-burden reflected in eco-costs for realization, operational, maintenance and disposal activities
- NPV of the alternative

6.2. Main elements regarding urban regeneration projects
When estimating the realization costs of urban regeneration projects, the municipality of Rotterdam regards several main elements. The elements are provided in Table 6.

Table 6: Main elements regarding urban regeneration (Kortram et al., 2013)

<table>
<thead>
<tr>
<th>Elements of the cost items</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Groundwork’s</td>
<td>(5) Street furniture</td>
</tr>
<tr>
<td>(2) Sewage systems</td>
<td>(6) Vegetation</td>
</tr>
<tr>
<td>(3) Pavements</td>
<td>(7) Lights</td>
</tr>
<tr>
<td>(4) Tram track</td>
<td>(8) Traffic guiding facilities</td>
</tr>
</tbody>
</table>

Per element a design might propose to perform several activities; e.g. the excavation of ground, cleaning gutters, placing streetlights, etc. To map the life cycle costs of such activities, we need to have an overview of the possible activities for each main element presented in Table 6. To do so we developed a matrix that shows the possible activities for each element. This matrix is provided in Appendix H.

The activities provided in the matrix form the basis of the ‘cost sheets’ in the LCC model. For each activity one could fill in the amount of quantities that are proposed by a design. These quantities are then automatically multiplied with their associated cost indicator. The outcome provides us the direct specified costs of that activity.

6.3. Cost sheets in the LCC model
The cost sheets in the model provide insight in the direct\(^\text{13}\) and indirect\(^\text{14}\) costs of an activity. These costs might deviate due to future uncertainties. Therefore, risks are included under the

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\(^{13}\) Cost indicator * quantity (also see Appendix G)

\(^{14}\) Execution costs, one-off costs, overhead costs and profit & risks (also see Appendix G)
The indirect costs are calculated by multiplying the direct specified costs with fixed percentages for execution, one-off, overhead costs and profit & risks. For these costs the municipality of Rotterdam uses the following percentages (Kortram et al., 2013):

- **Execution costs** \( (P_{EEX}) \) = 8% of realization costs
- **One-off costs** \( (P_{ONE}) \) = 3% of realization costs
- **Overhead costs** \( (P_{OVER}) \) = 7% of realization costs
- **Profit and risks** \( (P_{P&R}) \) = 5% of realization costs

This implies that a total percentage of 23% is used in order to calculate the indirect costs \( (P_{INDIRECT}) \).

\[
P_{INDIRECT} = 23\% \ (P_{EXE} + P_{ONE} + P_{OVER} + P_{P&R})
\]

Please note that in part 4.5 it is argued that not all of these indirect costs should be taken into account for each type of life cycle costs. The following equations are therefore used to calculate the indirect costs in the LCC model:

- Indirect removal costs = direct removal costs \* 0.23
- Indirect construction costs = direct construction costs \* 0.23
- Indirect operational costs = direct operational costs \* 0.07 (overhead costs)
- Indirect maintenance costs = direct maintenance costs \* none\(^{15}\)
- Indirect disposal costs = direct disposal costs \* 0.23
- Indirect eco costs = direct eco-costs \* 0.23

Together, the indirect costs are summed up with the direct costs and their budget reserves for risks. This results in the base estimate of an activity. Finally, this base estimate is provided with another fixed percentage to cover uncertainties such as scope changes or realization difficulties. In the model these are reflected under the item ‘unforeseen’.

An example of a cost sheet from the model is attached in Appendix J.

6.4. Cost indicators

To calculate the direct costs of an activity we are in need of the unit price for that specific activity. This unit price is also known as a cost indicator. For urban regeneration projects Rotterdam already developed cost indicators for removal, construction and maintenance activities. The latter are developed by the department ‘Stadsbeheer’ and are presented in the model ‘Beheerparagraaf 2013’ (Schot, 2013). The others are shown in the model ‘Ramingen en Kostenplan 2013’ (Kortram et al., 2013) and are set up by the department ‘Stad’. Please note that some of the cost indicators stated in the ‘Beheerparagraaf’ showed indicators for the price level of 2007. These indicators are corrected to the price level of 2013. This thesis assumes that Rotterdam has developed the cost indicators for removal, construction and maintenance activities correctly. For that reason no time is spend on verifying these numbers.

\(^{15}\) The cost indicators that Rotterdam has developed for its maintenance activities already include the indirect costs such as overhead, inspections and corrective maintenance (Gemeente Rotterdam, n.d.)
Currently, Rotterdam lacks however cost indicators that can be used for calculating the direct costs of operational activities. Additionally, as we believe that our society will not accept unsustainable situations in the future, cost indicators for the ecological burden caused by carrying out removal, construction, operational and maintenance activities also need to be developed. Both are discussed below.

Development of cost indicators for operational activities
In urban regeneration projects most of the operational activities consist of cleaning activities and the energy usage of the infrastructure.

Money spent on cleaning activities depend on the duration of the cleaning activity (in hours/year), the area cleaned in a given timeframe, the price of the equipment/machinery used and the labour costs. While money spent on energy consumption, depends on the amount of operating hours, energy usage (in kW) and the energy price per kW. These parameters are eventually used in order to develop the cost indicators for operational activities.

Please note that in this research the parameters are based on a single case study; the Coolsingel case. The parameters related to the case are shown in Appendix K. It shows parameters for cleaning activities and energy consumption at the Coolsingel. Below two examples are shown that illustrate how these given parameters are translated into usable cost indicators.

"Example 1 – Operational cost indicator ‘cleaning pavements mechanically’
In this example a usable cost indicator shows the price of cleaning pavements mechanically per square meter (€/m²). In Appendix K; Table 22, it is stated that this activity is performed by the use of a sweeper (Dutch: veegmachine). This sweeper costs 38.28 euros to run one hour. Furthermore, it needs to be operated by manpower. During the week these costs are 44.82 euros. However, on Saturdays they are 73.23 euros and on Sundays even 97.64 euros.

To clean 37538 square meter of pavements mechanically, 293 hours per year are spent on weekdays, 59 on Saturdays and 59 on Sundays. Summed up a total of 411 hours per year is spent on this activity.

The cost indicator for cleaning pavements mechanically can be calculated with the following formula:

\[
\frac{411 \times 38.28 \text{ (machine)} + 293 \times 44.82 \text{ (labor)} + 59 \times 73.23 \text{ (labor)} + 59 \times 97.64 \text{ (labor)}}{37538 \text{ (square meter)}} = 1.07
\]

The output indicates the euro price of mechanically cleaning per square meter per year. This factor is used to calculate these cleaning costs for the three proposed sketch designs."

"Example 2 – Operational cost indicator ‘energy costs Altra 2: 1x PLL 24 W LongLife’
In this example the unit price of energy costs is calculated for an ‘Altra 2 streetlight’. This type of lightning uses 0.024 kW and operates 4368 hours per year (see Appendix K; Table 23). The municipality of Rotterdam uses an energy price of 0.15 euro per kW for their calculations. This price also includes additional costs such as; energy taxes and transportation (Carels, 2014; van Run, 2014).

With this information, the cost indicator for an Altra 2 streetlight can be calculated with the following formula:

\[
0.024 \text{ (energy usage in kW)} \times 4368 \text{ (operating hours per year)} \times 0.15 \text{ (energy price)} = 15.72
\]

The output indicates the operational costs of an Altra streetlight per year."
Consideration
Consider that the developed cost indicators cannot yet be used for calculating the operational costs of other projects. For that reason they first need to be generalized. To do so, more case studies should be conducted. Here we suggest to make clusters of urban regenerations. A distinction is made between public spaces located in city centres and suburbs. A reason for this is explained by the fact that public spaces in city centres require higher qualities than areas located in suburbs. For that reason cost indicators will differ.

Development of cost indicators for the eco-burden caused by undertaken activities
Cost indicators used to calculate the eco-costs are based on the eco-burden caused by carrying out an activity or the eco-burden caused by the production process of a resource. The first can be subdivided in eco-burden caused by the use of machineries or burden caused by providing services, e.g. lightning. Please note that the eco-cost indicators are based on the study performed by Vogtlander (2013a).

Machineries can either be powered by fuel or electricity. In this thesis it is assumed that machineries are powered by fuel, more specifically by diesel. Eco-cost indicators for diesel-powered machines are calculated by multiplying the diesel usage per hour with the eco-cost factor of diesel combustion (€ 0.581/l). In Appendix L, the eco-cost indicators of different types of machineries are listed in Table 24.

Eco-costs caused by the provision of services are calculated for the burden caused by the use of electricity. For this, indicators are calculated by multiplying the amount of energy usage per hour [kWh] with the eco-cost factor of electricity (€ 0.095/kWh).

Lastly, the eco-burden caused by the production process of a resource is calculated by multiplying the quantity needed of a resource with its associated eco-cost factor. Important to note is that this is only calculated for the following materials: ground, concrete, bitumen, marble, stoneware and clinkers. These cost indicators are listed in Table 25 in Appendix L.

A schematic overview of the calculation process is depicted in Figure 24.

![Figure 24: Overview of calculating eco-costs](image-url)
Example 1 below shows the calculation of the eco-cost indicator for the activity ‘sand excavation’. 

“Example 1: activity ‘excavating sand’
This example provides more insights in the calculation of the unit price of eco-costs for the activity ‘sand excavation’. For this activity a trencher backhoe is used. This machine excavates 50 m$^3$ sand per hour. To do so the machine uses 10 litres of diesel. Each litre of diesel combustion costs the environment an eco-burden of 0.581 euro. So, for each hour of excavating the machine causes an eco-burden of 5.81 euro. Per m$^3$ this results in €0.1162 eco-costs (€5.81/50m$^3$).”

The cost indicators for removal, construction, operational, maintenance, disposal and eco-costs are provided in the data sheets of the LCC estimating model.

Consideration
Take into account that the eco-cost indicators could change heavily on the short term. For example, machines that currently run on diesel might be driven electrically within a timeframe of 10 years. For that reason it is argued whether the eco-costs should be used when assessing long term projects.
7. Conclusions
This chapter provides the conclusions of section 3 of the research; A model for estimating the LCC of urban regeneration projects.

In this section answer is given to the research question “how can the LCC of urban regeneration projects be modelled?” by introducing a LCC estimating model.

It is believed that with this model, public entities are able to calculate the life cycle cost of project alternatives. It should however be remarked that in order to be used in practice the model and the input variables need to be verified. Due to time constraints this part is not performed in the thesis.

We believe however that the model can be tested by verifying it with multiple realized projects. To do so one should have insights in the actual realization, maintenance and operational costs of such projects. Note that the disposal and eco-costs cannot be verified. The latter because they are based on virtual costs and thus are not documented. Obtaining the disposal costs will also be problematic because urban regeneration projects often are characterized by long life times. Therefore it is believed that these costs are rarely documented.

If the actual realization, maintenance and operational costs of a project are obtained, the model can be verified by filling in the quantities of the project. Large deviations should be marked and its causes find and solved.
Section 4. Practical application of VE in the fields of urban regeneration

In this section Value Engineering (VE) is applied on a single case study – the urban regeneration of the Coolsingel. Hereby answer is given on the fourth key question; “What can be learned from a practical application of Value Engineering in the fields of urban regeneration?”

To answer the question, first an introduction is provided of the case study. Here different design proposals for the future public space of the Coolsingel are discussed together with the current process of selecting the preferred one. Then the life cycle costs of the designs are estimated with the LCC estimation model. Based on these results and the expected future potentials of the designs a preferred alternative is selected.

For the preferred alternative several modifications are developed. To come up with proper modifications a Function Analysis System Technique (FAST) is used. This technique indicates what performances are intended to be delivered with the regeneration project. It captures what, by graphically displaying functions of the project. Functions that are believed to be realized sub-optimally by the measures proposed in the design, are selected and modified.

The developed modifications will be evaluated on their ratios between life cycle costs and performances.

The steps taken in the case study are presented in a tree, which provides answer to the fifth key question; “Which steps need to be considered in order to apply Value Engineering in the fields of urban regeneration?”
8. **Introduction to the case**

This chapter provides a general description of the Coolingsel case. First the project and the ambitions of the project are described. Then the award and assessment procedure is explained, followed by an overview of three design proposal made for this project.

8.1. **Project description**

The municipality of Rotterdam has high ambitions with the city centre. An essential part in these ambitions is; to transform the Coolingsel from ‘metropolitan traffic artery’ towards a ‘metropolitan city boulevard’ (PBR, 2011).

The Coolingsel connects ‘Churchillplein (South)’ with Hofplein (North), see Figure 25.

![Figure 25: City centre of Rotterdam - Project location (Gemeente Rotterdam, 2009)](image)

In the last years, dissatisfaction with the actual situation is expressed in several reports (PBR, 2011; Gemeente Rotterdam, 2008, 2009). Successive measures to improve the Coolingsel only led to further fragmentation of the main arterial road. Due to this, the Coolingsel currently forms a summation of spatial claims and lacks to represent the functionality and image of a city boulevard.

In order to transform the Coolingsel successfully, the municipality selected three architectural firms to develop a sketch design (conform the DNR-STB 2009). These firms are asked to transform the current situation, without making excessive changes to the current street profile. This means that the new situation still consists of two by two traffic lanes that are separated by a tram track in the middle. A subtle reason for this can be explained by the fact that additional costs need to be made if changes are proposed on the current street profile.

Furthermore, the architectural firms are not obligated to provide designs for the intersections ‘Hofplein’ and ‘Churchillplein’. Yet, if they make radical changes to the current street profile, they should at least provide a direction of how this profile can be connected on its surroundings.

The evaluation of the designs took place during the first weeks of January 2014. After this one firm is awarded the tender in order to develop his or her design into a definitive design (DO). This process is explained in the next part of this chapter.
8.2. Award and assessment procedure

The tender is awarded by a multidisciplinary committee. Important to note is that this committee consists of a governance principal (Dutch: bestuurlijke opdrachtgever (BOG)), official principal (Dutch: ambtelijke opdrachtgever (AOG)), project manager (PM) and some supporting officials.

The BOG is political responsible for the realisation of the project and intended policy objectives. The AOG is responsible that the global goals, results and scope of the project are met. Finally, the PM is responsible for the decision-making document (Dutch: beslisdocument). These documents consist of detailed information about the project and need to be delivered at the end of each project phase. In addition, they are used to support the decision-making process. Simply because, the committee is morally obligated to underpin their decisions transparently. Especially, in the case when projects are indirectly financed by taxpayers’ money.

The committee has developed a procurement guideline (Dutch: Aanbestedingsleidraad) in order to evaluate the three designs properly. This procurement guideline provides three award criteria (see Table 7). On each criterion a maximum of 10 points can be given by the committee. The total score on a criterion is achieved by multiplying this score with an associated weight factor. The firm with the highest total score is awarded the tender. An overview of this process is show in Table 7 below.

Table 7: Total score of a sketch design (PBR, 2013)

<table>
<thead>
<tr>
<th>Award criteria</th>
<th>Weight percentage and total score formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketch design</td>
<td>50%</td>
</tr>
<tr>
<td>Presentation and conversation</td>
<td>30%</td>
</tr>
<tr>
<td>Underpinning of remuneration</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Total score</strong></td>
<td>score sketch design * 50% + score presentation and conversation * 30% + underpinning of remuneration * 20%</td>
</tr>
</tbody>
</table>

The results of the assessing the sketch designs are stated in the decision-making document. From the table it can be concluded that the preference stated in that document will account for 50% in the total assessment. Since the thesis is focused on improving the quality of the decision-making document, the other two award criteria are not further researched. Please note however that sub-optimal decision making might also be caused by ambiguities in those criteria.

8.3. The design proposals

The municipality of Rotterdam selected three architectural firms to develop sketch designs for the future Coolsingel. The following firms have been selected:

- Fluitman & Perea;
- Lodewijk Baljon incorporation with UNStudio;
- West 8 incorporation with Grontmij and Speir + Major.

Below the designs are shortly discussed.
Fluitman & Perea
In their concept, Fluitman & Perea suggest to change the current street profile of the Coolsingel. The current tram track is shifted westwards. This creates room for a four-lane traffic track in the middle of the Coolsingel (see Figure 26). It is believed that this creates opportunities to develop wide sidewalks and cycle lanes. In front of the city hall the proposed street profile is interrupted by an immense square (see green-blue ellipse). This square is somewhat lifted from ground level. The changes proposed in the design are expected to increase spatial quality and above all the attractiveness of the Coolsingel.

Important to note is that the proposal lacks measurements. Therefore, it can be a risk that some proposed measures cannot be realised.

Lodewijk Baljon
This design proposal suggests no radical changes to the current street profile. The proposal can be divided into three parts: the connection between ‘Hofplein’ and ‘Churchillplein’ by tram and car, the west-east cross links and finally the pedestrian and cycle flows. Since no radical changes are proposed in this concept, it is questioned if the design will generate an attractive place to hang out. An illustration of the proposal is given in Figure 27.

West 8
Just like Fluitman & Perea, West 8 suggests to make radical changes to the current street profile. It is proposed to concentrate the car lanes to the east side of the tram track. This creates room to develop a wide boulevard at the west side of the tram track (see Figure 28).
Spatially, this provides an interesting image in the facets: greenery, user experience and appearance of the Coolsingel. Yet, from a trafficable viewpoint a lot of changes have to be made in order to connect the proposed profile on its surroundings. The big intersections ‘Hofplein’ and ‘Churchillplein’ also need to be redeveloped.

8.4. Current process of selecting the preferred alternative at Rotterdam

In Appendix E several meetings are described that show the current practice of how Rotterdam evaluated the three different sketch designs.

In line with the conclusions of section 2 of the research, it could be noticed that Rotterdam used a Likert scale (−−−, −0, +, ++++) to score the performances of the designs. In addition, they simply summed up the scores to come to a judgment. This process is shown in Table 8 below.

Table 8: MCE performed by the project team

<table>
<thead>
<tr>
<th>Performance criteria</th>
<th>Lodewijk Baljon</th>
<th>West 8</th>
<th>Fluitman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic safety</td>
<td>+</td>
<td>−</td>
<td>0</td>
</tr>
<tr>
<td>Social safety</td>
<td>0</td>
<td>0</td>
<td>−</td>
</tr>
<tr>
<td>User experience</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Spatial quality</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Maintainability</td>
<td>−</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sustainability</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Constructability</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Flexibility</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Visual appearance</td>
<td>−</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td>Total</td>
<td>+2</td>
<td>+1</td>
<td>−3</td>
</tr>
</tbody>
</table>

Note from the table that the project team preferred the design by Lodewijk Baljon, since it offers the highest performance according to this method.

The judgment is further underpinned by providing insights in the realization costs of the alternatives. To do so, the project team asked the department ‘Stad’ to estimate the realization costs of the three alternatives. The results are shown Table 9 below.

Table 9: Realization costs of the three alternatives

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwork</td>
<td>337.1</td>
<td>848.6</td>
<td>327.7</td>
</tr>
<tr>
<td>Sewer system</td>
<td>657.1</td>
<td>611.8</td>
<td>225.3</td>
</tr>
<tr>
<td>Pavements</td>
<td>17867.7</td>
<td>11754.3</td>
<td>11982.6</td>
</tr>
<tr>
<td>Tram track</td>
<td>342.2</td>
<td>897.3</td>
<td>6133.7</td>
</tr>
<tr>
<td>Street furniture</td>
<td>699.2</td>
<td>828.9</td>
<td>523.3</td>
</tr>
<tr>
<td>Green elements</td>
<td>289.4</td>
<td>1198.9</td>
<td>514.0</td>
</tr>
<tr>
<td>Lightning</td>
<td>722.5</td>
<td>1186.8</td>
<td>358.8</td>
</tr>
<tr>
<td>Traffic guidance</td>
<td>1433.5</td>
<td>2066.7</td>
<td>2066.7</td>
</tr>
<tr>
<td>Integration with surroundings</td>
<td></td>
<td>14071.2</td>
<td>14071.2</td>
</tr>
<tr>
<td>Total excl. VAT</td>
<td>22348.6</td>
<td>33464.7</td>
<td>36233.4</td>
</tr>
<tr>
<td>Total incl. VAT</td>
<td>27041.7</td>
<td>40492.3</td>
<td>43842.4</td>
</tr>
</tbody>
</table>

Based on the costs of realization, the table shows that the design of Lodewijk Baljon is much cheaper compared to the other two designs. The main reason for this is explained by the fact that both designs of West 8 and Fluitman require adaptations to the cross sections ‘Hofplein’ and ‘Churchillplein’.
Based on the information provided above, the project team made a final judgment and advised the commission to select the design of Lodewijk Baljon as the preferred alternative.

However, we strongly believe that this evaluation process might result in sub-optimal decision making. First of all because the alternatives are assessed on investment costs. While it is previously argued that when assessing long-term projects, it is important to take into account all the costs that might occur during the productive life. For that reason in chapter 9 the developed model in section 3 is used to estimate the LCC of the three sketch designs.

Furthermore, we believe that there is much more future potential in the design of West 8 than in the design proposed by Lodewijk Baljon. This believe is caused due to the proposal of a wide boulevard at the west side of the tram track. In the current state this option provides however major downsides, since the car lanes need to be relocated in order to handle the current amount of traffic intensity. This resulted in a four-stroke traffic lane, which requires adaptions to the cross sections ‘Hofplein’ and ‘Churchillplein’. Furthermore, it decreases the traffic safety, since crossing the road is believed to become more difficult.

However, when the design of West 8 is gradually developed, e.g. over a time period of 20 years, the current 2 stroke lane might be enough to handle the traffic intensity. After all, traffic studies indicate that changes to other parts in the city of Rotterdam will reduce the traffic intensity at the Coolsingel. Even to an extent of reducing the 2 by 2 lanes to 1 by 1 lanes (Gemeente Rotterdam, 2009).

So by implementing the design of West 8 gradually, we believe a much higher performance can be obtained then realizing the design of Lodewijk Baljon.

To underpin our thoughts, chapter 10 discusses the effects of modifications on the preferred design. Please note that the preferred design is selected on the lowest LCC and assumption of future potential.
9. **LCC estimates of the design proposals**

In section 3 of the research a deterministic LCC estimating model is developed in order to express the life cycle costs of the proposed sketch designs presented in the previous chapter. This chapter first discusses the results of the model in part 9.1. Then, in part 9.2 a sensitivity analysis is conducted on the results of the preferred alternative. This analysis shows us, which input variables provide the largest impact on the NPV of the alternative.

9.1. **Results of the model**

This part discusses the results generated by the LCC model. First the inputs are discussed followed by an elaboration on the outputs.

**Inputs**
The inputs are in line with the conclusions stated in section 2 of the thesis. For the designs the following inputs are used:

- Quantities proposed by the alternatives;
  - Removal quantities of current elements (equal for each alternative)
  - Construction quantities (alternative depended – non-equal)
- Risks and uncertainties;
  - Item miscellaneous, 30%
  - Item unforeseen, 10%
- NPV calculation;
  - Period of analysis, 60 years
  - Discount rate is set on 2.5% and 5.5%
  - Starting year of realization is set on 2015

**General assumptions**
The input are based on the following general assumptions, which are in line with the conclusions formulated at the end of section 2 of the thesis:

- Period of analysis is 60 year, and is based on:
  - Estimated physical lifetime
  - The project context: urban areas
  - Feasibility checks are performed with shorter periods (e.g. 10 years)
- Discount rate is 2.5%, a feasibility check is performed with a rate of 5.5%
- to is year 2015, realisation costs occur at the start of this year
- At the start of 2015 the urban regeneration becomes operational
- The operational phase ends at the end of 2074
- The year 2075 is used to dispose the infrastructure
- At the end of 2075 the rest value of the asset is assumed to be equal to zero
- VAT (Dutch: BTW) of 21%
Outputs
Table 10 below shows the outputs of the LCC model for the three different designs: Fluitman, Baljon and West 8. Note that eco-costs have been separated from the classical LCC analysis. After all, previous chapters stated that tangible (i.e. realisation costs) and intangible costs such as eco-costs, should not be summed up.

Table 10: Results LCC analysis for the three alternatives

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LCC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realisation costs</td>
<td>43842.39</td>
<td>27041.75</td>
<td>40492.27</td>
</tr>
<tr>
<td>Operational costs</td>
<td>563.45</td>
<td>667.94</td>
<td>325.24</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>1969.69</td>
<td>1575.57</td>
<td>1341.32</td>
</tr>
<tr>
<td>Disposal costs</td>
<td>2476.66</td>
<td>1940.29</td>
<td>2075.60</td>
</tr>
<tr>
<td>NPV</td>
<td>122687.47</td>
<td>96815.93</td>
<td>92463.70</td>
</tr>
<tr>
<td>LCCeco</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eco-costs realisation</td>
<td>8946.52</td>
<td>7845.88</td>
<td>10043.05</td>
</tr>
<tr>
<td>Eco-costs operation</td>
<td>16.92</td>
<td>20.95</td>
<td>16.75</td>
</tr>
<tr>
<td>Eco-costs maintenance</td>
<td>24.23</td>
<td>19.38</td>
<td>16.50</td>
</tr>
<tr>
<td>Eco-costs disposal</td>
<td>722.82</td>
<td>18.72</td>
<td>17.13</td>
</tr>
<tr>
<td>NPVeco</td>
<td>10218.34</td>
<td>9092.46</td>
<td>11070.75</td>
</tr>
</tbody>
</table>

From the table, one could conclude that Alternative 3 (West 8) should be preferred. Compared to the others, it has the lowest Net Present Value (NPV). Yet, it also bears the highest realisation costs. This implies that when a higher discount rate and shorter period of analysis is chosen, the output will probably suggest to realize Alternative 2 (Baljon). After all, high discount rates and short periods of analysis favour options with low capital costs (see chapter 4, part 4.5).

This is in fact graphically shown, by presenting the results of West 8 and Baljon (see Figure 29 to the right). The figure plots the impact of the length of analysis against the NPV. It directly shows us that a longer period of analysis promotes higher investments upfront, provided that this results in low recurring costs. Also it could be noticed that

![Figure 29: NPV affected by the period of analysis; break-even between Baljon and West 8 at a period of 35 years](image)

16 Costs include risks, uncertainties and VAT (Dutch: BTW)
17 NPV is calculated with a discount rate of 2.5% and a lifetime of 60 years
The break-even point lies at 35 years. This implies that West 8 should be selected as the preferred alternative, if the length of period for the analysis is set on 35 years or longer. Conversely, Baljon should be selected if a shorter period is selected. Please note that the discount rate in this example is set on 2.5%.

The effects of the discount rate are presented in Figure 30. To do so, both alternatives are provided with equal benefits. This is purely done to make the effects of the discount rate easier to comprehend. In the figure, the black dotted line represents the cumulative NPV of West 8 at a discount rate of 2.5%. The black solid line presents it at 5.5%. The same applies for the blue lines, which represent Baljon. Please note that the period of analysis is set on 60 years.

The figure directly indicates that higher net benefits in the future due to high investments upfront are less attractive when high discount rates are applied (see solid lines). Baljon for example, has lower capital investments compared to West 8, while it generates less net benefits in the future due to higher operation and maintenance costs (see Table 10). Still in the end its NPV is less negative than the NPV of West 8. This implies that when a discount rate of 5.5% is applied, Baljon will be preferred instead of West 8. Contriwise, West 8 is preferred when a discount rate of 2.5% will be applied (see dotted lines).

As the selection of different discount rates provide different rankings of alternatives, it is interesting to see at which discount rate the preference changes. This is graphically shown in Figure 31. Herein the blue line represents the design made by Baljon and the black line represents the design made by West 8. It could be noticed from the figure that the preference

![Figure 30: NPV affected by the discount rate](image)

![Figure 31: NPV of the alternatives at different discount rates](image)
changes towards the design of Baljon, when a discount rate of 3.9% or higher is applied. Conversely, when applying a discount rate lower than 3.9% the design of West 8 is preferred.

Furthermore, from the LCC analysis (see Table 10) it can be noticed that the first alternative (Fluitman) can be ruled out. It has the highest maintenance and disposal costs. Relatively, it also bears high realisation and operational costs. Together this resulted in having the highest NPV of the three alternatives, making it the least favoured option. This indicates that a selection needs to be made between Baljon and West 8.

In line with chapter 4, part 4.5, it is believed that publicly funded projects should be assessed over long time periods with low discount rates. As is illustrated in the previous figures the use of different time periods and discount rates could result in different rankings of alternatives. Therefore, to prevent manipulations of the outcomes by practitioners, both parameters should be set before performing calculations. In this case the parameters for selection are set to a time period of 60 years and a discount rate of 2.5%. In doing so, the results indicate to select the design of West 8 as preferred alternative.

However, proper assessments are not solely based on costs, but also should take into account the generated performance by each alternative. Since we believe that in the end higher performances can be obtained with the design of West 8, this design is selected as the preferred alternative.

Besides the impacts of the discount rate and period of analysis, there might be other factors that heavily affect the NPV of the proposals. To find these factors a sensitivity analysis is conducted on the preferred alternative in part 9.2.

### 9.2. Sensitivity analysis

A sensitivity analysis explores what-if situations; what happens if we change the value of an input variable to the NPV of West 8 (the output). This information can be achieved by providing each variable of a ‘lower expected value’ and a ‘higher-than-expected value’. These can be derived by assessing the underlying risks of the variables. In other words, a probability contour per variable can be incorporated in the LCC model to indicate the likelihood of occurrence of the variable (Smith, 1999). Nevertheless, it should be remarked that in practice risks do not occur at the same time. In sensitivity analyses this fact is not taken into account and therefore is one of the major limitations in such analyses. Furthermore, variables are regarded as independent from each other, while in fact certain variables can be interdependent (Davis Langdon, 2006). This is a second limitation of the analysis.

Because of pragmatic reasons, this thesis does not provide probability contours for the input variables in the LCC model. Instead, all variables are provided with a maximum deviation of +10% and minimum deviation of -10%. The results of these changes are reflected in a tornado graph.

The tornado graph reflects the percentage change of an input variable on the NPV when changing it with -10% (indicated in blue) and +10% (indicated in red). Variables with the highest impact are shown at the top of the graph, while the opposite applies for variables that have a low impact. The graph is shown in Figure 32 below and provides an overview of the 22 most influencing variables.
From the graph it is noticed that the discount rate and period of analysis have the largest impact on the NPV of the design provided by West 8. Both are important when economically evaluating project decisions, but are less important when trying to improve the value of designs, since they do not contribute to the performances of a design. Therefore, factors should be selected that affect the performance of a design when they will be modified. For example, if we change the proposed type of pavement, it will affect the visual appearance of the area. Remember that ‘visual appearance’ is one of the performance criteria selected for the Coolsingel project.

It could be noticed that the costs are highly influenced by; costs to fit the surroundings, pavement related activities, the amount of manual cleaning and the amount of FRI’s placed. To improve the value of West 8’s design, it is recommended to propose modifications that affects one or more of these critical factors.
10. Modifications on the preferred alternative

In this chapter modifications are proposed for the preferred alternative West 8. To explore modifications more easily, the Value Engineering (VE) approach suggests to use the technique FAST diagramming. The results of the diagram are discussed in part 10.1, the application of it is shown in Appendix M. Furthermore, in part 10.2 several modifications are developed for functions that are believed to be realized sub-optimally.

10.1. Results of the FAST diagram

To recap part 2.5 of the thesis, a Fast diagram shows what performances are intended to be delivered with the project. In this case; the diagram illustrates what performances needed to be delivered by the public space of the CoolSingel. By clearly capture what, instead of how modifications can be explored more easily since the physical measures proposed by the design of West 8 are eliminated from our thinking. The diagram is attached in Appendix M.

From the Fast diagram two functions are selected that are believed to be realized sub-optimally by the measures proposed in the design of West 8. Before these functions are discussed, first the most important measures proposed in the design are discussed.

West 8 proposes to concentrate the car lanes to the east side of the tram track, in order to widen the sidewalks to the west of the tram track; resulting in a large boulevard. In addition, it proposes the use of mixed vegetation and stone pavements to strengthen the visual appearance, user experience and sustainability of the public space. Summarized, the design proposed by West 8 consists of the following main measures:

- Wide boulevard
- Four-stroke traffic lane
- Stone paved streets
- Mixed vegetation, e.g. trees and pocket parks at the east side of the tram track

The wide boulevard is proposed to realize the function ‘widen sidewalks’. It is realized by relocating the two-stroke car lane at the west side of the tram track to the east side of the tram track. This results in the four-stroke car lane. However, the four-stroke car lane is believed to be difficult to cross and even unsafe. To keep it safe, the project team argued that extra traffic lights are needed. As a result from our conducted sensitivity analysis, the amount of traffic lights have a high influence on the NPV of West 8. For these reasons it is believed that the function ‘widen sidewalks’ is currently realized sub-optimal in West 8’s design. In line with part 2.5 of the thesis, Figure 33 schematically shows the selected function to be improved.

![Figure 33: Sub-optimally realized function in the design of West 8, relocate two-stroke traffic lane](image)

To realize high quality pavements, West 8 proposes to use stone paved streets. Also here, the sensitivity analysis indicates that the pavement type seems to have high influences on the NPV
of the proposal. Therefore, the second function that is selected to be sub-optimally realized is the ‘use high quality pavements’. This is depicted in Figure 34 below.

10.2. Proposed modifications

In this part modifications are proposed on the selected functions highlighted in yellow in Figure 33 and Figure 34. As indicated in part 2.4, there simply does not exist one singular method to generate modifications. However, several techniques that could be used are brainstorming, brain writing, mind mapping, etc. In this thesis none of these techniques are used. Main reasons are explained by the fact that we want to learn if it is possible to express the P/LCC ratio of design modifications, rather than developing perfect modifications on the design of West 8.

For the function presented in Figure 33, it is not proposed to relocate the two-stroke lanes, but to remove them. In Figure 35 the proposed situation by West 8 is shown to the left, while the modification is shown to the right. To keep in line with used terms stated in chapter 2, the proposed situation by West 8 is called the reference point (A<sub>REF</sub>), and the modification is called modification 1 (A<sub>MOD1</sub>).

The changes of the modification are represented in numbers in Table 11. Please note that the quantities are presented by an increase or decrease of the ones that are proposed.

Table 11: Modification 1 reflected in numbers

<table>
<thead>
<tr>
<th>Design West 8 (A&lt;sub&gt;REF&lt;/sub&gt;)</th>
<th>Quantity</th>
<th>Modification (A&lt;sub&gt;MOD1&lt;/sub&gt;)</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four-stroke traffic lane</td>
<td>8500</td>
<td>Two-stroke traffic lane</td>
<td>-4250</td>
</tr>
<tr>
<td># of m&lt;sup&gt;2&lt;/sup&gt; pavements</td>
<td>26060</td>
<td>Widen the sidewalks to the west side of the traffic lane</td>
<td>+15000</td>
</tr>
<tr>
<td># Trees</td>
<td>249</td>
<td># Trees</td>
<td>+35</td>
</tr>
<tr>
<td># of m&lt;sup&gt;2&lt;/sup&gt; areas grass and decorative plants</td>
<td>4290</td>
<td># of m&lt;sup&gt;2&lt;/sup&gt; areas grass and decorative plants</td>
<td>+1500</td>
</tr>
</tbody>
</table>
It should be remarked that if we want to calculate the value of this modification, the following formula is used:

\[ Value_{MOD1} = \frac{(P_{REF} + P_{VAR})}{LCC}, \]

where

- \( P_{REF} \) = Performance of the reference point (design of West 8)
- \( P_{VAR} \) = Increased or decreased performance obtained due to the modification
- \( P_T \) = Total performance of the design when modified (\( P_{REF} + P_{VAR} \))

Please remember that in part 2.6 of the thesis it is argued that the performance of the reference point can be assumed to be equal to the life cycle costs of the proposed design. This implies that if a time period of 60 years is selected and a discount rate of 2.5%, \( P_{REF} \) can be assumed to be equal to 92.5 million euros (see Table 10).

The increased or decreased performance obtained due to the modification (\( P_{VAR} \)) is defined by monetizing its performance per criterion, or if that is not possible, the scores on several criteria are grouped first into one score, and then monetized. The latter indicates the use of a Multi Criteria Evaluation (MCE).

In Appendix N an overview is provided of several effects that can be generated by certain measures (e.g. improving the air quality). Furthermore, it shows us how these effects can be measured and expressed in monetary values. Please note that if we want to use that overview for calculating the \( P_{VAR} \) of modification 1, we first have to explain the generated effects.

More or less, modification 1 proposes two large measures: changing from four-strokes to two-strokes and as a result of that the sidewalks at the west side of the road are widened. The two are shortly discussed below.

**Two-stroke traffic lane**

The first effect of this measure is an increase in travel time due to the reduction of the amount of traffic lanes (from 4 to 2 lanes). As indicated in Appendix N, the effect can be measured by the Willingness to Pay (WTP) for travel time reduction, which is assumed to be 9 euro per hour (Kim, 2013). Furthermore, we assume that the 4-stroke road at the Coolsingel handles a traffic intensity of 10000 cars per day. Now if we change to a 2-stroke road, congestion is assumed which will decrease the travel speed at the Coolsingel from 40 km/h to 5 km/h. The distance to be covered is approximately 0.8 kilometre. From these assumptions it is calculated that the increase in travel time is 8.4 minutes per car.

This implies that the decreased performance generated by the measure is around 3.78 million euros per year ((€9.00*8.4/60)*10000*300\(^{18}\)). It is however highly assumable that the traffic intensity at the Coolsingel will decrease over time due to development plans in other areas of the city (Gemeente Rotterdam, 2009). In this thesis it is assumed that the traffic intensity after 10 years will be halved. Then, the ‘extra’ travel time gained due to the modification equals zero. The reduction of ‘extra’ travel time is assumed to decrease linearly.

\(^{18}\) To calculate the WTP for travel time reduction per year, 300 days instead of 365 days is taken. This is a correction for holidays, as the amount of work to work traffic will be remarkably lower during those days.
The second effect of the measure is a reduction of costs for changing the cross sections ‘Hofplein’ and ‘Churchillplein’. When realizing a four-stroke road the project team estimated 14 million euros for modifying these sections. We assume that only 7 million euro is needed for modifying the sections if only the current two-stroke lane at the east side of the tram track is removed.

Finally, extra traffic lights need to be placed for crossing the four-stroke lane in a secure manner. However, it is believed that the amount of traffic lights can be reduced now that pedestrians only need to cross a two-stroke lane.

Widen sidewalks on the west side of the road
As a result of not realizing the four-stroke traffic lane, there is room available to widen the sidewalks. When widening the sidewalks, it is proposed to develop extra trees and decorative plants (see Figure 35). In Appendix N it is stated that streets provided with trees increase the WTP for goods with approximately 9%. Streets that are provided with mixed vegetation perform even better and provide an increase of around 12%. Note that vegetation especially has a positive effect on the sales of luxury goods.

Now if it is assumed that there are 20 shops located at the west side of the Coolensingel, each having a turnover of 500000 euro per year. Then the increase in turnover is around 300000 euro per year (20*$500000*0.03) due to the extra realization of trees and decorative plants at the west side of the Coolensingel. Note that a 3% increase is used, instead of 12%. The reason for this is that in the proposed design of West 8 there are already trees suggested at the west side of the Coolensingel. The upgrade from trees to mixed vegetation results in an effect of approximately 3%.

Furthermore, vegetation also seems to have a positive effect on the value of property (Dutch: WOZ-waarde). It could be noticed from the appendix that several studies indicate that properties might increase with 5% in value if they face trees. Moreover, if properties face mixed vegetation their value might even increase with around 8%. It is assumed that the property value of the 20 shops located at the west side of the Coolensingel will increase with 3% due to the measure. Furthermore, it is assumed that the current property value of a shop is 300000 euro. If both assumptions are taken into account, then the measure will provide a one-time increase of 9000 euro per shop. The total increase of property value generated by the measure is 180000 euro (300000*0.03*20). Please note that the increase in property value of other properties, such as livings, government buildings, etc. are neglected. Main reasons are explained by the fact that there are currently no livings located at the Coolensingel. Furthermore, the property values of government buildings are hard to assume. For that reason they could better be neglected.

The extra mixed vegetation will also have an effect on the reduction of fine dust in the area. In Appendix N it is stated by several studies that a tree captures 0.1 kg fine dust per year, while one square hectare grass or decorative plants captures 1 kg per year. This implies that the modification (see Table 11) provides a total reduction of 4.5 kg fine dust per year. The monetized value of 1 kg fine dust is assumed to be equal to 403 euro. This value is based upon costs for medical care (also see Appendix N). If the upper stated is considered, the extra performance obtained due to the measures can be monetized by multiplying the kg reduction
of fine dust with the costs for medical care. This results in an increased performance of 1814 euro per year (4.5*403).

A conclusive overview of the results of the two measures described above are provided in Table 12 below. The table takes into account the increased and decreased performances generated by modification 1. Furthermore, the quantities that are presented in Table 11 are interchanged with the values used for estimating the life cycle costs of West 8’s design. This provided us the life cycle cost of modification 1. Note that these costs are also presented in Table 12.

Table 12: Performance and LCC of modification 1 compared to the design of West 8

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>West 8</td>
<td>0</td>
<td>40.49</td>
<td>0.33</td>
<td>1.34</td>
<td>2.08</td>
</tr>
<tr>
<td>$A_{MOD1}$</td>
<td>-</td>
<td>34.55</td>
<td>0.37</td>
<td>1.63</td>
<td>1.84</td>
</tr>
<tr>
<td>Increase travel time</td>
<td>-3.78 M€/y</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benefits increase retail sales and property value</td>
<td>+0.30 M€/y</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Benefits increase fine dust reduction</td>
<td>+0.018 M€</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

For the function ‘use of high quality pavements’ (see Figure 34) it is proposed to use concrete pavements instead of stone pavements. This modification is called modification 2 and is illustrated in Figure 36 hereunder. Please note that West 8 is called reference point ($A_{REF}$), and the modification is called modification 2 ($A_{MOD2}$).

Table 13: Changes in the cost indicators due to modification 2

<table>
<thead>
<tr>
<th>Design West 8 ($A_{REF}$)</th>
<th>Cost indicator [€/m²]</th>
<th>Modification ($A_{MOD2}$)</th>
<th>Cost indicator [€/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructing stone pavements</td>
<td>55.00</td>
<td>Constructing concrete pavements</td>
<td>10.00</td>
</tr>
<tr>
<td>Maintaining stone pavements</td>
<td>13.50</td>
<td>Maintaining concrete pavements</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Table 13: Changes in the cost indicators due to modification 2

19 The cost indicators are derived from the LCC estimating model presented in section 3 of the thesis.
The increased or decreased performance obtained due to the modification is defined by monetizing the effects of decreasing the quality of pavements. The direct effects are stated in Appendix N. In this, it is assumed that the pavement quality affects the WTP for products and properties. When comparing natural stone with concrete pavements, the effects are assumed to be an increase of 3% for product sales and 2% for property values.

Please consider that in this case both sides of the Coolingsingel are effected by the measure. Therefore, not 20 but 40 shops are assumed to be affected. Like in the previous modification, the turnover of each shop is assumed to be 500000 euro per year. The decrease in turnover for all 40 shops due to the measure is around 600000 euro per year (40*500000*0.03). Furthermore, it is argued that the property value of the shops will also decrease due to the measure. Also here the average property value of a shop is assumed to be 300000 euro. With a decrease in property value of 2%, the monetized decreased performance is around 240000 euro (40*300000*0.02). Note that this is a one-time decrease.

A conclusive overview of the decreased performance generated by the second modification are provided in Table 14 hereunder. Furthermore, the table also shows the effects of changing the pavement type on; the realization, operational, maintenance and disposal costs.

Table 14: Performance and LCC of modification 2 compared to the design of West 8

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>West 8</td>
<td>0</td>
<td>40.49</td>
<td>0.33</td>
<td>1.34</td>
<td>2.08</td>
</tr>
<tr>
<td>$A_{MOD2}$</td>
<td>-0.60 M€/y, -0.24 M€</td>
<td>35.60</td>
<td>0.33</td>
<td>0.88</td>
<td>2.08</td>
</tr>
</tbody>
</table>

Please be aware that we did not monetize the performance of how this ‘concrete image’ relates to other materials used in the city centre of Rotterdam. For example, Rotterdam uses a toolkit called the ‘Rotterdamse Stijl’, which offers a catalogue of materials to be used for the main infrastructures. It should be remarked that designers are obligated to use these materials. For centrum boulevards, such as the Coolingsingel, the toolkit prescribes the use of natural stone pavements (Gemeente Rotterdam, 2010). The effects of deviating from this type of pavement is however not taken into account in this thesis.

In the next chapter the proposed modifications are evaluated on their $P$/LCC ratios. The ratios will be relatively compared to the ratio of West 8.
11. **Evaluating the modifications: The P/LCC ratio**

This chapter provides the evaluation between the design of West 8 and two modifications on that design. The situation is presented in Table 15 below. West 8 is presented as $A_{\text{REF}}$, while the modifications are presented by $A_{\text{MOD1}}$ and $A_{\text{MOD2}}$. Further note that the life cycle costs (LCC) of the alternatives are calculated with the LCC estimating model and are discounted with a rate of 2.5% to their present values. For the period of analysis 60 years is taken.

Table 15: Situation of the evaluation procedure

<table>
<thead>
<tr>
<th>Alternative</th>
<th>LCC [in M€]</th>
<th>Increased or decreased performance [M€]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{\text{REF}}$</td>
<td>92.5</td>
<td>0</td>
</tr>
<tr>
<td>$A_{\text{MOD1}}$</td>
<td>96.7</td>
<td>-2.7</td>
</tr>
<tr>
<td>$A_{\text{MOD2}}$</td>
<td>73.3</td>
<td>-36.2</td>
</tr>
</tbody>
</table>

To evaluate the modifications provided in Table 15 on their P/LCC ratios, it is assumed that the total performance of the reference point is equal to the life cycle costs needed in order to realize the reference point. In this case the performance of the reference point is 92.5 million euros.

Table 16 shows the results of the modifications, when evaluated with the P/LCC ratio.

Table 16: P/LCC ratios of the modifications

<table>
<thead>
<tr>
<th>Alternative</th>
<th>LCC [M€]</th>
<th>$P_{\text{VAR}}$ [M€]</th>
<th>$P_{\text{REF}}$ [M€]</th>
<th>$P_{\text{T}}$ [M€]</th>
<th>P/LCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{\text{REF}}$</td>
<td>92.5</td>
<td>0</td>
<td>92.5</td>
<td>92.5</td>
<td>1</td>
</tr>
<tr>
<td>$A_{\text{MOD1}}$</td>
<td>96.7</td>
<td>-2.7</td>
<td>92.5</td>
<td>89.8</td>
<td>0.93</td>
</tr>
<tr>
<td>$A_{\text{MOD2}}$</td>
<td>73.3</td>
<td>-36.2</td>
<td>92.5</td>
<td>56.3</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Note that $P_{\text{VAR}}$ in the table indicates the increased or decreased performance realized by the modification, while $P_{\text{REF}}$ represents the performance of the reference point. The ratios are graphically presented in Figure 37 below.

![Graphical representation of the P/LCC ratios of the modifications](image-url)

Figure 37: Graphical representation of the P/LCC ratios of the modifications

From the graph and table above we can notice that both modifications do not improve the total value of the design. Both are even considered economically not rational, since the costs outrun the performances obtained.
Modification 2 can be ruled out immediately. First of all because it offers the lowest value, over a long-time period. Secondly, because a different strategy of implementing the modification will not affect the value to great extent. This in contrast to modification 1.

We still believe that this modification can result in value improvement. However, to do so the modification needs to be implemented gradually. With this we mean that the municipality could already start with some small parts of the modification, such as developing mixed vegetated areas, changing pavements, etc. However, when they directly remove the traffic lanes situated to the west of the tram track, a heavy increase of travel time will be caused. As previously stated this increase is a result of the current traffic intensity that could not be handled by a two-stroke traffic lane. However, since the municipality has plans to reduce the traffic intensity in the inner city, the extra gained travel time due to the modification decreases over time. It is even assumed that after 10 years the traffic intensity will be halved and the extra travel time of 8.4 minutes will be zero. From that moment the modification performs optimal.

Now let’s assume a situation in which the three alternatives are realised not directly, but over 10 years. Consider that in this case the starting year in the LCC model is changed from 2015 to 2025. Note that the period of analysis is still 60 years and the discount rate 2.5%. The results are depicted in Table 17 below.

Table 17: P/LCC ratios of the modifications when realized in the year 2025

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A_REF</td>
<td>92.5</td>
<td>0</td>
<td>92.5</td>
<td>92.5</td>
<td>1</td>
</tr>
<tr>
<td>A_MOD1</td>
<td>96.7</td>
<td>+15.1</td>
<td>92.5</td>
<td>107.6</td>
<td>1.11</td>
</tr>
<tr>
<td>A_MOD2</td>
<td>73.3</td>
<td>-36.2</td>
<td>92.5</td>
<td>56.3</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Note from the table that if modification 1 is realized 10 years later, the P/LCC ratio is higher than the ratio of the preferred alternative. This is mainly caused due to the fact that no decreased performance is obtained for the increase of travel time at the Coolsingel. The P/LCC ratios of the alternatives when realized in the year 2025 are graphically presented in Figure 38a. In Figure 38b the values of the alternatives are plotted against the time.

Figure 38: Graphical representation of the P/LCC ratios in 2025 to the left, and over time to the right
From that figure it is easily identified at which given point in time a modification can be best implemented. The figure is called the value time of implementation model (V/t,i model). Herein, the preference for implementation is the point in time where the value of a modification exceeds 1 (V_{\text{MODIFICATION}}>1).

Now if we take a closer look at the figure, it could be noticed that modification 1 could be best implemented in the year 2018. This indicates that for now it is a better strategy to wait until other parts in the city are further developed. With this we do not recommend to do nothing. In fact it is recommended to gradually develop the alternative provided with modification 1. From now on start with implementing measures that do not affect the profile of the traffic lanes. Then in 2018, start with removing the two traffic strokes to the west of the tram track and start making the boulevard.

When evaluating the modifications, it should however be remarked that we did not take into account congestion in other parts of the city due to the reduced traffic capacity at the Coolsingel. Also we did not take into account negative external effects of upgrading the value of an area, on neighbouring areas. For example, as a result of upgrading the public area at the Coolsingel, it becomes more attractive to the public. In this case it is highly possible that daily people visiting the Koopgoot (nearby area), after the upgrade, prefer to visit the Coolsingel.
12. **VE from a practitioner perspective**

It may be discussed if this academic research, in which the urban regeneration of the Coolsingel is used as case study, is suitable to formulate specific implications for the Coolsingel case. As described in part 1.6, the research is not aimed to be a consulting report for the Coolsingel case. This causes a limitation of specific, practical feedback for the project. Nevertheless, it is useful to formulate implications for the decision making process regarding the Coolsingel case.

To do so, the application of the VE methodology is discussed with several people working at the municipality of Rotterdam. More specific, we discussed the method with traffic expert Stephen Janssen, team leader ‘civil structures’ Harun Yucel and consultant sustainable infrastructure Leon Dijk. The aim of these conversations were to get their opinions on the method from the practical field. For instance, they were asked questions like “Is the method useful?”, “Do we agree on the fact that the current process might lead to sub-optimal decisions?”, “Which parts in the method require further improvements?”, “What are the main constraints?”, etc. It should be remarked that it would have been more convenient to discuss the method with the project manager of the Coolsingel Elske Geelhoed. Unfortunately, she changed jobs which made this rather difficult. We tried to get in contact with her replacement, however due to too busy schedules it was not possible to arrange a meeting with her in the limited timeframe of this research. That is why the aforementioned employees were selected to discuss the VE method with.

These three respondents all believe that the VE methodology is beneficial and will facilitate the decision making process. For this, they provide the following arguments:

- A preference system that bases the preference of an alternative on the highest ratio between performance and life cycle costs, eliminates people’s personal (subjective) preferences. This makes it easier to conduct discussions.
- The results of the study are well documented and easy to understand. By presenting the results graphically the respondents were able to comprehend them in a glance.
- VE might provide more openness to the decision making process. Main reasons are provided by the fact that results are understandable for different parties involved. It should however be remarked that this ‘openness’ needs to be observed and derived from the field of practise. People with experience in the field of practise should be asked whether the approach show differences compared to a development process without VE.
- The VE methodology is believed to be applicable not only in urban regeneration projects but also in other construction projects like e.g. tunnelling projects.

Besides the benefits of the VE methodology, they also stated several constraints of the method. These are summed up below:

- During the process it became clear that it is extremely difficult to analyse the effects of modifications in ‘small’ elements of a project. Therefore, it is suggested to come up with modifications for ‘big’ elements. However the VE method does not provide a manner of how to characterize the elements in a project as ‘big’ or ‘small’.
- The monetized effects of urban regeneration are still often based on assumptions. These assumptions can easily be manipulated by the calculating party. As a governing body, the municipality of Rotterdam acts objectively. However, it is believed that individuals within the
organization might act differently. Especially, now that people are fighting to keep their current jobs.

- Quantifying the performances and life cycle costs of urban regeneration projects is difficult and time consuming. Insight in these values need to be available beforehand, since there is little time available to define them during the decision making process.

- Participants participate in a VE study at the expenses of their day-to-day activities. Therefore to undertake a VE study it should be identified when the effects of the study are noteworthy. This is the case when the gains are larger than the effort to conduct it. Hence, the respondents argued that VE should not be applied in every urban regeneration project. Instead, practitioners should carefully select projects for which the effort of a VE study is believed to be beneficial. According to the respondents this selection could be depended on the level of political and financial interests in a project.
13. Conclusions

This chapter provides the conclusions of section 4 of this research; a practical application of Value Engineering (VE) in the fields of urban regeneration.

This section provides answer to the key questions four and five in this research:

- "What can be learned from the practical application of Value Engineering in the fields of urban regeneration?"
- "Which steps need to be considered in order to apply Value Engineering in the fields of urban regeneration?"

The fourth key question is answered by applying VE to a practical case – the regeneration of the public space of the Coolsingel.

From this we learned that VE is a useful tool to provide insight into value enhancing ideas. By constructing the FAST diagram modifications can be explored more easily since the physical measures proposed by a design are eliminated from our thinking. However, setting up the FAST diagram can be time consuming. First of all, because there does not exist an ideal FAST diagram. Secondly, because practitioners can be caught up in displaying too much details.

From the diagram, practitioners should select functions that are believed to be realized sub-optimally by the solutions proposed in the preferred alternative. Sub-optimal functions are functions that are realized by solutions that cost a lot of money and generate relative low performances. The selection process of functions can be facilitated by performing a sensitivity analysis on the estimated life cycle costs of the alternative. Proposed solutions that have a high influence on the total costs of a project should be selected and further analysed. Results from the Coolsingel case point out that if we change the way in which the functions ‘Widen sidewalks’ and ‘provide high quality pavements’ are realized, the life cycle costs of the preferred alternative are highly affected. We believed that the functions ‘Widen sidewalks’ and ‘Provide high quality pavements’ could be realized more optimally. Therefore, alternative solutions are proposed to the ones that are proposed by the preferred alternative.

When designing the modifications it became clear that it is extremely difficult to analyse the effects of modifications on ‘element’ level (e.g. the effect of placing one extra tree). Moreover, during the earlier stages of project development it is more interesting to see the effects of excessive design changes. This could be explained by the fact that during the earlier stages the costs for design changes are relative low compared to latter stages of project development (also see part 1.3, Figure 1). Therefore, it is concluded that during the earlier stages of project development, decision makers should be provided with insights in excessive alternative solutions (modifications) designed for sub-optimally realized functions.

To widen the sidewalks at the Coolsingel, it is proposed to remove the two-stroke traffic lane on the west side of the tram track, instead of relocating them to the east side of the track (modification 1). For the other function ‘provide high quality pavements’ it is proposed to use concrete stones instead of natural ones (modification 2).
Both modifications are evaluated relative to the solutions suggested in the preferred alternative. The preference is based on the solution that offers the highest ratio between life cycle costs and performances (P/LCC ratio).

The results of the Coolsingel case point out that both modifications did not improve the value of the current proposed design, when implemented directly. Modification 1 scores a ratio of 0.93 and modification 2 scores a ratio of 0.77. Interestingly, when implementing the alternatives at different points in time, results indicate that the P/LCC ratio changes. For example, when implementing the modifications in the year 2025 results showed that modification 1 scores a ratio of 1.11. The point in time where the P/LCC ratio of modification 1 becomes larger than 1 can be found when implementing the alternatives in the year 2018. These results indicate that it is a wiser decision to gradually develop the public space at the Coolsingel over time and start with removing the two stroke traffic lane in the year 2018.

It should however be remarked that the monetized effects achieved by the modifications are surrounded by uncertainties. Main reasons are explained by the fact that monetized effects are based on Willingness to Pay (WTP) values gathered from earlier conducted stated or revealed preference studies in the fields of urban regeneration. However, many effects obtained by urban regeneration are bound to location-specific characteristics. An example is the WTP for extra vegetation. This WTP is believed to be much higher in central areas of the city than in the outskirts of it. Simply, because scarcity will increase the demand for extra vegetation in those areas. This implies that some WTP values are related to city or sub city areas. Therefore, to reduce uncertainty in the monetized values of effects, it is concluded that municipalities should conduct stated and revealed preference surveys on city or even on sub city level.

From discussions with several people working at the municipality of Rotterdam it is concluded that the VE methodology is believed to be beneficial and will facilitate the decision making process. Main reasons are explained by the fact that it provides openness and transparency to the decision making process.

Besides the benefits, the VE method also has several constraints. First of all, participants in a VE study participate at the expenses of their day-to-day activities. This implies that it should be identified when the effects of VE studies are noteworthy. From our conversations with people working in the practical fields, it is concluded that VE should not be applied in every urban regeneration project. Instead, VE should be applied in projects where political and financial interests are important. A second drawback of the method is that still a lot of work has to be done in monetizing the performances of urban regeneration projects. When performances are based on assumptions, outputs can easily be manipulated in favour by the calculating party. In this case the subjective nature surrounding the decision making process is not reduced, it only looks that way.
Answer to the fifth key question shows the steps that need to be considered when applying VE in the fields of urban regeneration. This lead to the methodology presented in Figure 39. The methodology and knowledge gained from the practical application of VE, form the answer to the first part of the main question “How could Value Engineering be used in the earlier stages of project development?”
Section 5. Conclusion and recommendations

The answers on the key questions and form the conclusions of this research. In this section answer is given to the main question of the research "How could Value Engineering be used in the earlier stages of project development in order to improve the value of urban regeneration projects?" by presenting a method to apply Value Engineering (VE) in the fields of urban regeneration and stating the lessons learned from its practical application. Furthermore, the section defines several recommendations for the municipality of Rotterdam and for further research.
14. Conclusions
For this study, the following main research question is formulated:

“How could Value Engineering be used in the earlier stages of project development in order to improve the value of urban regeneration projects?”

In this research a methodology is developed to apply VE in the fields of urban regeneration. Figure 40 presented further on in this chapter shows the developed methodology, which consists of five different phases and seven steps. The most important conclusions for these phases are discussed below. By this, the first part of the main question is answered. The urban regeneration of the Coolsingel at Rotterdam is used as case study to see what can be learned from the practical application of VE. This will answer the second part of the question.

Phase A: Characterization of the intended functions of the urban regeneration project and the life cycle costs of the physical solutions proposed in the preferred design.

In the first phase, different functions of a project are identified by conducting a function analysis with experts (step 1). This analysis is seen as one of the most important pillars of VE. It is a process, in which the project team distances itself from the physical solutions provided in an alternative. The functions are graphically presented in a FAST (Function Analysis System Technique) diagram. With regard to such diagrams, the following conclusions are formulated:

- Practitioners can be caught up in displaying too much details in FAST diagrams. In this case diagrams become complex and difficult to understand. As a result the efforts of conducting a VE study becomes so intense that the benefits of it are lost.
- A function in the FAST diagram can be obtained in several ways. It is important to map how preferred functions in a project are realized by the physical solutions proposed in an alternative. This linking of functions and physical solutions is not always straightforward and could be time consuming.
- By focusing on functions rather than on physical solutions, it was easier to come up with modifications for the preferred alternative.

In step 2 of the VE methodology the life cycle costs of a preferred alternative are estimated. To do so, a deterministic life cycle cost estimation model (LCC model) is developed. With the LCC model municipalities are able to estimate not only the realization costs of urban regeneration projects, but also recurring costs such as costs for maintenance, operational and removal activities. Data provided in the model is based on real-world data gathered at the municipality of Rotterdam. When developed, the model is used to estimate the life cycle costs of three different alternatives developed for the Coolsingel case. Based on this practical application the following conclusions are formulated:

- Urban regeneration projects are designed to be beneficial for the public. Judgments should therefore be based on social benefits generated by the project, rather than on the rate of return on capital invested. Results of the case study indicate that project alternatives with high social benefits and low recurring costs, realized by high capital costs up-front, are financially more attractive when low discount rates and long periods of analysis are applied. Therefore, it is concluded that municipalities should use low discount rates and long periods of analysis.
when assessing project alternatives. Otherwise, results of the model will often indicate to choose the alternative that bears the lowest costs up-front.

- Some data in the LCC model is solely based on real-world data obtained from the Coolsingel case. Cost indicators in the model are well underpinned for disposal and construction costs. However, indicators for maintenance and operational costs require verification. Therefore, the model cannot yet be used for estimating the life cycle costs of other urban regeneration projects, before this verification process is conducted.

- For urban regeneration projects, the municipality of Rotterdam distinguishes eight main elements (i.e. groundwork, sewage systems, pavements, etc.). Per element a design proposes several activities to perform (e.g. excavating ground, cleaning gutters, etc.). In this study those activities are based upon the activities proposed by the designs developed for the Coolsingel case. As a result the LCC model covers a large part of activities for which it could estimate the life cycle costs. However, it is highly possible that project specific activities are lacking when it is applied in other urban regeneration projects. In this case the model will lack accuracy, unless it is complemented with those activities.

Phase B: Selection of functions that are realized sub-optimal in the preferred alternative.

During phase B of VE, functions are selected that are realized sub-optimal in the preferred alternative. This selection process can be facilitated by performing a sensitivity analysis on the estimated life cycle costs of the preferred alternative (step 3 and 4). This analysis explores what happens if we change the value of an input variable to the total life cycle costs of the preferred alternative. Variables that, if changed, highly affect the life cycle costs are found interesting to modify. The following conclusions are derived when applying step 3 and 4 in the Coolsingel case:

- If all variables are provided with a minimum deviation of -10% and maximum deviation of +10%, it is concluded that the adaptations to fit the surroundings, the pavement type, the amount of manual cleaning and the amount of traffic lights (FRI’s), highly influence the total life cycle costs of the preferred alternative. Therefore, proposed physical solutions in this alternative are modified, if they incorporate one or more of these variables. This is the case for the solutions proposed to realize the functions ‘Widen sidewalks’ and ‘Provide high quality pavements’. As a result, it is aimed to improve the value of the preferred alternative by developing alternative solutions to these functions.

- The sensitivity analysis is conducted by applying a fixed deviation of plus minus 10 percent to the input variables in the LCC model. However, some variables might deviate more than 10 percent, while others might deviate less. Applying a probability contour to each input variable, might result in a different ranking of variables that highly affect the life cycle costs of an alternative. When the ranking of variables changes, it could also be more useful to modify different physical solutions.

- To increase the value of a project one could eliminate costs that do not contribute much to the performance of a project, or add extra performances to the project for relatively low costs. The sensitivity analysis facilitates in the selection of the proposed solutions to modify. However, this selection is based on the principal of eliminating costs in order to increase the value of a project. Solutions that, if changed, highly affect the performances of a project are not taken into account. In conclusion, the sensitivity analysis facilitates the selection process, but does not guarantee the best selection of solutions to modify.
Figure 40: Overview of how to apply VE in the fields of urban regeneration
Phase C: Development of modifications

During this phase, modifications are designed that improve the value of the preferred alternative (step 5). With regard to the development of modifications the following conclusion is formulated:

- Modifications should take place on a ‘meso-level’ and not on a ‘micro-level’ of scale. For example, modifications on a meso-level of scale would indicate a choice between; a vegetated street profile or not. While on a micro-level of scale the choice would be more detailed (e.g. the amount of vegetation). Simple reasons are explained by the fact that the effects of modification conducted on a micro-level of scale are difficult to analyse.

For the Coolensingel case two functions are selected that are believed to be realized sub-optimal by the measures proposed in the preferred alternative. To recap, these functions are: ‘Widen sidewalks’ and ‘Provide high quality pavements’.

To widen the sidewalks it is proposed to remove the two-stroke traffic lane on the west side of the tram track, instead of relocating them (modification 1). This modification changes the amount of traffic strokes from four to two strokes. For the other function ‘provide high quality pavements’ it is proposed to use concrete stones instead of natural ones (modification 2). The modifications are believed to have the following effects:

- Due to modification 1 room is available to apply mixed vegetation on both sides of the Coolensingel. Furthermore, there is no need for excessive changes to the cross sections ‘Hofplein’ and ‘Churchillplein’. However, a disadvantage of the modification is congestion at the Coolensingel, which is a result of the fact that the current traffic intensity cannot be handled by a two-stroke traffic lane.
- Modification 2 will reduce the costs of the project. However, it will also decrease the attractiveness of the public area.

Phase D: Evaluation of modifications

In this phase the proposed modifications are evaluated relative to the solutions proposed in the preferred alternative. The preference in VE is based on the solution that offers the highest ratio between life cycle costs and performances (P/LCC ratio). This implies that both parameters need to be quantified. With regard to this process the following conclusions are formulated:

- The performance of a modification can be quantified by estimating the performance of the preferred alternative (fixed part) and adding this amount with the increased or decreased performance achieved by a modification (variable part). This implies that the preferred alternative acts as a reference point on the basis of which it is determined whether proposed modifications enhance the value of the preferred alternative or not.
- The performance of the reference point (fixed part) is set equal to the life cycle costs of the reference point. Simply because we are interested in the fact whether proposed modifications increase the value of the preferred alternative or not. As a result, the P/LCC ratio of the reference point (preferred alternative) is equal to 1.
Quantifying the relative increased or decreased performance generated by modifications is difficult and above all surrounded by uncertainties. In the case study, the quantification is based on Willingness to Pay (WTP) values gathered from earlier conducted stated or revealed preference studies in the fields of urban regeneration. However, many effects obtained by urban regeneration are bound to location-specific characteristics. This is explained by the fact that for some performances the demand is much higher in central areas of the city than in the outskirts of it, and the other way around. To reduce uncertainty of WTP values, it is concluded that municipalities should conduct revealed and stated preference surveys in city and sub city areas.

From the evaluation process in the CoolSingel case, the following conclusions are formulated:

- Both modifications that are proposed do not enhance the value of the preferred alternative, when implemented directly. Modification 1 scores a P/LCC ratio of 0.93 and modification 2 scores a ratio of 0.77. While the reference point scores a ratio of 1.
- The ratio of an alternative solution is influenced by the point in time it is implemented. Therefore, taking into account the implementation time of an alternative is important in order to make proper decisions.
- Results point out that it is best to remove the two-stroke traffic lane (modification 1), instead of relocating them. However, this is only the best alternative when implemented in the year 2018 or after.

**Phase E: Presentation of the results**

In the final of the VE methodology, the results of the study are documented and incorporated in the decision-making document. For decision makers, the following advantages are concluded:

- Presenting the results of the VE study in a graph with the horizontal axis life cycle costs and on the vertical axis performances (P/LCC model) has several advantages. First of all, decision makers are directly provided with the information of value-enhancing modifications. Secondly, this insight could help in conveying the idea that the cheapest design is not always the best design and that adding performance could matter.
- Presenting the results of the VE study in a graph with the horizontal axis time of implementation and on the vertical axis value provides decision makers the insight when it is best to implement value-enhancing modifications.

The provided methodology in this thesis shows how VE could be applied in the fields of urban regeneration. By applying the VE methodology on a practical case, it is illustrated that it could be used to improve the value of urban regeneration projects. However, the methodology will only be used in practice when the benefits gained by it are noteworthy. To do so, its application should be kept simple. One way to ensure this is by reducing the amount of required information, by collecting it in advance. For instance, WTP values for certain performances of public areas can be collected and assembled into a database. When the project team decides to conduct a VE study, this database can be used to determine the relative increased or decreased performance of changes made to the initial design. So in conclusion, from a theoretical point of view the thesis provides a transparent system to apply VE in the fields of urban regeneration. However, to make the method practically useful, additional research has to be done to reduce the amount of effort associated with its practical application.
15. **Recommendations**

In this chapter recommendations are formulated for the municipality of Rotterdam. Furthermore, the chapter formulates recommendations for further improvements of the proposed methodology.

15.1. **Recommendations for the municipality of Rotterdam**

Recommendation 1.

In urban regeneration projects, where political and financial interests are important, VE studies should be conducted by municipalities during the decision making process. This should be decided by the governance principal (Dutch: bestuurlijke opdrachtgever (BOG)) of a project. After all, he is responsible to ensure political and financial interests within a project. When decided to undertake a VE study, the *project manager (PM)* is the one to conduct it. For this, he or she sets-up a VE team, and is recommended to perform the study in accordance with the provided steps in this research.

Recommendation 2.

Proper application of the VE method is heavily dependent on the availability of well underpinned data regarding monetized social benefits in urban regeneration. Without well underpinned data, results are likely to be unreliable. In addition, stakeholders can easily manipulate them in order to protect their interests. Therefore, it is recommended to develop a database in which social benefits are monetized. As a backbone, this data should be based on various types of stated and revealed preference surveys held in different parts of the city. The department ‘Milieu Ruimte Ondergrond (MRO)’ is believed to be the best party when it comes to the development of this database, as they already made good progress in monetizing the benefits of sustainability measures.

Recommendation 3.

Complement the developed LCC model, with missing cost indicators to make it generically applicable. This process needs to be conducted by the clusters ‘Stadsbeheer (SB)’ and ‘Stadontwikkeling (SO)’. Department ‘Schoon’, which is part of the cluster SB, should be responsible for the development of generic cost indicators for cleaning activities. To gather this information, it is recommended to study multiple cases located in different areas of the city. Furthermore, department ‘Heel’ should verify the developed cost indicators regarding maintenance activities. Last but not least, department ‘Stad’ (part of SO) is responsible for assembling the information into the LCC model.

Recommendation 4.

Results indicate that the use of different periods of analysis and discount rates in the LCC model, result in different rankings of alternatives. To prevent manipulations, practitioners are recommended to set both parameters beforehand.

Recommendation 5.

Set-up a cross-functional team that is responsible for ensuring up to date cost indicators in the LCC model and up to date monetized social benefits. Emphasis should be placed on ‘cross-functional’, since it should consist of one person from ‘Stad’, one from ‘Heel’, one from ‘Schoon’ and one from the department ‘MRO’. The person from Stad will be responsible for cost indicators related to investment and removal costs. The person from Heel should be
Conclusions and Recommendations

The person from Schoon should be responsible for keeping up to date cost indicators regarding cleaning activities. Lastly, the person from MRO is responsible for data related to the monetized values of social benefits.

Recommendation 6.
Use the performance life cycle cost model (P/LCC model) to present results. In a glance, it provides decision makers with all kinds of information. For instance it quickly answers questions like “is it beneficial to modify the design?”, “what was the maximum budget and were the minimum requirements of the project?”, etc. If presented, it gives decision makers directly insight into value enhancing possibilities.

Recommendation 7.
Use the value time of implementation model (V/\textit{t}_{\text{oi}} model) to indicate at which point in time modifications can be best implemented. Regarding urban regeneration projects, it quickly provides decision makers how they could best develop the urban area. The moment is presented graphically in the model with a line that indicates where the value of a modification becomes higher than 1 (V_{\text{MODIFICATION}}>1).

Recommendation 8.
Practitioners should evaluate projects on the highest ratio between performances and life cycle costs, instead of the highest net difference between both parameters. Simply because municipalities do not have unlimited resources to spend, and ratio preference systems indicate which alternative provides best value for money. This is not the case when applying difference preference systems. In those systems it is relatively easier to get a higher difference between performances and costs if the costs are higher.

Recommendation 9.
Convince decision makers involved in the Coolsingel project to remove the two-stroke traffic lane at the Coolsingel in the year 2018, instead of relocating them directly. By this, higher value for money will be obtained.

15.2. Recommendations for further research

Recommendation 1.
One of previously argued recommendations is to develop a database that contains monetized social benefits of urban regeneration projects. Throughout the research it is argued that these social benefits can be reflected in the Willingness to Pay (WTP) for various urban area improvements. In this study, such values are derived from earlier conducted stated or revealed preference studies. However, WTP values for the same measures to improve an urban area can vary per area. Therefore, further research can consist of performing stated and revealed preference surveys in different parts of the city of Rotterdam.

Recommendation 2.
Get more insight into the probability contour of the life cycle costs estimated with the LCC model. In this study, a sensitivity analysis is performed to indicate which factors in the LCC model affect the total life cycle costs of an alternative the most, when changed. To do so, factors are changed by plus minus 10 percent. However, some factors might deviate more than
10 percent, while others might deviate less. Therefore, further research can be conducted in defining per factor a ‘lower expected’ and ‘higher-than-expected’ value. Hereby, the rankings of factors that heavily affect the life cycle costs of alternative are better underpinned.

Recommendation 3.
Get more knowledge about the benefits of VE by applying it in different stages of the decision making process. In this study, VE is applied in order to improve the value of a preferred alternative. Currently, there are none studies found that use VE in the latter stages of the decision making process. What most of the current studies have in common is that they focus on the development process of a design. Herein the highest potentials of VE are found to be generated when applied during the earlier stages of project development. However, the increasing complexity within projects, will probably also increase the complexity of maintaining them. That is why it is interesting to see whether VE can be used in order to come up with improved strategies for maintaining and operating projects.

Recommendation 4.
In this study a framework is developed of how to apply VE in the fields of urban regeneration. However, due to time constraints the practical use of the framework within the municipality of Rotterdam is not tested. Therefore, further research should indicate whether the benefits gained by applying the VE framework, outweigh the efforts of applying it. We believe that this could be indicated by people with experience in the field of practise. They could tell whether the application of the framework shows differences, compared to a decision making process in which VE has not been applied.

Recommendation 5.
One of previously argued recommendations is to evaluate projects on the highest ratio between performances and life cycle costs, instead of the highest net difference between both parameters. In this thesis, it is explained from a theoretical point of view why a ratio preference is preferred, instead of a difference preference system to indicate the preferred alternative (see part 2.8). However, both systems are applied in practise. Therefore, further research can indicate which of the two systems is used more often in practise. Practitioners can then be asked why they prefer to use one of the systems. In that way, a clear conclusion can be formulated about which system to prefer when it comes to the evaluation of project alternatives.

Recommendation 6.
Extend the topic of this study of how to apply VE in the fields of urban regeneration, to other fields in the construction sector. For example it is interesting to study the benefits of applying it in civil engineering projects, such as tunnelling projects. In that way, it can be determined in which fields of practise the method is most beneficial.
This section provides the epilogue on this research. Here we will discuss the limitations and difficulties encountered during the research. Furthermore, it discusses the applicability of the VE framework in the fields of practice.
16. Epilogue
This chapter of the thesis elaborates on the limitations and difficulties that we have encountered during the thesis, which are listed below. Also the future practicability of the Value Engineering (VE) framework within the municipality of Rotterdam is discussed.

16.1. Limitations and difficulties within the research

Disregarding the effort of conducting a VE study
It should be remarked that participants in a VE study participate at the expenses of their day-to-day activities. However, this study does not provide a clear answer to what amount of effort it takes to apply the proposed VE framework in practice. Yet, we can conclude that the amount of effort is reduced when the municipality possesses the complemented LCC model and the database with monetized social benefits. In that way, only effort is spent on setting up the VE team and applying the different VE steps as proposed. We believe that the latter does not require a lot of effort, since most of the efforts in this study went into developing the LCC model and monetizing the effects of social benefits in order to perform the calculations.

The research relies on a single-case only
In this research the Coolsingel case is used to provide an educational enrichment on the applicability of the developed VE framework. Although results point out that the application of it leads to value enhancing insights in order to facilitate decision making, we are not yet allowed to generalize this statement. This implies that from a scientific point of view, decision makers cannot yet be convinced of using the framework for this matter. Therefore, we recommend to conduct multiple case studies.

Generalizability of the LCC model
Some data in the LCC model is based on real-world data derived from the Coolsingel case. The municipality works with different sets of quality requirements for different areas in the city. Inner city areas, such as the Coolsingel, are intended to deliver a higher level of quality, than rural ones, such as Lombardijen. Therefore, high quality areas cost more money to maintain and operate. This implies that the LCC model cannot yet be used for estimating the life cycle costs of project alternatives designed for public areas located in the outskirts of the city.

Disregarding externalities of improving the value of specific urban areas
Increasing the value of specific urban areas, could negatively affect the value of areas located in the neighbourhood. For instance, as a result of upgrading the public area at the Coolsingel, it becomes more attractive to the public. In this case it is highly possible that daily people visiting the Koopgoot (nearby area), after the upgrade, prefer to visit the Coolsingel. This indirectly decreases the value of the Koopgoot. Therefore, it is important to analyse whether the value upgrade realized at the Coolsingel is higher than the value downgrade it indirectly causes at the Koopgoot. In this study those externalities are not taken into account. This forms a limitation of the research, since it is believed that the total value of a proposed upgrade consists of the net difference between the generated value upgrade and associated value downgrade that upgrade causes in neighbouring areas.

Confusion surrounding the term ‘value’
The term ‘value’ is used in many studies. The definition of value used in this thesis, the VE definition, differs from definitions used in other theories. As should be clear now, value in VE is defined as the ratio between performances and costs of a project. In Appendix A however,
other definitions of the concept of value are provided. For instance, in the value-price-cost model developed by Hennis de Ridder, it is argued that the value of something can be reflected in the Willingness to Pay (WTP) for that something. While in VE this definition is interchanged by the term ‘performance’. Confusion about the concept of ‘value’ is caused due to the fact that VE uses ‘performance’ as an interchangeable term for value. That is why in part 2.3 of the research it is stated that value in the VE approach resembles the cost-effectiveness of a project. It shows decision makers to what extent a project or modification provides value for money.

Monetising the performance of urban regeneration projects
The research provided a method of how the performance of urban regeneration projects can be expressed in monetary terms. When we applied this method in practice, several difficulties were encountered. Above all, performance determination in urban regeneration is a subjective process. In urban regeneration many stakeholders are involved that each have their own perception of ‘how such projects should perform’. This implies that among those persons the ‘Willingness to Pay’ (WTP) for extra performance on something (e.g. the WTP for “extra” vegetation) is diverse. Therefore, some studies argued that the average WTP can be obtained when every person is asked what he is willing to spend for ‘that something’. This goes well in urban regeneration when the WTP for ‘that something’ is not tied to location-specific characteristics. A good example is the WTP for travel time reduction, which is measured by the Value of Time. Here the WTP for travel time reduction is determined for various types of traveling motives, such as commuting, business, etc. In a research performed by the institute KiM (2013), WTP indicators for those traveling motives are based on stated preference surveys. WTP’s that are bound to location-specific characteristics however, should be used with caution. An example is the WTP for extra vegetation. This WTP is believed to be much higher in central areas of the city than in the outskirts of it. Main reasons are explained by the fact that the demand for extra vegetation is possibly higher in central areas of the city. This implies that the municipality of Rotterdam should develop different kinds of WTP’s for the performances of urban regeneration, based on stated and revealed preference surveys conducted in different parts of the city.

Finding the right level for displaying the functions in the FAST diagram
It took us some time to develop the FAST diagram for the Coolsingel project. The methodology on FAST diagramming provided us an example of how to construct such a diagram for designing a pencil. However, a pencil has a much lower level of complexity than an urban regeneration project. Due to the complexity of urban regeneration projects it is highly possible that practitioners get caught up in displaying too much details. In this study, we did not provide a method of how to define the level of detail in FAST diagrams.

Selecting the functions for modifications from the FAST diagram
In this thesis it is proposed to underpin the selection of sub-optimal realized function by the means of a sensitivity analysis. This research did not missed the fact to see whether experts at the municipality of Rotterdam would have selected different functions to modify. In this case it would have been possible to see if the sensitivity analysis really contributes in selecting sub-optimal functions. Or that better functions are selected when this process is done by an expert team as proposed in the VE methodology.
16.2. Practical application of this study within the municipality of Rotterdam

In this research a methodology is developed to apply VE in the fields of urban regeneration. To ensure that the proposed methodology will be implemented during the decision making process, it is important to focus first on complementing the LCC model and the database with monetized social benefits. Both will reduce the amount of effort spent, when performing the evaluation phase (phase D) of the VE methodology.

Then, it is necessary to apply the method in different urban regeneration projects. In that way, decision makers can be convinced of the fact that the method facilitates decision making.

Conclusively, the LCC model needs to be complemented, a database with monetized social benefits should be developed, and lastly decision makers should be convinced of the facilitating opportunities the VE method offers them.

In order to perform these activities, funds need to be provided by the municipality of Rotterdam.
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Appendix A. Different expressions of value

In part 2.3 it is emphasized that in Value Engineering (VE) the definition of value, differs from definitions used in other theories. Please remember that in VE the value of an alternative resembles the cost-effectiveness of that alternative. This appendix elaborates on different perceptions of the term value.

Definition of value in the Value-Price-Cost model
For analysing transactions in the construction industry, the Value-Price-Cost model is introduced, see Figure 41 (Dreschler et al., 2005).

The model shows the most relevant parameters in the transactions between parties in the construction industry. It suggests that the total benefit should be increased. The total benefit consists of the benefit for the demander (in this context the client or more specific the municipality of Rotterdam), which is the difference between value and price, and the profit for the supplier (contractor or architect), which is the difference between price and costs. The total benefit is positive, when the transaction is beneficial for both parties.

In the model, value is reflected in the ‘Willingness to pay’ for a certain solution. Simply put, the willingness to pay is the amount of money an individual is willing to spend on a certain object. Since individuals have different perceptions about objects, the willingness to pay and thus the value of objects is subjective. Cost can be related to the minimum amount of money for which a supplier is willing to produce an object. The price is somewhere located between value and costs.

Definition of value in Cost-Benefit analysis
In Cost-Benefit Analysis (CBA), value is expressed in the difference between all project inflows (tangible and intangible benefits) and outflows (costs and disadvantages). In a conversation with Joost Vogtlander problems arise in CBA, when tangible\textsuperscript{20} and intangible\textsuperscript{21} benefits are summed. Therefore he argues to strictly separate tangible and intangible benefits when performing such analysis.

Furthermore, van der Mol and Heijden (1990) present several methods to express the effects of projects. If the advantages and disadvantages can be measured in physical units, the value

\textsuperscript{20} Benefits that do physically exist
\textsuperscript{21} Benefits that do not physically exist
of a project can be reflected in the market price. Important to note is that the market should consist of a well-functioning price mechanism. If this prerequisite is lacking, so-called “shadow” prices can be used to calculate the correct market price. Effects for which an (economic) market does not exist, such as clean air, can be measured by proposed approximation methods in literatures. However, caution should be taken when adding the values of tangible effects and such intangible effects.

Summary of value definitions
All definitions of value, compare some level of performance, functionality or quality with the associated level of price or costs. In essence, three manners can be distinguished which differently evaluate the value of projects. As illustrated in Figure 42, measures can be evaluated on: a value-price ratio (manner I), a surplus (manner II), or on total benefit (manner III).

In the Value Engineering (VE) definition, projects are evaluated on a Value-Price ratio or Value-Cost ratio. In the latter, literatures often define costs as the price to be paid by stakeholders. This implies that both ratios mean the same.

The Cost-Benefit Analysis applies the second manner, in which projects are evaluated on the difference between generated in- and outflows. Finally, the Value-Price-Costs model suggests to choose the project that maximizes the total benefit for both the demander (public entity) and supplier (contractor and designer).
Appendix B. FAST Diagramming ‘Pencil example’

Part 2.5 shortly elaborates on the technique FAST diagramming. This appendix will provide a more detailed description of how to apply the technique. This is done by providing a FAST diagram for the development of a pencil, which also is used to illustrate the diagram in the study performed by van Geffen and Hendriksen (2005).

Remember that the description of a function is restricted to a two word format – an active verb and a measurable noun. The first thing to ask is “what does it need to perform?” Then the model is build up by asking ‘how’ questions from left to right and check with ‘why’ questions, from right to left. If it does not make sense, a function is missing or wrongly formulated.

Building up a FAST diagram for a pencil is illustrated below, the diagram itself is depicted in Figure 43.

“What does a pencil do? It makes marks. Why does it make marks? To record information. Since ‘record information’ could be done in various ways, i.e. with a computer, and the study object that we are trying to improve is a pencil, ‘make marks’ is the basic function. When this function is left out, the pencil will be useless. When you make marks, you want to contrast colour, so you can read it. How do you make marks? By depositing lead. How do you deposit lead? By transmitting force. Why you transmit force? To deposit lead.

Besides making marks you might want the pencil to achieve other objectives, like erasing marks, protecting wood and accommodating grip. These will be the ‘Design Criteria/Objectives’. Furthermore it may have to be a beautiful pencil at any time and you may want it to display information on it (type of lead; name). These are ‘all the time functions’. (van Geffen & Hendriksen, 2005, p. 6).

![FAST diagram for a pencil](image-url)
Appendix C. Pairwise Comparison (PWC) matrix

In part 3.4 the Pair Wise Comparison (PWC) method is introduced as a method to express an individual’s preference between two mutually distinct performance criteria. This appendix provides an example of PWC, shown below in Figure 44.

In the PWC matrix an individual can express his preference between two mutually distinct criteria. In the figure, one could prefer ‘Traffic safety’ above ‘Social safety’ or the other way around. When preferring traffic safety, one needs to fill in an A in the matrix. When preferring social safety, like in the figure, than a B should be placed in the matrix. Per letter 1 point can be obtained. In cases of no preference, one needs to fill in A/B. In that case each letter gets 0.5 points. Practitioners can check if the matrix is filled in correctly by checking the sum. In every case the sum should be equal to 36 points.

Figure 44: Filled in PWC matrix

In the PWC matrix an individual can express his preference between two mutually distinct criteria. In the figure, one could prefer ‘Traffic safety’ above ‘Social safety’ or the other way around. When preferring traffic safety, one needs to fill in an A in the matrix. When preferring social safety, like in the figure, than a B should be placed in the matrix. Per letter 1 point can be obtained. In cases of no preference, one needs to fill in A/B. In that case each letter gets 0.5 points. Practitioners can check if the matrix is filled in correctly by checking the sum. In every case the sum should be equal to 36 points.
Appendix D. Wisdom of crowds

In part 3.4 the method Pair Wise Comparison (PWC) is introduced. The underlying principle of this method is to take into account the preference of multiple stakeholders with regard to the performance criteria of a project. This appendix shows statistical experiments that illustrate that collectively stakeholders are remarkably intelligent.

Surowiecki (2004) demonstrated in his book ‘Wisdom of Crowds’ that under the right circumstances, groups are remarkably intelligent, and are often smarter than the smartest people in them. Groups do not need to be dominated by exceptionally intelligent people in order to be smart. Even if most of the people within a group are not well-informed or rational, it can still reach a collectively wise decision. Below the ‘jelly-beans-in-the-jar’ experiment demonstrates that crowds are remarkably intelligent.

Jelly-beans-in-the-jar experiment
A classic demonstration of group intelligence is the ‘jelly-beans-in-the-jar’ experiment, in which various people were asked to guess the amount of jelly beans in a plastic jar. It seems that invariably the group’s estimate is superior to the vast majority of the individual guesses.

When James Surowiecki ran the experiment in an office building with a jar that held 4510 beans, the group estimate was 4514. Finance Professor Jack Treynor who also ran the experiment in his class with a jar that contains 850 beans, the group estimated 871. In the last experiment only one of the fifty-six people in the class made a better guess.

Two important lessons can be draw from this experiment. First, the members of the group were not talking to each other or working on a problem together. They were making individual guesses, which were aggregated and then averaged. Second, in many cases, there will be a few people who do better than the group. This is, in some sense, a good thing, since especially in situations where there is an incentive for doing well (e.g. the stock market) it gives people reason to keep participating. There is however no evidence in these studies that certain people consistently outperform the group.
Appendix E. Interviews and meetings

During the research it was possible to attend several meetings with regard to the Coolsingel project. Based on those meetings, some hypothesis are formulated in chapter 1 of the research. Furthermore, they are used to describe the current selection process at the municipality of Rotterdam, as provided in part 8.4. This appendix provides an overview of the attended meetings.

Cost estimation meeting

The aim of this meeting was to come up with an action plan to estimate the costs of each sketch design provided. Below some general information of the meeting is given.

<table>
<thead>
<tr>
<th>Project:</th>
<th>Redevelopment Coolsingel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>9 January, 2014</td>
</tr>
<tr>
<td>Location:</td>
<td>Municipality of Rotterdam, meeting room 15.29</td>
</tr>
<tr>
<td>Duration:</td>
<td>15.00 – 16.30</td>
</tr>
</tbody>
</table>

**Attendees**

- Elske Geelhoed: Project Manager
- Monique Marijnissen: Urban planning expert
- Remco Versteeg: Cost estimator
- Patrick Lans: Cost estimator
- Alex Duijvenbode: Cost estimator

The meeting starts with a short evaluation of the sketch designs. During the meeting the project manager asked the cost estimators if they were able to provide an estimation of the investment costs for each sketch design. In addition, she notified that it was important to have these results within three weeks in order to include them in the decision making document.

It was then prompted why this document is not provided with a section that shows the expected future costs of each alternative. The project manager simply answered “during the study phase of a project, expressing life cycle costs is not part of our assessment system”. In addition, it was asked why the decision making document is not provided with a Social Cost Benefit Analysis (SCBA) for each alternative. According to the group; “SCBA’s are too ‘heavy instruments’ to be applied during the earlier stages of urban regeneration development”. In addition to this they indicated that there is simply not enough time (three weeks) to conduct such studies properly.

**Findings**

From this meeting two important findings can be derived:

1. The first decision making document (end of study phase) does not provide insight into the life cycle costs of the sketch designs.
2. The municipality of Rotterdam does not quantifies the benefits (or performances) of the different sketch designs, during the study phase of urban regeneration development.
First assessment meeting

During the assessment meetings, these three designs were evaluated and the results have been reported in the decision making document. It is important to underpin these results objectively, in such manner that the assessment commission is well informed to make a proper decision. First a general description of the meeting is provided, followed by some highlights of the most important findings.

Project: Redevelopment Coolsingel
Date: 16 January, 2014
Location: Municipality of Rotterdam, meeting room 14.70
Duration: 9.00 – 13.00

Attendees and meeting set-up

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elske Geelhoed</td>
<td>Project Manager (PM)</td>
<td></td>
</tr>
<tr>
<td>Monique Marijnissen</td>
<td>Urban planning expert (U)</td>
<td></td>
</tr>
<tr>
<td>Arjen Knoester</td>
<td>Urban planning expert (U)</td>
<td></td>
</tr>
<tr>
<td>Remco Versteeg</td>
<td>Cost estimator (C)</td>
<td></td>
</tr>
<tr>
<td>Jos Menting</td>
<td>Maintenance expert (M)</td>
<td></td>
</tr>
<tr>
<td>Marcus Edelenbosch</td>
<td>Traffic expert (T)</td>
<td></td>
</tr>
<tr>
<td>Hans Baggerman</td>
<td>Traffic expert (T)</td>
<td></td>
</tr>
<tr>
<td>Linda Rijnsburger</td>
<td>Sustainability expert (S)</td>
<td></td>
</tr>
</tbody>
</table>

The meeting starts with a short introduction about the award criteria mentioned in the procurement guideline (Dutch: Aanbestedingsleidraad). Per criterion a maximum of 10 points can be scored. The total score for each award criterion is achieved by multiplying the scores with the following weight percentages.

Table 18: Weight percentage of the award criteria (PBR, 2013)

<table>
<thead>
<tr>
<th>Award criteria</th>
<th>Weight percentage and total score formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketch design</td>
<td>50%</td>
</tr>
<tr>
<td>Presentation and conversation</td>
<td>30%</td>
</tr>
<tr>
<td>Underpinning of remuneration</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Total score</strong></td>
<td>score sketch design * 50% + score presentation and conversation * 30% + underpinning of remuneration * 20%</td>
</tr>
</tbody>
</table>

As mentioned above, the overall objective of the assessment meetings is to underpin the evaluation of the three sketch designs, which accounts for 50% in the total score of the assessment. This first assessment meeting focuses on developing the performance criteria. In addition, it serves as an introduction for the team members.

After the introduction, individuals in the team are asked to state their opinions about the three sketch designs. These different opinions are then translated into performance criteria and where necessary, complemented with requirements proposed in the document ‘Imaginative Program Requirements (Dutch: Verbeeldend Programma van Eisen (PBR, 2011))’. The selected criteria are shown in Table 19 below.
Table 19: Performance criteria for the Coolsingel

<table>
<thead>
<tr>
<th>Performance criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic safety</td>
<td>An optimum balance between the various modes of transport (car, pedestrian and cyclist). This could be translated into cross ability, car and cycle flows.</td>
</tr>
<tr>
<td>Social safety</td>
<td>The extent to which a person feels safe and secure on the Coolsingel. This could be achieved by clarity and the reduction of dark unpleasant spots.</td>
</tr>
<tr>
<td>User experience</td>
<td>The extent to which the public space is used optimally. For the visitor it must be clear that the Coolsingel functions as a city boulevard. Furthermore, pedestrian flows are in line with its surroundings.</td>
</tr>
<tr>
<td>Spatial quality</td>
<td>The extent to which the public space is regarded as ‘pleasant to stay’. This is translated in the amount and attention given to the development of special spots and places to stroll and linger.</td>
</tr>
<tr>
<td>Maintainability</td>
<td>The extent to which the Coolsingel is easy to maintain.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>The extent to which smart innovations are suggested for the following topics; energy consumption/generation, water storage, greenery, air pollution, noise nuisance and materials used.</td>
</tr>
<tr>
<td>Constructability</td>
<td>The extent to which proposed solutions can be constructed.</td>
</tr>
<tr>
<td>Flexibility</td>
<td>The extent to which the Coolsingel is adaptable for future events or developments.</td>
</tr>
<tr>
<td>Visual appearance</td>
<td>The extent to which high quality materials and street elements are introduced in order to increase the looks of the Coolsingel.</td>
</tr>
</tbody>
</table>

The team then discusses to what extent the designs perform on each criterion. Scores are assigned on an ordinary scale, consisting of the following rank order: minus, zero and plus. The first is assigned when the design scores poorly on the criterion. A plus is given when the design performs well on the criterion, and a zero is provided when performing moderate. It is observed that team members had difficulties in ranking the designs.

After the scores were assigned, people from the sections ‘Traffic and Transport’ and ‘Urbanism’ were arguing about the importance of some criteria. Since one of the designs scores high on traffic safety, but relatively low on spatial quality, both urban planners were not in favour of this solution. However, the other two designs score relatively high on spatial quality, but lack traffic safety. As no solution was prompted, they decided to promote the design with the overall best score on all criteria in the decision making document.

In the end, the team members were asked to report the scores on the criteria and underpin them with words. To do so, each member is provided with the criteria that suits his own discipline. The deadline for delivery was set on 21 January 2014; so that everybody could read the comments before the second assessment meeting on 23 January 2014. This meeting is described further on in this appendix.

Findings

Two important findings can be derived from the observations stated above:

1. There is ambiguity about the mutual importance between the performance criteria;
2. The ordinary scale does not indicate the relative degree of difference between the possible orders (-, 0 and +).

The first finding can be attributed to the subjective nature surrounding the performance criteria. Each individual team member seems to have a different perception on how the
Coolsingel should perform. More generally spoken; “the assessment team is struggling in defining the performances of public infrastructures, as they are dealing with individualistic perceptions in multi-actor decision-making environments.”

The second finding indicates the problem of using ordinary scales for assessments. After all, the difference between plus and zero can be much higher, than the differences between minus and zero. When during the assessment meeting an individual claims that a certain measure proposed in the design has a poor influence on a criteria, it automatically is assigned with a ‘min’. Regardless from knowing the actual amount in numbers. In general terms; “the assessment team has difficulties in assigning the scores of the alternatives on the different performance criteria, as the relative degree of difference between the possible scores is unknown.”

Second assessment meeting
The second assessment meeting is in line with the first assessment meeting. Again first a general description of the meeting is given. Then the most important findings are highlighted.

Project: Redevelopment Coolsingel
Date: 23 January, 2014
Location: Municipality of Rotterdam, meeting room 5.20
Duration: 12.00 – 15.00

Attendees and meeting set-up:

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elske Geelhoed</td>
<td>Project Manager</td>
<td>(PM)</td>
</tr>
<tr>
<td>Olav Beugels</td>
<td>Project Coordinator</td>
<td>(PCO)</td>
</tr>
<tr>
<td>Monique Marijnissen</td>
<td>Urban planning expert</td>
<td>(U)</td>
</tr>
<tr>
<td>Arjen Knoester</td>
<td>Urban planning expert</td>
<td>(U)</td>
</tr>
<tr>
<td>Remco Versteeg</td>
<td>Cost estimator</td>
<td>(C)</td>
</tr>
<tr>
<td>Jos Menting</td>
<td>Maintenance expert</td>
<td>(M)</td>
</tr>
<tr>
<td>Marcus Edelenbosch</td>
<td>Traffic expert</td>
<td>(T)</td>
</tr>
<tr>
<td>Hans Baggerman</td>
<td>Traffic expert</td>
<td>(T)</td>
</tr>
<tr>
<td>Linda Rijnsburger</td>
<td>Sustainability expert</td>
<td>(S)</td>
</tr>
</tbody>
</table>

The meeting starts by discussing the reported comments from the first assessment meeting. In line with these comments, scores have been modified. Again a lot of discussions were involved during this process.

After everybody agrees on the scores, the overall performance of each design is determined by cancelling out the ‘plusses’ and ‘minus’. In other words, during this process they neglect the fact that some criteria might be of more importance than others. Hence, one of the team members made a comment on this manner of evaluation, which is in line with the first finding described at the end of the first assessment meeting. The project manager responded by informing us that; “this team provides preliminary work for the assessment commission. They will eventually make the assessment and it is our role to support them as much as possible. Since the commission is more familiar with project assessments, we will only provide them of an advice on the designs that stem from our multidisciplinary viewpoints.”
Table 20, shows that the project team made a selection between the three alternatives based on a Likert-scale.

**Table 20: MCE performed by the project team**

<table>
<thead>
<tr>
<th>Performance criteria</th>
<th>Lodewijk Baljon</th>
<th>West 8</th>
<th>Fluitman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic safety</td>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Social safety</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>User experience</td>
<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Spatial quality</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Maintainability</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sustainability</td>
<td>+</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Constructability</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Flexibility</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Visual appearance</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>+2</strong></td>
<td><strong>+1</strong></td>
<td><strong>-3</strong></td>
</tr>
</tbody>
</table>

In the end, the assessment commission will be provided with a document in which the scores of the designs on the criteria are reported and underpinned in words. In addition, a cost estimation of the investment costs for every design is attached to the document. This means that costs that occur during the productive life are not estimated. However, like the performance criteria, the maintenance expert expresses his thoughts about this subject in words.

**Findings**

The following important findings are derived from the upper stated:

1. Maintenance and operational costs are underpinned in words, rather than in monetized quantities. Furthermore, environmental and removal costs are neither estimated nor described in words;
2. The Performances/benefits of proposed measures are expressed and underpinned in a qualitative way;
3. While some team members are aware of the fact that some criteria are more important than others, the assessment commission is still provided with a document that does not take this problem into account;
4. Although the assessment commission provides a general format on how the award is granted (see, Table 18), it provides however no guidelines on how the assessment team should assess the sketch designs.
Appendix F. Overview of the key parameters in LCC

In part 4.5 of the thesis a description is given of the key parameters in Life Cycle Costing (LCC). This appendix provides a schematic overview of these key parameters.

<table>
<thead>
<tr>
<th>Cost categories</th>
<th>Comments</th>
<th>Cost models</th>
<th>Economic evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realisation costs</td>
<td></td>
<td><img src="image1.png" alt="Realisation Costs Graph" /></td>
<td>Realisation costs ($C_r$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All costs that happen at the present</td>
<td>All removal and construction costs that occur at the present</td>
</tr>
<tr>
<td>Operational costs</td>
<td>Recurring costs on an annual basis. The costs often are similar from year to year</td>
<td><img src="image2.png" alt="Operational Costs Graph" /></td>
<td>Operational costs ($C_o$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All discounted to present value</td>
<td>$C_o = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>Recurring costs, usually on an annual basis. The costs may vary from year to year</td>
<td><img src="image3.png" alt="Maintenance Costs Graph" /></td>
<td>Maintenance costs ($C_m$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All discounted to present value</td>
<td>$C_m = \sum_{t=1}^{n} \frac{M_t}{(1+r)^t}$</td>
</tr>
<tr>
<td>Disposal costs (End-of-life)</td>
<td>Costs occur at the end of the assets’ life-time</td>
<td><img src="image4.png" alt="Disposal Costs Graph" /></td>
<td>Disposal costs ($C_{dis}$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All discounted to present value</td>
<td>$C_{dis} = DL_sn$</td>
</tr>
</tbody>
</table>

Appendices

130
Appendix G. Terminology used in cost estimating

This appendix provides information about terms that are often used when estimating the costs of a project and for that reason pop up in part 4.6 of this research. The terms that are highlighted are also used in the Standaard Systematiek Kostenramingen (SSK) and for that reason show similarities with the definitions provided in the report Werk in Uitvoering (PRI, 1995). The following terms often are found throughout the literature of cost estimating:

**Direct costs**
Direct costs are costs of a project that could be related to a single object. These costs are often calculated by a price * quantity and could be derived from historical data.

**Indirect costs**
Indirect costs are costs of a project that could not be related to a single object. In other words, these costs are not directly dependent on quantities. Four types of indirect costs can be distinguished and are discussed below (CROW, 2012).

**Execution costs:** these costs are often time-related costs for the contractor such as, rent for the shack, site preparations, etc.
**One-off costs:** are for example costs related to the supply or discharge of material.
**Overhead costs:** are costs related to management, communication or secretarial support.
**Profit & Risks:** are costs defined by the contractor and depend on the risks involved in the project.

**Additional costs**
These costs will not be included in the work specification document (in Dutch: ‘het bestek’). Two categories could be distinguished; exploitation costs and engineering costs.

**Ground acquisition costs:** loss of capital, loss of revenue, compensation, etc.
**Engineering costs:** work permits, equipment (machinery), personal wages, etc.

**Miscellaneous**
These costs form an addition to the base estimate. One expects to make these costs by means of specifying the design during the following project stages. After all, in the earlier stages of the projects, estimates are based on big parts. If the level of detail increases, these big parts will be decomposed in small parts. The costs related to this process form the cost item ‘miscellaneous’.

**Unforeseen**
These costs also form an addition to the base estimate. Unforeseen costs could occur on either the direct, indirect or additional costs that may be caused by; scope changes, unforeseen realisation complexities, etc. In the deterministic approach this cost item is calculated as a percentage on the base estimate.

**Taxes**
Taxes are set by the government in the form of a percentage (in Dutch: BTW).
Appendix H. Activity matrix for urban regeneration projects

Table 6 in part 6.2, shows the main elements regarding urban regeneration projects. Per element a design might propose to perform several activities. This appendix provides a matrix that gives us several examples of such activities.

Table 21: Activity matrix urban regeneration

<table>
<thead>
<tr>
<th>Activities</th>
<th>Removal activities</th>
<th>Construction activities</th>
<th>Operational activities</th>
<th>Maintenance activities</th>
<th>Disposal activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main elements</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Groundwork’s</em></td>
<td>Excavation and disposal of ground</td>
<td>Supply, process and compress different soils</td>
<td>-</td>
<td>-</td>
<td>Same as removal measures</td>
</tr>
<tr>
<td><em>Sewage systems</em></td>
<td>Removal of swirls, gutters, etc.</td>
<td>Placement of swirls, gutters, etc.</td>
<td>Cleaning swirls and gutters</td>
<td>Maintain swirls, gutters, etc.</td>
<td>Same as removal measures</td>
</tr>
<tr>
<td><em>Pavements</em></td>
<td>Removal of asphalt, concrete, clinker paved streets, etc.</td>
<td>Placement of asphalt, concrete, clinker paved streets</td>
<td>Cleaning asphalt, stone, marble and clinker pavements</td>
<td>Maintain asphalt, stone, marble and clinker pavements</td>
<td>Same as removal measures</td>
</tr>
<tr>
<td><em>Tram track</em></td>
<td>Removal of current track</td>
<td>Placement of new tram track</td>
<td>By RET</td>
<td>By RET</td>
<td>Same as removal measures</td>
</tr>
<tr>
<td><em>Street furniture</em></td>
<td>Removal of trash cans, fencing, furniture, cycle racks, etc.</td>
<td>Placement of trash cans, fencing, cycle racks, etc.</td>
<td>Emptying trash cans</td>
<td>Maintain trash cans, fencing, cycle racks, etc.</td>
<td>Same as removal measures</td>
</tr>
<tr>
<td><em>Vegetation</em></td>
<td>Removal of plants, trees, etc.</td>
<td>Placement of trees, grass and decorative plants</td>
<td>Cleaning grass and areas with decorative plants</td>
<td>Maintain trees and areas with grass and decorative plants</td>
<td>Same as removal measures</td>
</tr>
<tr>
<td><em>Lights</em></td>
<td>Removal of streetlights</td>
<td>Placement of streetlights in different heights</td>
<td>The use of energy</td>
<td>Maintain streetlights</td>
<td>Same as removal measures</td>
</tr>
<tr>
<td><em>Traffic guiding facilities</em></td>
<td>Removal of FRI’s (Dutch: VRI’s), surveillance cameras, monitoring systems, signs and parking guidance system</td>
<td>Placement of FRI’s, surveillance cameras, monitoring systems, signs and parking guidance system</td>
<td>The use of energy</td>
<td>Maintain FRI’s, surveillance cameras, monitoring systems, signs and parking guidance system</td>
<td>Same as removal measures</td>
</tr>
</tbody>
</table>
Appendix I. NPV sheet in the LCC estimating model

This appendix contains the layout of the NPV sheet in the LCC estimating model, as depicted in Figure 45 below. From the figure it could be noticed that the variable input factors are the period of analysis, the discount factor and the starting year. Furthermore one could see the costs declining in the future. This is caused by the time value of money. In other words, the costs are presented in their time-equivalent value in the year 2015.

<table>
<thead>
<tr>
<th><strong>Input factors: LCC</strong></th>
<th><strong>Input factors: Eco-costs</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>205</td>
</tr>
<tr>
<td><strong>Life-cycle</strong></td>
<td>30.5</td>
</tr>
<tr>
<td><strong>Discount factor</strong></td>
<td>2.8%</td>
</tr>
<tr>
<td><strong>Realisation costs</strong></td>
<td>8,764,649</td>
</tr>
<tr>
<td><strong>Operational costs</strong></td>
<td>5,964,138</td>
</tr>
<tr>
<td><strong>Maintenance costs</strong></td>
<td>1,341,492</td>
</tr>
<tr>
<td><strong>Disposal costs</strong></td>
<td>1,775,117</td>
</tr>
</tbody>
</table>

**Net Present Value Calculation: Life cycle costs**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Realisation</td>
<td>8,764,649</td>
<td>8,389,252</td>
<td>8,033,042</td>
<td>7,696,831</td>
<td>7,378,619</td>
<td>7,088,397</td>
<td>6,817,165</td>
<td>6,563,922</td>
<td>6,330,679</td>
<td>6,116,436</td>
</tr>
<tr>
<td>Maintenance</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
<td>(1,341,492)</td>
</tr>
<tr>
<td>Disposal</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
<td>(1,775,117)</td>
</tr>
<tr>
<td>NPV per year</td>
<td>(8,764,649)</td>
<td>(8,389,252)</td>
<td>(8,033,042)</td>
<td>(7,696,831)</td>
<td>(7,378,619)</td>
<td>(7,088,397)</td>
<td>(6,817,165)</td>
<td>(6,563,922)</td>
<td>(6,330,679)</td>
<td>(6,116,436)</td>
</tr>
</tbody>
</table>

**Net Present Value Calculation: Eco-costs**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco-costs Realisation</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
<td>0.885252</td>
</tr>
<tr>
<td>NPV per year</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
</tr>
<tr>
<td>Cumulative NPV</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
</tr>
<tr>
<td>NPV at start</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
<td>(6,885,022.01)</td>
</tr>
</tbody>
</table>

Figure 45: NPV calculation of an alternative
Appendix J. Cost sheets in the LCC estimating model

This appendix contains the layout of a cost sheet in the LCC estimating model, see Figure 46. More specifically, it shows a screenshot for filling in the construction quantities of pavements. The quantities can be filled in under the column ‘amount’. Then they are multiplied with their associated cost indicator stated in the column ‘price per unit’. This will give us the direct specified costs. To incorporate risks, the direct specified costs are multiplied with a fixed percentage of 30%. This risk budget is given in the column ‘miscellaneous’. Furthermore, the indirect specified costs are calculated by multiplying the direct specified costs with a percentage of 23%. Also here a budget reserve of 30% is added for risks. Summing up the total direct and indirect costs will result in the base estimate. This estimate adds another 10% to incorporate uncertainties such as scope changes or realisation difficulties. These are stated in the column ‘unforeseen’. Adding up the base estimate with this last budget reserve will result in the total LCC estimate of an activity (e.g. placing asphalt).

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
<th>Price per unit</th>
<th>Same unit</th>
<th>Direct costs</th>
<th>Indirect costs</th>
<th>Base estimate</th>
<th>Unforeseen</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>[€/unit]</td>
<td>[€/unit]</td>
<td>Specified %</td>
<td>Miscellaneous Specified %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constructing asphalt traffic lanes excl. bases</td>
<td>m2</td>
<td>€</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Placing asphalt (AG22 base, AG22 bind, AG16 bind and SMA D/B)</td>
<td>ton</td>
<td>€ 15.25</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Placing adhesive layer (Dutch kleding)</td>
<td>m2</td>
<td>€ 0.15</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Placing adhesive layer (Dutch asfaltbeg)</td>
<td>m2</td>
<td>€ 0.28</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Supply costs AG22 base 01-B</td>
<td>ton</td>
<td>€ 45.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Supply costs AG16 bind T1-B</td>
<td>ton</td>
<td>€ 55.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Supply costs AG16 bind T1-B PMB</td>
<td>ton</td>
<td>€ 56.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Supply costs SMA D/B (Non-reducing layer)</td>
<td>ton</td>
<td>€ 60.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Place road-marking</td>
<td>m2</td>
<td>€</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Placing road-marking</td>
<td>m2</td>
<td>€ 46.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Constructing asphalt cycle lanes excl. bases</td>
<td>m2</td>
<td>€</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Placing asphalt (AG22 base 01-B and AG16 surfac)</td>
<td>ton</td>
<td>€ 27.50</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Placing adhesive layer (Dutch kleding)</td>
<td>m2</td>
<td>€ 0.15</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Supply costs AG16 base 01-B</td>
<td>ton</td>
<td>€ 45.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Supply costs AG16 surfac</td>
<td>ton</td>
<td>€ 17.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Place road-marking cycle lanes</td>
<td>m2</td>
<td>€</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
<tr>
<td>Placing road-marking</td>
<td>m2</td>
<td>€ 46.00</td>
<td>m2</td>
<td>30%</td>
<td>€</td>
<td>30%</td>
<td>€</td>
<td>10%</td>
</tr>
</tbody>
</table>

Figure 46: A screenshot of a cost sheet in the LCC estimating model
Appendix K. Operational parameters for activities at the Coolsingel

Part 6.4 in the research discusses the development of cost indicators related to urban regeneration. This appendix shows values that are used to calculate operational cost indicators. To be more specific, the appendix contains parameters used to calculate the cost indicators for cleaning activities (see Table 22) and energy consumption (see Table 23). Note that these parameters are based on data collected from the case study: the urban regeneration of the Coolsingel.

Table 22: Parameters used for calculating the cost indicators for cleaning activities, based on (Visser, 2013)

<table>
<thead>
<tr>
<th>Activities</th>
<th>Hours/year</th>
<th>Costs/hour [in euros]</th>
<th>Cleaning amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating sewer system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning swirls (with swirl dredger)</td>
<td>0.083</td>
<td>-</td>
<td>0.083</td>
<td>60.00</td>
</tr>
<tr>
<td>Cleaning gutters (with pressure spray)</td>
<td>0.033</td>
<td>-</td>
<td>0.033</td>
<td>32.70</td>
</tr>
<tr>
<td>Operating pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning pavements mechanically (with sweeper)</td>
<td>293</td>
<td>59</td>
<td>59</td>
<td>411</td>
</tr>
<tr>
<td>Cleaning non-machinery reachable areas (with</td>
<td>2730</td>
<td>546</td>
<td>546</td>
<td>3822</td>
</tr>
<tr>
<td>(leaf)blower)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High pressure cleaning (with pressure spray)</td>
<td>156</td>
<td>-</td>
<td>156</td>
<td>32.70</td>
</tr>
<tr>
<td>Removal of weeds (with electrical weed</td>
<td>128</td>
<td>-</td>
<td>128</td>
<td>17.50</td>
</tr>
<tr>
<td>remover)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating street furniture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emptying trash cans (with garbage truck)</td>
<td>124</td>
<td>25</td>
<td>25</td>
<td>174</td>
</tr>
<tr>
<td>Operating green elements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning non-machinery reachable areas (with</td>
<td>2730</td>
<td>546</td>
<td>546</td>
<td>3822</td>
</tr>
<tr>
<td>(leaf)blowers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 23: Parameters used for calculating the cost indicators for energy consumption, based on (Carels, 2014; van Run, 2014)

<table>
<thead>
<tr>
<th>Type of lightning</th>
<th>Energy usage [in kW]</th>
<th>Operating hours/year</th>
<th>Cost/kW</th>
<th>Cost/piece/year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating costs lightning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streetlight (l=4m), Altra 2: 1x PLL 24 W LongLife</td>
<td>0.024</td>
<td>4368</td>
<td>0.15</td>
<td>15.72</td>
</tr>
<tr>
<td>Streetlight (l=4m), Altra 2: 2x PLL 24 W LongLife</td>
<td>0.048</td>
<td>4368</td>
<td>0.15</td>
<td>31.45</td>
</tr>
<tr>
<td>Streetlight (l=5m), Altra 2: 1x PLL 36 W LongLife</td>
<td>0.036</td>
<td>4368</td>
<td>0.15</td>
<td>23.59</td>
</tr>
<tr>
<td>Streetlight (l=5m), Altra 2: 2x PLL 36 W LongLife</td>
<td>0.072</td>
<td>4368</td>
<td>0.15</td>
<td>47.17</td>
</tr>
<tr>
<td>Streetlight (l=10m), Indal Airtrace: 1x CPO-TW 90 W</td>
<td>0.09</td>
<td>4368</td>
<td>0.15</td>
<td>58.97</td>
</tr>
<tr>
<td>Streetlight (l=10m), Indal Airtrace: 2x CPO-TW 90 W</td>
<td>0.18</td>
<td>4368</td>
<td>0.15</td>
<td>117.94</td>
</tr>
<tr>
<td>Groundspot, DecaLED Spot 3</td>
<td>0.005</td>
<td>4368</td>
<td>0.15</td>
<td>3.28</td>
</tr>
<tr>
<td><strong>Operating costs traffic guidance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FRI’s pedestrian crossings, LED</td>
<td>0.125</td>
<td>8736</td>
<td>0.15</td>
<td>163.80</td>
</tr>
<tr>
<td>FRI’s junctions, LED</td>
<td>0.75</td>
<td>8736</td>
<td>0.15</td>
<td>982.80</td>
</tr>
<tr>
<td>Surveillance cameras, Sanyo VCC-3972P</td>
<td>0.00022</td>
<td>8736</td>
<td>0.15</td>
<td>0.29</td>
</tr>
<tr>
<td>Dynamic signage (parking guidance), LED</td>
<td>0.21</td>
<td>8736</td>
<td>0.15</td>
<td>273.00</td>
</tr>
</tbody>
</table>
Appendix L. Eco-cost indicators

Part 6.4 illustrates how in the LCC estimating model the ecological burden of several activities is calculated. This appendix provides two tables that provide an overview of the cost indicators that are used in the LCC model.

Table 24: Machinery types and associated eco-cost indicators (Doormalen, 2014; Vogtlander, 2013a)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Trencher backhoe (Dutch: 'kleine' graafmachine)</td>
<td>10</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>5.81</td>
<td>-</td>
</tr>
<tr>
<td>Transport truck</td>
<td>12.5</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>7.26</td>
<td>-</td>
</tr>
<tr>
<td>Tamper (Dutch: triplaat)</td>
<td>0.8</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>0.46</td>
<td>-</td>
</tr>
<tr>
<td>Excavator (Dutch: 'grote' graafmachine)</td>
<td>15</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>8.72</td>
<td>-</td>
</tr>
<tr>
<td>Asphalt paver</td>
<td>12.5</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>7.26</td>
<td>-</td>
</tr>
<tr>
<td>Paving machine</td>
<td>11</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>6.39</td>
<td>-</td>
</tr>
<tr>
<td>Swirl dredger (Dutch: kolkuiger)</td>
<td>5</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>2.91</td>
<td>-</td>
</tr>
<tr>
<td>Pressure spray (for swirls)</td>
<td>-</td>
<td>1.8</td>
<td>-</td>
<td>0.095</td>
<td>0.17</td>
<td>-</td>
</tr>
<tr>
<td>Pressure spray (for pavements)</td>
<td>-</td>
<td>1.8</td>
<td>-</td>
<td>0.095</td>
<td>-</td>
<td>0.0007</td>
</tr>
<tr>
<td>Sweeper</td>
<td>8</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>4.65</td>
<td>-</td>
</tr>
<tr>
<td>Electrical weed remover (leaf)blower</td>
<td>-</td>
<td>0.4</td>
<td>-</td>
<td>0.095</td>
<td>-</td>
<td>0.00013</td>
</tr>
<tr>
<td>Garbage truck</td>
<td>15</td>
<td>-</td>
<td>0.581</td>
<td>-</td>
<td>8.72</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 25: Production process of resources and associated eco-costs (Vogtlander, 2013a)

<table>
<thead>
<tr>
<th>Production process</th>
<th>Resource type</th>
<th>Eco-costs [€/ton]</th>
<th>Eco-cost indicator [€/ton]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground production process</td>
<td>Sand</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Concrete production process</td>
<td>Concrete</td>
<td>36.00</td>
<td>36.00</td>
</tr>
<tr>
<td>Bitumen production process</td>
<td>Bitumen</td>
<td>813.00</td>
<td>813.00</td>
</tr>
<tr>
<td>Stoneware production process</td>
<td>Stoneware</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Marble production process</td>
<td>Stoneware</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>Clinker production process</td>
<td>Clinker</td>
<td>50.00</td>
<td>50.00</td>
</tr>
</tbody>
</table>
Appendix M. FAST diagram Coolsingel case

This appendix provides the FAST diagram for the Coolsingel project. In fact, two FAST diagrams are included in the appendix; one that provides the bigger picture of the case and one that is provided with more detailed functions. The first one is necessary to understand the focus point of the study and is presented in Figure 47 below.

From the figure it can be noticed that the higher order function of the project is to ‘attract more people towards the Coolsingel’. Roughly, this can be achieved by upgrading the public space and by improving the current micro-economic situation. The latter relates to the real estate located at the Coolsingel. Since the context of this research is focused on the public space (urban regeneration), it is not further discussed how the micro-economic situation of the Coolsingel can be improved.

This implies that the research will focus on improving the functions provided at the right of the figure. These functions are used as input for the FAST diagram provided on the next page in Figure 48.

Please note that the functions highlighted in yellow are the ones that are believed to be realized sub-optimally by the physical measures proposed in the design of West 8.
Figure 48: FAST diagram Coolsingel project
## Appendix N. Monetization of effects

This appendix provides an overview of the monetized effects of urban regeneration projects. The monetized values are used to calculate the performance of the developed modifications given in chapter 10. The monetized values are presented in the table below.

<table>
<thead>
<tr>
<th>Category/Effect</th>
<th>Measuring unit</th>
<th>Effect indicator</th>
<th>Measuring unit for monetization</th>
<th>Monetization</th>
<th>Price level</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transport</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase/decrease of travel time</td>
<td>WTP for travel time reduction</td>
<td>€9.00, WTP for one hour of travel time reduction</td>
<td>n/a</td>
<td>€9.00/hour of travel time reduction</td>
<td>n/a</td>
<td>(KIM, 2013)</td>
</tr>
<tr>
<td><strong>Health/sustainability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase of air quality (within urban area)</td>
<td>Fine dust capture by trees</td>
<td>0.1, kg fine dust per tree</td>
<td>WTP for fine dust reduction</td>
<td>€403/kg fine dust</td>
<td>2013</td>
<td>(Ministerie van LNV, 2006; TNO, 2004)</td>
</tr>
<tr>
<td>Increase of air quality (within urban area)</td>
<td>Fine dust capture by grass areas or decorative plants</td>
<td>1, kg fine dust per 1000 m²</td>
<td>WTP for fine dust reduction</td>
<td>€403/kg fine dust</td>
<td>2013</td>
<td>(Kirchholtes, 2013)</td>
</tr>
<tr>
<td><strong>Micro-economics/visual appearance/user experience</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase of property value due to a street scenario with trees</td>
<td>WTP for properties at a street with trees</td>
<td>5% increase of property value (WOZ-waarde), compared to no trees</td>
<td>n/a</td>
<td>5% increase of property value</td>
<td>2013</td>
<td>(Luttik &amp; Zijlstra, 1997; Ministerie van LNV, 2006)</td>
</tr>
<tr>
<td>Increase of property value due to a street scenario with mixed vegetation</td>
<td>WTP for properties at a street with mixed vegetation</td>
<td>8% increase of property value (WOZ-waarde), compared to no trees</td>
<td>n/a</td>
<td>8% increase of property value</td>
<td>2013</td>
<td>(Luttik &amp; Zijlstra, 1997; Ministerie van LNV, 2006)</td>
</tr>
<tr>
<td>Increase of property value due to high quality pavements</td>
<td>WTP for properties at streets with stone pavements</td>
<td>2% increase of property value, compared to concrete pavements</td>
<td>n/a</td>
<td>2% increase of property value</td>
<td>n/a</td>
<td>Estimate</td>
</tr>
<tr>
<td>Increase of retail sales due to a street scenario with trees</td>
<td>WTP for products at streets provided with trees</td>
<td>9% increase of sales, compared to no trees</td>
<td>n/a</td>
<td>9% increase of sales</td>
<td>2013</td>
<td>(Wolf, 2003, 2005)</td>
</tr>
<tr>
<td>Increase of retail sales due to a street scenario with mixed vegetation</td>
<td>WTP for products at streets provided with mixed vegetation</td>
<td>12% increase of sales, compared to no trees</td>
<td>n/a</td>
<td>12% increase of sales</td>
<td>2013</td>
<td>(Wolf, 2003, 2005)</td>
</tr>
<tr>
<td>Increase of retail sales due to high quality pavements</td>
<td>WTP for products at streets provided with stone pavements</td>
<td>3% increase of property value, compared to concrete pavements</td>
<td>n/a</td>
<td>3% increase of retail sales</td>
<td>2013</td>
<td>Estimate</td>
</tr>
</tbody>
</table>
This is a pivotal time for urban regeneration. We must take a long term view. These words were uttered by famous architect Richard Rogers some years ago, yet easier said than done. Too many times, decisions at municipalities are not properly underpinned. Decisions are based on investment costs and performances are vaguely described in non-measurable terms. Change is needed to prevent sub-optimal decision-making. Value Engineering might be the solution for public entities.

Michell Hogeveen