# The effect of asphalt maintenance regimes on inflation correction in Dutch DBFM contracts

## D.S. Vervoort

**TU**Delft Delft University of Technology

ITERFIDELIS Asset, Ageing & Risk Management

**Challenge the future**

# Colophon

| | |
|---|---|
| **Thesis title** | The effect of asphalt maintenance regimes on inflation correction in Dutch DBFM contracts |
| **Place & date** | Utrecht, 26th September 2013 |
| **Version** | Final version 1.3 **for publishing on repository** |
| **Author** | D. (David) S. Vervoort |
| | davidvervoort@gmail.com |
| | +31 (0) 6 48192102 |
| | Student ID: 1279815 |

**Supervisors**

Prof. Drs. Ir. J.K. Vrijling    -    TU Delft – CitG

Dr. R. Schoenmaker    -    TU Delft – CitG

Dr. W.W. Veeneman    -    TU Delft – TPM

Ir. S. de Jong    -    Iter Fidelis

**Study program**

MSc Construction Management and Engineering
Delft University of Technology

# Preface

This report is the result of a graduation project for the Master Construction Management & Engineering. My personal goal was to dive into a very specific topic and uncover its unknown dynamics. Furthermore, the subject of inflation correction in large-scale infrastructure projects is on the interface of technology and finance, a personal preference.

I would like to thank the people at my host company Iter Fidelis, who have facilitated me with a comfortable environment for my research. Stef de Jong especially, who has been sharp and effective in giving critical feedback during the process.

Furthermore I would like to thank my interviewees, Rutger te Grotenhuis, Mahesh Moenilal and Kees Vermeij who have helped me a lot in learning the financial and technical knowhow necessary for the research.

Also, I would like to thank my committee, Han Vrijling, Rob Schoenmaker and Wijnand Veeneman who have helped me with their periodic critical helicopter views and academic mentality.

The picture on the cover page is a cheeky homage to the inability of a mathematical model to predict the future. Only God himself is able to define the developments in the world, including the development of price level indices. This fresco of Michelangelo depicts the divine index-finger that has the power to create.
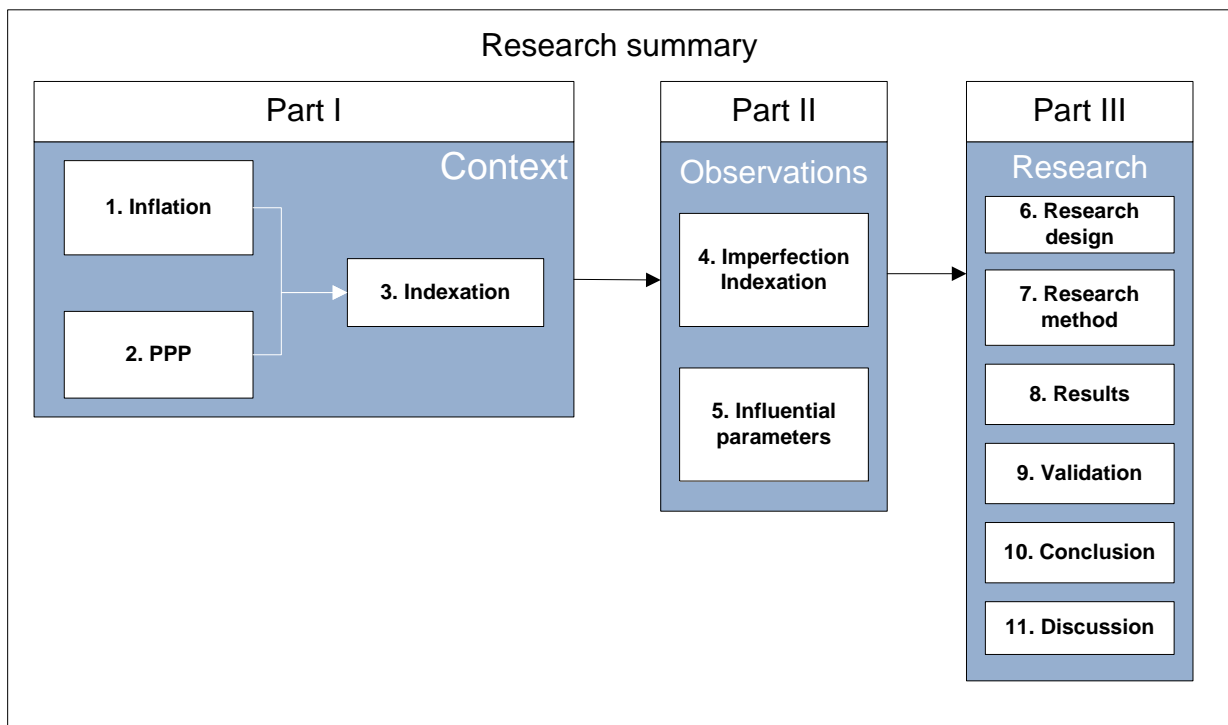
D.S. Vervoort

# Reading guide

The subject of this research is the method of reimbursing the cost due to price rise in a long term construction project. This subject is specialistic and must first be understood to recognize the problem at hand. To be able to understand the problems that follow from it, this report starts with an elaboration of the context in which the reimbursement method is placed, and why reimbursement is necessary in the first place. Following from this, observations are made on the imperfections of the method and the reasons for this imperfection. When this is all clear, the problem can be stated and the research is described.

It is recommended that the reader starts with the research summary so the outline of the document is clear from the start, and the different elements can be related to the research as a whole.

The picture below depicts the outline of the report schematically.

# Contents

## Research summary

Inflation is a worldwide phenomenon that influences future investment decisions. Inflation is the devaluation of money, causing a reduction of purchasing power and price level rise. Nobody knows how high inflation will be, and thus price levels in the future a uncertain.

In long-term projects with expenses in the future, it is important to take price level development into account. At the beginning of the project an investor wants to know the size of his expenses in the future to be able to estimate the profit of an investment. Inflation rates over the short term can be estimated, but over the long term, estimates introduce a big risk. Too low estimates of price rise result in higher cost than expected, resulting in financially unsuccessful projects. Too high estimates result in an offer that is not competitive.

In modern large-scale road infrastructure projects in the Netherlands, Rijkswaterstaat and contractors enter into long-term contracts. These contracts span over 20 to 30 years and include maintenance expenses that are subject to inflation. In order to maximize Value for Money, Rijkswaterstaat relieves the private parties of estimating price level rise during the contract period. This is done by an index formula.

The index formula escalates the payments from Rijkswaterstaat according to the price level rise of the expenses of the contractor. Independent organization publicize measurements of the price level at specific points in time. These objective index figures are input for the index formula.  But the formula itself is a model and has, inherently, its imperfections. These imperfections originate from the workability of the formula, and cause a mismatch between the extra cost due to price level rise, and extra income due to inflation correction payments.

The largest component in the design of the maintenance plan of road infrastructure is the maintenance regime of asphalt. Typically asphalt pavement lasts for 8-10 years, so it must be replaced during the contract period in order to keep the required motorway available. The contractor has a number of possible maintenance regimes to choose from to maintain the required availability. These regimes have a different cashflow and react differently on the imperfection of the index formula and thus have a different mismatch between inflation cost and inflation correction.

This research aims on finding out what maintenance regime has the best performance on this mismatch because there is a lack of knowledge of the mismatch between a DBFM project's inflation cost and its inflation correction payments. Furthermore, the effect of different maintenance plans on this mismatch is unknown as well. The most influential component of the maintenance budget is the pavement resurfacing because of its financial weight, numerous maintenance strategies, planning uncertainty and unstable product prices.  It would be valuable to know how the resurfacing strategies perform on inflation correction in different scenario's. This is important because inflation correction influences the tenderbid as well as the profitability for the private party. When the parties in DBFM projects are more aware of the gap and how it can be influenced, the projects will result in a higher value for money for the government. The research question is:

*Which resurfacing strategy minimizes the net present value mismatch between inflation correction and actual inflation cost in DBFM road projects in The Netherlands?*

To answer the research question, four different maintenance regimes are tested in a model simulating six variable price level developments relevant to the maintenance of asphalt. For this price level development simulation, an Autoregressive Integrated Moving Average (ARIMA) modelling technique is used. Besides the price level simulation, the model varies the timing of the maintenance activities in each calculation. The timing varies according to data of maintenance intervals in existing road sections.

The research shows there are two types of mismatches. The first is already taken into account by the private parties in current DBFM projects. This first mismatch can be exposed by means of a deterministic base case. The second mismatch is not yet incorporated in the mismatch, this type is exposed with the probabilistic analysis of this research.

The research concludes that the maintenance regime with the best behaving inflation correction is a regime that uses rejuvenating measures to postpone traditional resurfacing peaks. Furthermore, the differences of the mismatch between the maintenance regimes is relevant to the project's financial success. The choice of maintenance regime has an impact of over 2% of the asphalt maintenance budget.

With the understanding of the mismatch in inflation correction, the contractor is better able to mitigate this risk and create an offer with better value for money. This is beneficial to the efficient use of tax money by the government.

Even though the index formula allows for this mismatch, the index formula works as well as possible within the constraints of workability.

# Part I – Context: Inflation and PPP

This part will describe the context of the research. Starting with the global phenomenon of inflation, and its effects on long-term projects. It is followed by the modern contract type of these long-term contracts; Public Private Partnerships and the DBFM type in particular. The existence of inflation and DBFM contracts make indexation necessary, this method of cost escalation is explained thereafter.
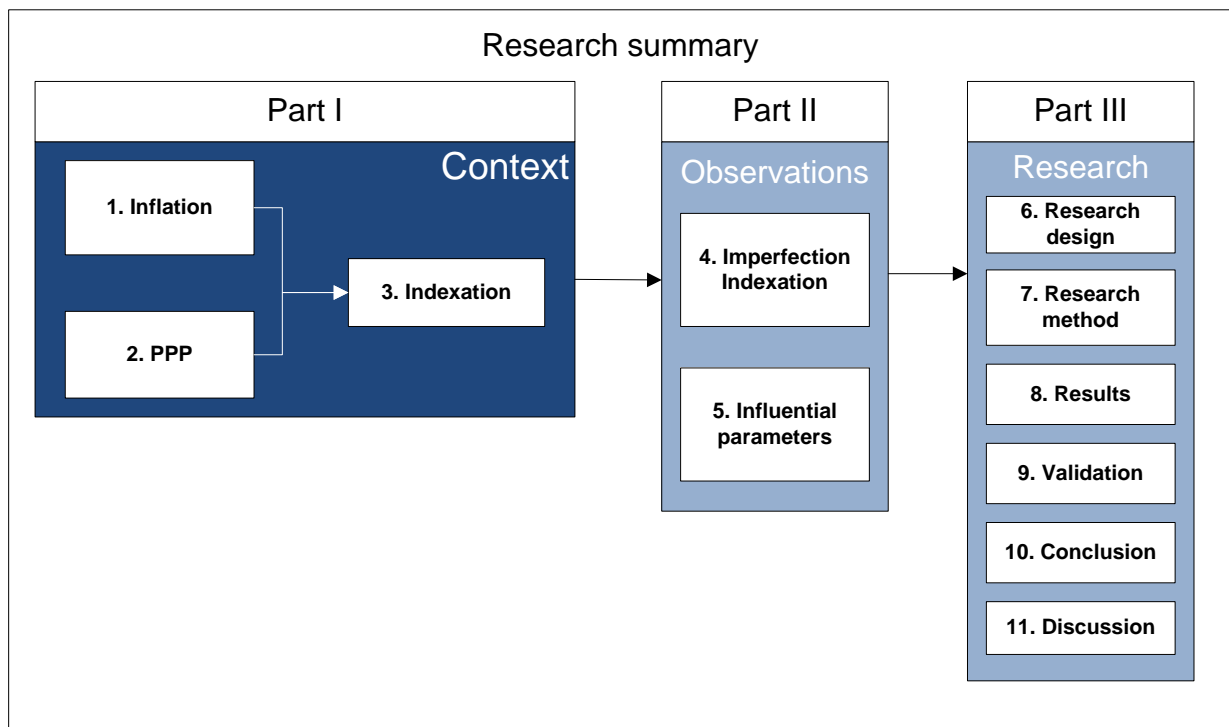
# 1. The inflation phenomenon

"*Inflation is a dangerous disease to a society*"; this is an eye-opening statement by Nobel-prize winning economist Milton Friedman to the public in the seventies (1977). In accordance with this statement, inflation has become a major concern of politicians and the public ever since (De Volkskrant, 2013) (Mishkin, 2001). Over the last half a century, inflation has seen large fluctuation from inflation rates with double digits in the 70's to deflation (negative inflation rate) in '87 (see Graph 1). But what is inflation?
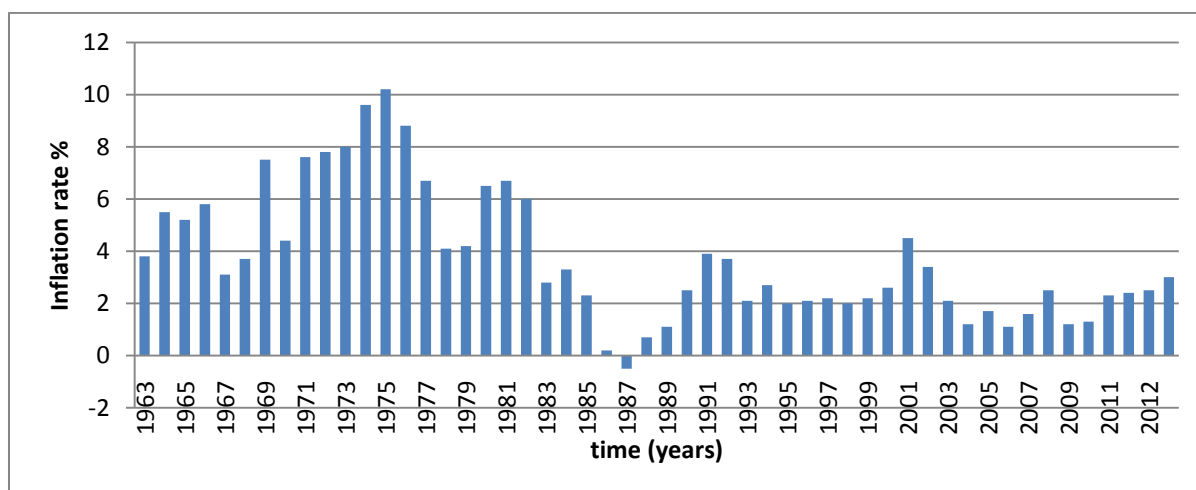


**Graph 1: Dutch annual Inflation rate (CPI) 1963- 2013**

## 1.1 Inflation

Inflation is the rising of price levels (Mishkin, 2001), or in other words, the devaluation of money (Schöndorff, 2000). The effect of inflation is a decline of the buying power per unit of a currency, which is bad for consumption and eventually the economy. The biggest danger is that of hyperinflation, where money devaluates so quickly, that workers are paid three times a day in order to pay for breakfast, lunch and dinner (Friedman, 1977).

Most economist agree that the source of *sustained* high inflation is a monetary phenomenon resulting from too much money in an economy. With sustained high inflation, the economist mean the hyperinflation as in Latin America in the 90's for instance, or German price rise in the early 20's. There is strong empirical evidence that for these cases, the growth of the money supply is to blame for inflation (Mishkin, 2001). The money supply is the amount of money available to an economy at a specific point in time. The growth of the money supply is a result of printing money or creating money by monetary authorities and banks granting loans to private parties. The motive to increase the amount of money in an economy is often to reduce unemployment by stimulating the economy or to cover the government's budget deficit (Friedman, 1977). The economic mechanism of supply and demand corrects for the (artificial) increase of demand, caused by the extra money supply, by a price level rise to balance supply with the demand. This reaction of the economy continues to occur when the input of money stays above the natural rate of growth. The rise of prices is called inflation.

Besides the decrease of buying power, inflation also has good characteristics, but those are only temporary. The increase of demand by the increase of money in an economy, encourages companies to produce more output, increasing production and employment. This effect is then compensated

when the employees' buying power decreases because of the inflation. There is a time lag here of two years in which the new equilibrium is found. Note than this effect is offset when a country is used to or expects a certain level of inflation (Friedman, 1977). Furthermore, a positive aspect of inflation is that it encourages the spending of money for investments and consumption because the buying power decreases over time.

Price stability is beneficial to an economy because it gives consumers and enterprises trust to make investments (Ministry of Finance, 2013). While there is consensus that high inflation is bad for an economy (Mishkin, 2001), most monetary authorities set an inflation level above 0%. The European Central Bank (ECB), which is responsible for money supply in the Euro zone defines price stability as:

> *"Price stability is defined as a year on year increase of the Harmonised Index of Consumer Prices (HICP)[1] for the euro area of below 2%"*

The ECB aims at just below 2% annual inflation, rather than 0%, because the rate is "*low enough for the economy to fully reap the benefits of price stability*" and it "*provides an adequate margin to avoid the risk of deflation*" (the opposite of inflation causing people to stop spending money because it becomes more valuable over time). A constant rate of inflation allows prices and all various kinds of income to increase in a similar fashion cancelling out the disrupting effects of inflation (Woltjer, 2002) (Encyclopedia Americana, 1976).

Inflation as used above is the general devaluation of money caused by the price rise of commodities in an economy as a whole. But because different products may have different prices and price changes, there are different inflation rates per product. This specific price level development is far more vulnerable to changes in supply and demand, and less influenced by long term policy of monetary authorities.

Concluding, high inflation rates are bad for an economy, but small inflation rates are maintained by monetary authorities. Inflation is generally known as a measure of devaluation of money in an economy but specific inflation rates per commodity can be defined. Inflation is a phenomenon that has to be dealt with in transactions over time, the following chapter will explain the effects of inflation on such transactions.

## 1.2 Effect of inflation in long-term contracts

Expected, regular and low inflation rates are not too harmful to an economy, because prices and incomes can stay in balance. This type of inflation does however, increase the cost of contracts. Contracts have to become more complex in order to incorporate the regularly increasing salaries and prices of commodities (Woltjer, 2002).

Transactions with a reasonable time between estimation and actual payments are subject to the inflation phenomenon described in the previous paragraph. When you want to buy a car next year, and base your budget estimates on the cost of a car this year, you will find, for example a cost of €50.000. But after a year, inflation of 3% has driven the price up to €51.500. The difference becomes exponentially larger over time and after 25 years, the price has doubled. The initial cost estimation is

---

[1] Harmonized Index of Consumer Prices is the measure of price level of general consumer goods in the Euro area, comparable to the Consumer Price Index (CPI) of the Dutch bureau of Statistics

insufficient to purchase the car because of the effect of inflation. To overcome this problem, this effect has to be taken into account in budgeting.

People have long recognized that the prices of goods, services, and assets must be corrected for the effects of inflation in order to make meaningful economic comparison over time. To correct for the effects of inflation, economists distinguish between what they call nominal prices, and real prices. (R. C. Merton, 2000). The first economist, Adam Smith, defined the difference as:

> *"The real price of everything, what everything costs to the man who wants to acquire it, is the toil and trouble of acquiring it: what is bought with money or with goods is purchased by labour. The nominal price is the price in terms of money"*
>
> (Smith, 1776).

In other words; the real price refers to the purchasing power and the nominal price refers to the price in actual currency (e.g. Euros or dollars) (Ross, 2005). The nominal price in the future can be modelled with the inflation rate, time period and the nominal price at t=0, with the following model:

$$C_t = C_t^0 * (1 + i)^{(t-t_0)}$$

$C_t = nominal\ price\ at\ t$
$C_t^0 = nominal\ price\ at\ t = 0$
$i\ \ = inflation\ rate$
$t\ \ = point\ in\ time\ at\ which\ nominal\ price\ is\ unknown$
$t_0\ \ = point\ in\ time\ at\ which\ nominal\ price\ is\ known$

Construction projects often take several years which means they are, to some extent, influenced by inflation. For example, a contractor has to estimate the cost of the construction and outfitting of an office building for its client. This estimation should then include the price rise of the carpet installed three years after the client and the contractor have agreed on a price. The contractor has to estimate the nominal price at the time the carpet is bought. Typically, cost estimates are formed in nominal prices, and escalated with an inflation estimation.

This method of incorporation the devaluation effect of inflation is highly dependent on the estimate of the inflation rate *i*. Graph 1 shows the inflation rate has roughly fluctuated between 1 and 4% during the last two decades in The Netherlands.
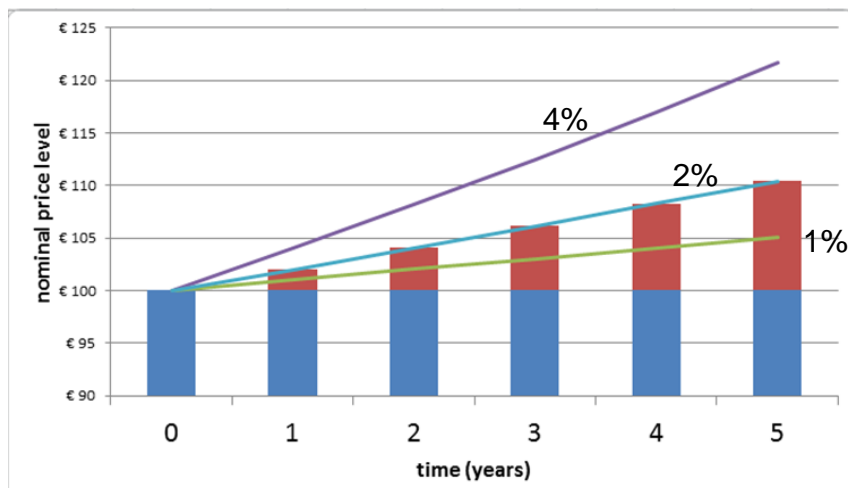
**Graph 2: The effect of different inflation rate estimates on nominal price over a five-year period**

Graph 2 shows the nominal price level change after five years with different inflation rates. This graph resembles a 5-year project with annual expenses of €100, estimated at the start of the project (t=0). The contractor estimates an inflation rate of 2% and adds the cost for inflation, depicted by the red blocks, to the budget. The risk for the contractor is that when the estimate is lower than the actual inflation rate, the nominal expenses are higher than expected and the estimated budget is insufficient. If the actual inflation rate is 4% for instance, the difference between the blue and purple line is lost by the contractor. With a lower inflation rate than expected, the contractor experiences the opposite effect, but then his bid was not very competitive.

This example also shows that over time, the different estimates deviate more and more from each other. This uncertainty makes the estimation method very difficult for long term projects.

## 1.3 Indexation as a solution to inflation problem

A famous case of the inflation problem in long-term contracts involves Coca Cola. When the company began in the early 20th century, Coca-Cola made an agreement to supply its bottlers and distributors with cola syrup at a constant price *forever*. Of course, subsequent inflation would have caused Coca-Cola to lose large sums of money had they honoured the contract. After much legal effort, Coca Cola and its bottlers put in an *inflation escalation clause* (Ross, 2005). This clause is also known as the indexation clause and will be explained in this section.

Indexation is the escalation of cashflows based on the price level development. Fixed costs or income are corrected for inflation. *Indexation* is the most commonly used word to describe this inflation correction or cost escalation. The word 'indexation' comes from the method used to define the height of the escalation. The amount of escalation is calculated by the change in price level, laid down in the price level index which is published periodically.

### Types of indexation

There are two kinds of indexation in large construction contracts; *overall* - and *selective* indexation. Overall indexation uses a general price level index to escalate all components in a cashflow. All costs with independent price level developments are escalated with an index that approaches the weighted average price level development of the different cost components. This can be the Consumer Price Index (CPI) which resembles the price rise of the cost for an average household, but

also a more typical index like the general index for Dutch infrastructure projects: *GWW algemeen*. Overall indexation was first used in 1946 for a water treatment plant in California on the progress payments to the contractor (Eaves, 1976).
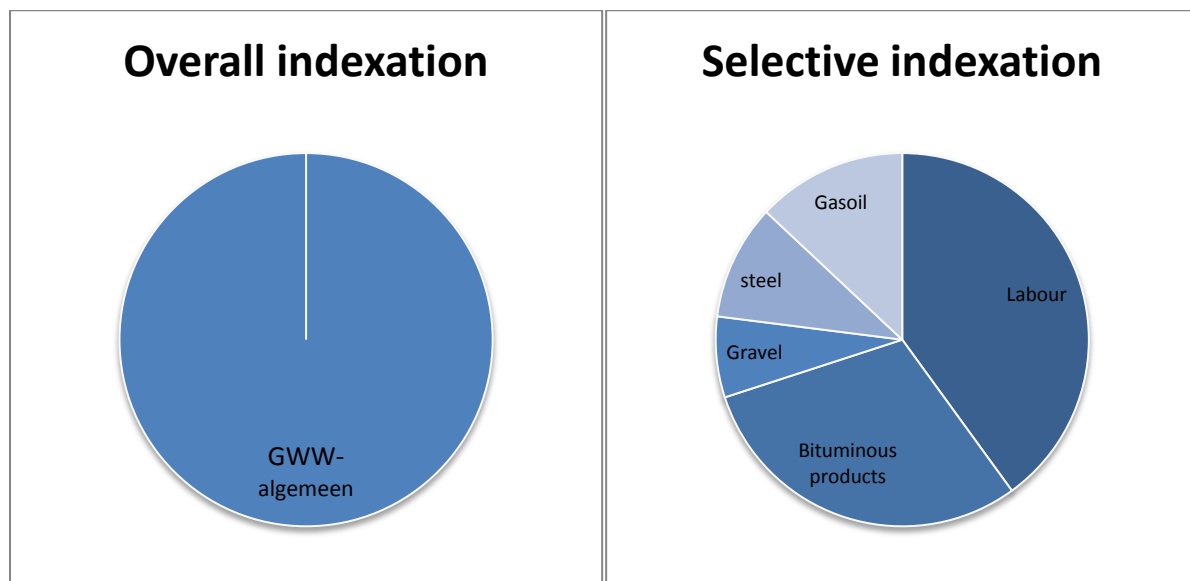


**Figure 1: Showing the difference between the two types of indexation. Overall indexation uses only one general index to represent the price rise of cost during a project. Selective indexation uses specific indexes to represent specific components of the cost of a project.**

This type of indexation became disputed in 1975, when it was used in highway contracts in the Unites States . Then, road contractors demanded escalation of asphalt and bituminous products following the unpredictable, record shattering rise of petroleum prices, this was the start of selective indexation. Selective indexation is more accurate than overall indexation but requires publication of specific price level indices (Eaves, 1976). Selective indexation allows for a specification of the cashflow according to the share of cost in a cashflow. The cost in a project for instance, consist of labour and steel, then each cost component is escalated using their corresponding price level index. Selective indexation is necessary because different commodities have different inflation rates.

## 1.4 Measurement of inflation

In the Netherlands there are two organizations that measure specific inflation rates for use in the construction sector. There is the Central Bureau of Statistics (*Centraal Bureau voor de Statistiek*), which publicizes inflation rates for general use, and there is the CROW (knowledge centre for infrastructure, traffic, transport and public space), which specifically targets the construction sector.

Inflation is the price rise of a certain good or a basket of goods between two points in time, 2% per year for instance. To compare price levels at more than two moments in time with a varying inflation rate, price level indices are used. A price level index is a set of index figures that shows the ratio between the price of a certain product in a specific period and the price of the same product in a pre-set fixed period (CBS, 2013). The pre-set fixed period is called the base year. The year of 2005 can be chosen as base year and the index figure is set at 100 for that year. With a price rise of 5% per year, the index figure of 2006 will be 105 and 2007 will be 110,25. The index figure of 2007 gives the price of a commodity compared to the price of the same commodity in the base year.

For example, if a commodity costs €5,00 in 2005, the price in 2007 can be calculated with the index figures:

$$Price\ _{2007} =\ Price_{2005} * \frac{Index\ figure_{2007}}{Index\ figure_{2005}} = €\ 5,00 * \frac{110,25}{100} = €\ 5,00 * 1,1025 = €\ 5,51$$

A price level index can be measured for every commodity for any time window. Since 1995, most price level indices are publicized quarterly and since 2010, CROW even publicized their indices monthly (CROW, 2012). CROW indices are specific to one single product used in construction, while CBS indices are aimed on comprising price level developments for specific activities in the industry. Table 1 shows the different price level indices that are published by the two different organizations.

| Price level Indices | |
|---|---|
| **CROW (specific)** | **CBS for GWW (aggregate)** |
| Labour cost | GWW-general |
| Gasoil high tax | Sewerage |
| Gasoil low tax | Roads with open surface |
| Gasoil excl. Tax | Roads with closed surface |
| Electricity | Earthworks |
| Gravel and industrial gravel | Waterworks |
| stone chippings and crushed sand | Bridges & Viaducts |
| concrete mortar | Railroads |
| Concrete products | Electrotechnical facilities |
| Cement | |
| rubble | |
| Plastics | |
| Steel for concrete | |
| Steel (excl. Steel for concrete) | |
| Bitumen for roadworks | |
| Bituminous mixes (excl. Bitumen for roadworks) | |
| Mineral asphalt mixture | |

Table 1: CROW and CBS price level indices relevant to construction industry

The CBS indices are called aggregated indices because they are built-up from a set of cost components (commodities and other resources). The aggregated indices are calculated using the three major cost components in the construction sector; labour, equipment and material. The organization uses the budgets of representative projects for each index to find the share of cost components. The index 'roads with closed surface' for instance, uses the shares in the budget of the construction of one kilometre of highway, including the asphalt, electrical installations, guiderail, cost for lab or and material. The price rise of the aggregated index is then calculated using the indices of the specific products and their representative shares in the budget. Besides the indices specifically

published for the construction industry, CBS keeps track of other aggregated price indices like the well-known Consumer Price Index (CPI) and the Producers Price Index (PPI).

The CROW-type indices are product specific indices. The organization does sample checks in a population of suppliers of a product. The given prices are proportionalized with a weight factor matching the market share of the supplier in the relevant market.

Graph 3 shows two of the price level indices of the CROW-range. This gasoil price index shows a rise in the long term but also downward motions of the index on the shorter term. The financial crisis in the end of 2008 is clearly marked with the high peak and steep downfall of the price in that period. The second line in the graph shows the index of price level developments of labour cost, which is far more stable. The graph clearly shows the different behaviour of two different indices. More about the properties of this data are discussed in Appendix A.
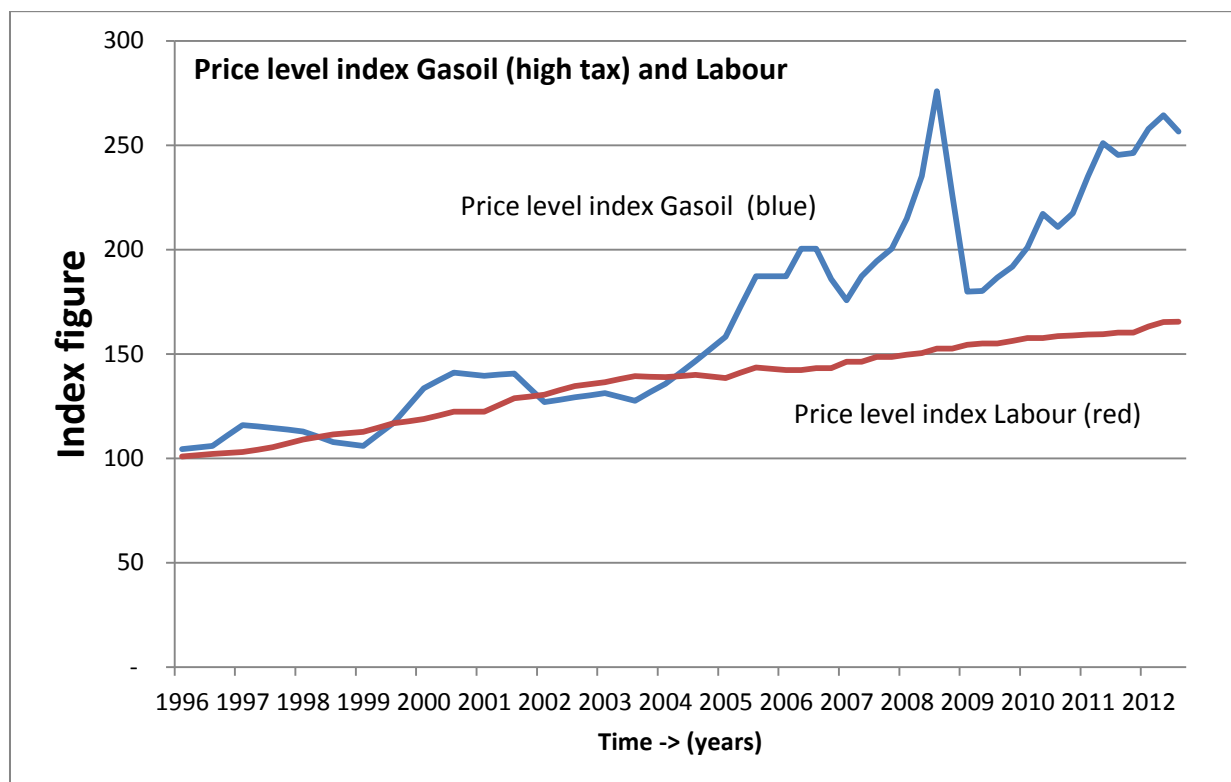


**Graph 3: Price level index of Gasoil (high tax) and Labour cost from 1995-2012**

## 2. Public Private Partnership

During the past decades, new forms of contracts have been introduced in large, long-term construction projects. This chapter will explain this modern movement called Public-Private Partnerships (PPP) and the relevance of the inflation phenomenon.

### 2.1 Introduction

Traditionally, the government is responsible for the provision of a country's infrastructure. One of the reasons is that infrastructure construction requires high initial investments and only have a return on the long-term (Yescombe, 2007). This traditional government role has changed in accordance with the zeitgeist of the 1980's called 'New Public Management'. This line of thought prescribes a roll-back of state, and the outsourcing of public services.

The tendency towards a small government has resulted in the involvement of private parties in public responsibilities and  with that, the rise of Public Private Partnership (PPP) throughout the world. The term Public Private Partnership originated in the United States, initially relating to joint public- and private sector funding for educational programs, and then in the 1950s to refer to similar funding for utilities. But the term came into wider use in the 1960s to refer to public-private joint ventures for urban renewal.

The idea behind Public Private Partnership is that the party that is most capable of carrying, mitigating and valuing a risk, is also taking it. Theoretically, this results in a better value for money and subsequently a more efficient use of tax money. The way of looking at a project from a value of money point of view is vital in the PPP mind-set. Van Ham and Koppenjan (2002) give a broad definition of PPP in the transport infrastructure sector:

*Public-Private-Partnership is a form of structured collaboration with the construction and exploitation of infrastructural facilities[2].*
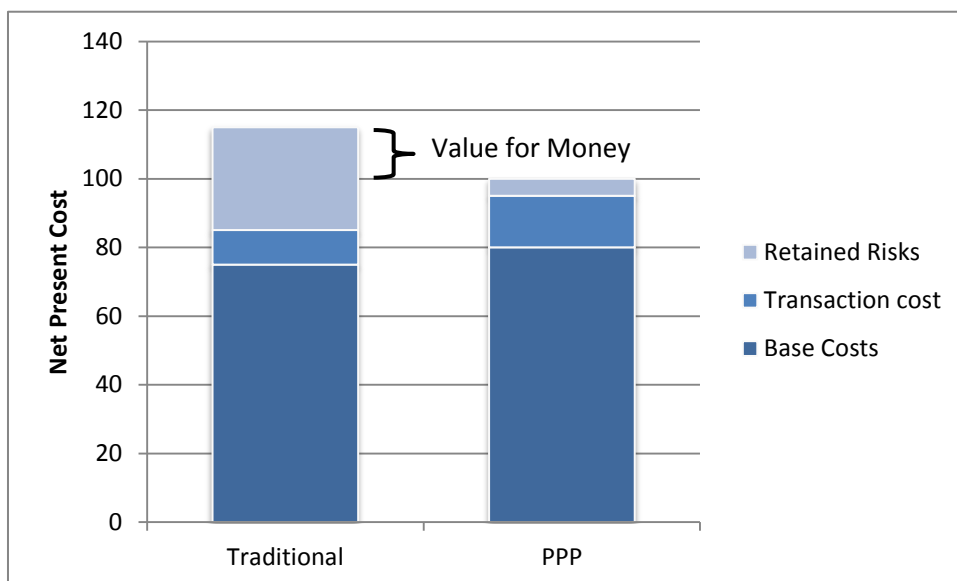


**Graph 4: Showing the difference in cost between Traditional and PPP procurement from the viewpoint of a government. Base cost including financing cost as well as the transaction cost are higher, but total cost are reduced by the transfer from risks to the party that is best able to carry it (M. Siemaiatycki, 2012).**

---

[2] Translated from Dutch: "*Publiek-private samenwerking is een vorm van gestructureerde samenwerking bij de aanleg en exploitatie van infrastructuur voorzieningen*"

PPP is widespread throughout the world and is not only limited to the developed countries, in fact PPP has seen a large increase in developing countries as it is a useful form to attract private capital (Asian Development Bank, 2008).

PPP projects come in different kinds of shapes and forms which can be roughly divided into two groups; *concessions* and *alliances* (J. Koppenjan, 2002). In a concession, the private party is granted the right of developing an infrastructure asset, in return for periodic payments after completion. The contractor is required to design, build, finance, maintain and operate the asset. In an alliance agreement, several individual projects are combined and integrated to improve value for money (Prof. dr. E.H. Klijn, 2008).

In modern PPP practice, the public authority specifies its requirements for an edifice or service in terms of outputs with a certain quality level. These requirements set out the public services which the facility is intended to provide, but which do not specify how these are to be provided. It is then left to the private sector to design, build, finance and maintain the facility to meet these long-term output specifications. A government requires a connection between two river banks for instance, and requires the connection to be available for 99% of the year. The private party is free to build a bridge or a tunnel, as long as the availability requirement is met.

The private party receives payments over the life of the PPP-contract on pre-agreed basis which are intended to repay the financing costs and give a return to investors. The periodical availability payments are subject to deductions of failure to meet the output specifications and there is no allowance for cost overruns.

In the Netherlands, the concession type is moulded in the form of a Design, Build, Finance & Maintain (DBFM) contract. The Dutch government has embraced PPP rather late, but has eventually adopted the DBFM-form and reached a European top-position in this method (Ministry of Finance, 2012). The following section will elaborate on this Dutch PPP form in road infrastructure.

## 2.2 DBFM projects in The Netherlands

Most governments use a public road authority to manage the country's infrastructure, in The Netherlands this role is fulfilled by Rijkswaterstaat (RWS). RWS is responsible for the main road- and waterway network in The Netherlands. In 2003, new government policy demanded from Rijkswaterstaat to deliver higher quality with fewer people by working more efficiently, focusing on the users of the infrastructure and cooperating with private parties. To achieve this, the authority introduced the principle of "the market unless" (*de markt tenzij*). This new principle is in line with New Public Management and means that most of the traditional tasks of RWS are being transferred to the market (Rijkswaterstaat, 2012).

As part of this "the market unless"-principle Rijkswaterstaat is increasingly realizing the country's infrastructure demands through Design, Build, Finance & Maintain (DBFM) contracts. This Dutch method is composed from the experiences abroad and took the good parts while leaving the problematic ones (Sieswerda, 2013). Especially the British Private Finance Initiative-concept has been an important inspiration (Klijn, 2007). The Dutch PPP situation is interesting because there is a large future project portfolio compared to her surrounding countries (Cate, 2013). And, according to Sieswerda (2013), He, and other experts with him (Flyvbjerg, 2003), expect that the Dutch method

will be exported in the near future when other countries adopt the DBFM-typology and apply it to the public road system.

At the time of this research, two road infrastructure projects are already in their exploitation phase, the regional road N31 Wâldwei (€135M) and motorway A59 (€218M). Larger projects are currently in construction phase like the second Coentunnel and Westrandweg (€600M), the A12 motorway Utrecht-Maarsbergen-Veenendaal (€373 M), and the A15 Maasvlakte-Vaanplein (€1,2B). In the near future, DBFM projects will be realised on the Schiphol-Amsterdam-Almere (SAA) corridor (4 projects totalling €4,1B). After that, the portfolio will likely be filled with projects improving the highway infrastructure around Rotterdam, on which studies are now being performed (PPS Netwerk, 2012).

One must note that the DBFM method is a small part of the total infrastructure expenses of the Dutch government. Expenses for DBFM projects are limited to 20% total infrastructure expenditure in order to prevent future budgets to be spent already (Algemene Rekenkamer, 2013).

## Mechanism of DBFM contracts

The Design Build Finance and Maintain (DBFM) contract is the preferred PPP-form of the Dutch government. In DBFM contracts with Rijkswaterstaat as principal, the private party is responsible for the design, construction, financing and maintenance of an infrastructure asset. The contracts are initiated by Rijkswaterstaat, but she does not fully specify her demands, instead, she describes the requirements on a functional level. The private party is then free to design a solution that meets the functional requirements. This responsibility also brings forth large risk, shared between different private parties in a consortium, which are organized in a Special Purpose Company (SPC). The 'F' component in DBFM means that the consortium is responsible for the arrangement of funds needed to invest in the construction phase. The consortium shareholders are mostly contractors and investment funds. The financing is commonly done through equity from the consortium and debt, provided by financial institutions like banks (J.H.W. Koster, 2008).

In return for the availability of the asset during the exploitation period, the SPC is paid by Rijkswaterstaat for the service provided (transportation link) through a quarterly Availability Payment (AP). The availability payment is used to repay the debt incurred by the SPC in the design and construction phase as well as the costs of maintenance over the exploitation phase. The availability payment is dependent on the quality of the service provided; when predetermined performance levels are not met, fines are deducted from the availability payment.

In order to get the assignment for a DBFM project, contractors have to participate in tenders. Public authorities like Rijkswaterstaat hold tendercompetitions in order to find the best party for their project. In these competitions, contractors (often organised in consortia) compete with each other to make the best offer. This offer consists of a price as well as quality documents. In these documents, the contractor is able to show their design solutions, risk mitigations and other aspects which are beneficial to the value for money. This qualitative value is quantified by an assessment on EMVI-score (EMVI = Economically most beneficial offer). The contractor with the best combination of price and EMVI-value is awarded the DBFM-project.

## Cashflow DBFM

To understand the mechanisms behind DBFM-contracts, insight in the cash flow is very important and clarifying. Graph 5 shows an example of a schematic cash flow of a DBFM-contract. Below the

horizontal time-axis are the expenses of the contractor, starting orange with tender and preparation cost, followed by the red peak in construction costs. After construction, the operational phase starts where the largest part of expenses consists of the repayment of debt incurred to fund the construction activities. The repayment of debt and interest payments is called *debt service*. The other two expenditures in lighter blue are the constant regular maintenance costs and peaks of large maintenance activities. Regular maintenance is for instance; mowing of grass and regular inspections. Large maintenance examples are resurfacing of the road, replacements of expansion joints and lighting replacements.
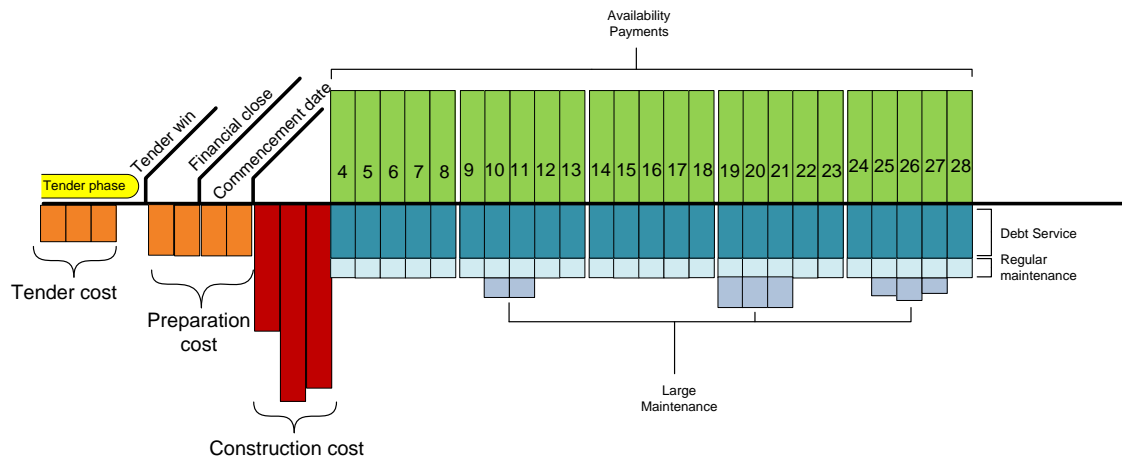


**Graph 5 Basic Cash flow of DBFM project, showing tender- and design cost (orange), followed by high cost for construction. When construction is finished, the private party is paid for the availabilty of a service through periodic Availability Payments (green. During the exploitation phase the private party uses these incomes to repay loans and pay for maintenance activities (blue).**

All these expenses should be reimbursed by the Availability Payments (green) over the operational years of the project. These payments are reduced with fines when availability or other quality standards are not met. The amount of the availability payments is based on a repayment of the expenses of the contractor, so the difference in income and expenses is zero. Of course, a reasonable profit for the private party is included in this calculation.

## Benefits and drawbacks of DBFM

Now that the workings of DBFM agreements are explained, the benefits as well as the downsides are elaborated, starting with the benefits which are listed below (Yescombe, 2007) (Ruding, 2008):

- The initial investment cost of DBFM projects fall outside the government budget, this enables the public sector to make (or accelerate) investments in infrastructure which would otherwise have not been possible.
- DBFM offers improved "Value for Money" (VfM) through the transfer of risk to the private sector. The private sector would be better able to manage the risks and offers therefore better VfM.
- DBFM offers improved VfM trough life-cycle costing, because the same investor is responsible for construction and maintenance, they are incentivized to minimize life-cycle

cost. Private investors may be prepared to spend more on the initial investment if this will result in a greater saving in maintenance cost.

- DBFM contracts make better use of private sector skills. The private sector is considered to be superior to the public sector in e.g. project management, efficiency and innovation.
- A role for the financial parties as supervisors, because they have money invested in the project, the banks and other institutions check on the contractor's work.

However, the DBFM agreement is not perfect; DBFM projects also have drawbacks. Theoretical and practical shortcomings are listed hereafter;

- The private party borrows money at higher cost than the government. Interest rates are lower for a stable government than for (a consortium of) companies that are able to go bankrupt. Therefore the financing is more expensive with a PPP structure. (Yescombe, 2007)
- PPP projects have higher transaction cost than traditional projects because they require a more extensive purchasing process. Moreover, the contract complexity requires the public authority to thoroughly prepare the agreement, which takes time and money. This is costly and time consuming for the public party as well as for the contractors (Peijs, 2005) (Ruding, 2008).
- After the lengthy preparation, a longer than traditional purchasing period in the form of a tendering procedure takes place. This delays the actual completion of the asset (Ruding, 2008).
- Lack of integrality and cooperation in consortia. Large projects are often done by a consortium of different private parties. Practice shows that the cooperation between these parties is problematic. In the handling of fines for instance, it is unclear which party takes responsibility (Rebel Group, 2011).
- Practice also shows the letter of the contract is not followed precisely. Fines are often used as negotiating material resulting in different behaviour than is meant by the incentives in the contract. (Rebel Group, 2011)
- The realization of changes in the project scope is problematic. Changes introduce new risk to the private party. Subsequently, the private party demands very high reimbursements for changes in the contract. Procedures that are designed to include flexibility in PPP projects are often very time consuming (Rebel Group, 2011). The participation of risk-averse banks in the financing component is the most important cause for this unwillingness for change .

DBFM projects have their drawbacks but the Dutch government still believes the benefits outweigh the drawbacks. This PPP model will be used in the near future and extended to waterway infrastructure. The Dutch government lets us know; PPP is here to stay (Ruding, 2008).

# 3. Indexation

This chapter will describe indexation, a method of handling the inflation phenomenon from chapter 1 in the Public Private Partnership contracts described in chapter 2.

## 3.1 Indexation in Dutch DBFM projects

The contract period of DBFM projects generally ranges between 20 to 30 years, and as explained in Chapter 1, lengthy projects introduce inflation risk. Inflation risk is the risk of higher price rise than expected, resulting in higher cost with a negative effect on a project's budget. In accordance with the PPP-principle where the party best able to carry a risk, is taking it, a Dutch DBFM agreement includes an indexation clause to transfer the consequences of inflation risk. This chapter will explain the used indexation mechanism laid down in such an agreement.

The risk of price level development is transferred from the private party to Rijkswaterstaat because she is best able to carry that risk. Rijkswaterstaat can carry the risk because her annual income from the central government is also corrected for price level development. If this is not the case, like it is at the moment due to budget cuts of the government, Rijkswaterstaat gets into trouble just as a private party would do. The current policy of the Dutch government has frozen the budgets, resulting in the eroding of the capacity of the budgets (Cobouw, 2013).

The goal of the mechanism is to escalate the income of the private party according to the increase due to inflation of his expenses. The starting point of the indexation mechanism is therefore the income of the private party; the Availability Payment (AP, (*Bruto) Beschikbaarheids Vergoeding*). The AP is paid quarterly and is the leading parameter in a tenderbid on which projects are awarded.

Each quarter the AP is corrected for inflation by multiplying it with the Index Number. The index number is a weighted average of the price change for different commodities measured in their respective index figures. Equation 1 in the box below shows the calculation method of the Index Number. The Dutch DBFM indexation method is of the selective type because it specifies the price level change of different commodities.

$$\text{Index number}_{t,p} = 1 + \sum_{n=1}^{6}(a_{n,p} * m_{n,t})$$

Index number $_{t,p}$ : index number for year t in period p

index n : index group n

period p : 5-year period

$a_{n,p}$ : weighting factor of index n in period p

$m_{n,t}$ : mutation of index n in year t calculated as:

$$m_{n,t} = \frac{i_{n,t}}{i_{n,t=0}} - 1$$

$i_{n,t} = index\ figure\ for\ index\ group\ n\ in\ year\ t$

$i_{n,t} = index\ figure\ for\ index\ group\ n\ at\ financial\ close$

Indexfigure : a figure publicized by a statistic agency like CROW, CBS or Eurostat describing the proportion between the value of a quantity in a specific period compared to that of the base period.

**Equation 1: Index number calculation; part of the indexation formula (Rijkswaterstaat, 2010)**

In order to establish the index number, the index clause demands that the private party fixes which indices are to be used with what weighting factor. The private party has to fix these parameters for each period of five years during the exploitation phase. The parameters are already fixed in the tenderbid because indexation influences the price in the bid and therefore influences the competition. No changes can be made during the duration of the contract because it would harm the fairness of the tendercompetition. An explanation of this effect is given later in this chapter. In order to get a better understanding of the meaning, use and relationships between the elements *index number*, *index figure*, *index group* and *weight factor*, Figure 2 shows them in a scheme.
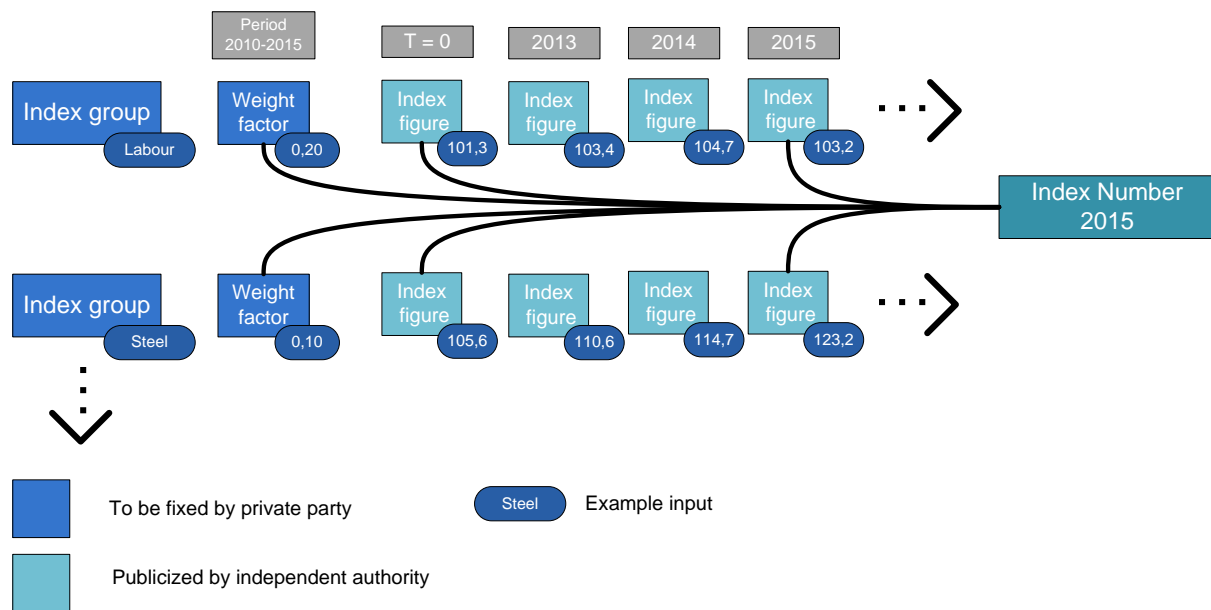


**Figure 2 parameters of the index formula and their relationship used in the index clause. Each indexgroup consists of a set of data called index figures. These index figures resemble the price change between different points in time. By taking a weight factor into account, a cost item can be decomposed in, for instance, labour and materials.**

The number of index groups that can be chosen to resemble the cost components is limited by the arbitral number of six. This limitation improves workability and forces private parties to use aggregated indices.

Both the weight factors per period and the chosen indices are laid down in a table supplied in the contract (Table 2). The indices are to be chosen in order to represent the share of each index group per maintenance activity in a five-year period. When the parameters perfectly match the maintenance activities, the risk of price rise is –theoretically- fully transferred. When the match is inaccurate, a residual risk remains at the contractor. The mechanism will be explained with an example.

| n | index n | publishing Authority | publication period | $a_{n,1}$ | $a_{n,2}$ | $a_{n,3}$ | $a_{n,4}$ | $a_{n,5}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | [••] | [••] | January | [••] | [••] | [••] | [••] | [••] |
| 2 | [••] | [••] | January | [••] | [••] | [••] | [••] | [••] |
| 3 | [••] | [••] | January | [••] | [••] | [••] | [••] | [••] |
| 4 | [••] | [••] | January | [••] | [••] | [••] | [••] | [••] |
| 5 | [••] | [••] | January | [••] | [••] | [••] | [••] | [••] |
| 6 | [••] | [••] | January | [••] | [••] | [••] | [••] | [••] |

**Table 2: supplied table to fix index parameters (Rijkswaterstaat, 2012)**

<u>Example I</u>

Take project A, the mowing of a lawn by lawnmower over five years, commissioned by Lord Green.

| | | |
|---|---|---|
| Annual cost fuel: | €30 | - subject to inflation |
| Annual cost labour: | €70 | - subject to inflation |
| annual debt service for lawnmower loan: | €100 | - not subject to inflation |

Annual Availability Payment: €200

<u>Case 1:</u>

Annual inflation on fuel: 4%
annual inflation on labour: 6%

index weighting factor fuel: 30/200=0,15
index weighting factor labour: 70/200=0,35

actual cost over 5 years:

| Year: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Fuel** | 31 | 32 | 34 | 35 | 37 |
| **Labour** | 74 | 79 | 83 | 88 | 94 |
| **Debt service** | 100 | 100 | 100 | 100 | 100 |
| total | **€205** | **€211** | **€217** | **€224** | **€230** |

Inflation correction on Availability payment, following Equation 1:

| Year: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $m_{fuel}$ | 0,04 | 0,08 | 0,12 | 0,17 | 0,22 |
| $a_{fuel}$ | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 |
| $m_{labour}$ | 0,06 | 0,12 | 0,19 | 0,26 | 0,34 |
| $a_{labour}$ | 0,35 | 0,35 | 0,35 | 0,35 | 0,35 |
| *Index number* | 1,027 | 1,056 | 1,086 | 1,117 | 1,251 |
| **Indexed AP** | **€205** | **€211** | **€217** | **€224** | **€230** |

## 3.2 Other indexation clauses

The described index clause is not the only method used to transfer the risk of inflation from the contractor to the Public Authority. The Dutch government building service (Rijksgebouwendienst) does not cut up the exploitation period into five-year chunks but leaves the parameters unchanged during the entire contract-period . The building service does allow for unlimited  specification of product groups; the choice of index groups is not limited to six as is the case for infrastructure projects (Rijksgebouwendienst, 2012).

One of The Netherlands' first DBFM-projects, the second Coentunnel, also uses a different formula. The index clause in this contract states that the weight factors are fixed per year instead of per a period of five years. Another difference to the clause in the standard contract is that the contractor is not free to choose which index groups are to be used in the formula, six commonly used indices are fixed by the Public Authority (Coentunnel Company B.V., 2008). The effect of these differences is still unknown because the Coentunnel project is still in its construction phase without indexation. (Eynde, 2013)

Despite these differences in indexation clauses, this research will focus on the method used in Rijkswaterstaat's standard contract. It is unchanged in the last three versions and is expected to remain that way in the future DBFM projects (Cate, 2013). Also because of the focus on road infrastructure, the index clause of the government building services will not be part of this research.

## 3.3 Indexation influence on tenderbid

As stated above, the indexation influences the tender bid because when comparing the bids, Rijkswaterstaat makes assumptions on inflation percentages in order to estimate the cost after inflation correction. In the case of example I, the principal would make an estimate of the inflation for the coming years based on historical figures. Then he calculates the index correction as done in the example. This bid is then 5x200 + index correction which is 5 + 11 + 17 + 24 + 30 = 87, totaling €1087 with assumptions of 4 and 6% annual inflation for fuel and labour respectively (see example 1 on previous page).

A second lawnmower-contractor that entered the competition set his index parameters all on 0, taking the entire inflation risk on his own. This contractor uses the exact same way of working and therefore has the same cost components (fuel and labour) as in example I. To cover this risk he asks for a higher annual payment; €205. The total cost of the second bid comes to 5 x 205 = €1025 which is lower than the bid from the first contractor. This contractor however, is exposed to the risk of inflation. In the case that the inflation is at the level expected in example I, 4% on fuel and 6% on labour, the contractor loses €1087-1025 = €62 (5,7% of his bid).

This example shows that choices on index parameters influence the tender competition. Strategic choices can be made based on how much risk a contractor wants to take or transfer. This also makes clear why it is demanded that index parameters are fixed in the tender bid for the entire exploitation period; because changes would undermine the fairness of the tender competition.

With the mechanism and goal of the index clause in Dutch DBFM contract clear, it is possible to take a critical look at the clause. This will be done in the following chapter.

# Part II - Observations

This part will describe observations on the indexation method. Imperfections of the method are revealed one at a time. These imperfections will introduce the existence of the index-gap which is the subject of this research. The introduction of the index-gap is followed by an explanation of the influential factors for the index-gap and eventually narrows these factors down to a researchable scope.
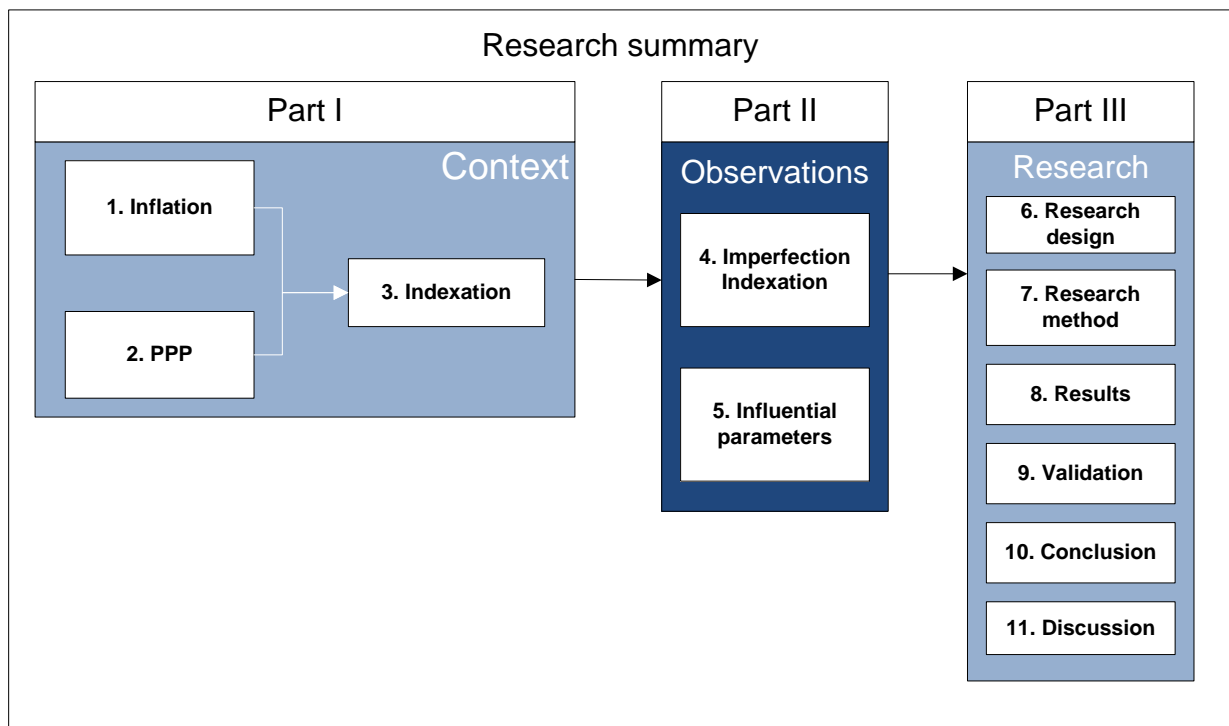
# 4. Imperfection of Indexation method

The Rijkswaterstaat method uses a formula that models reality. Inherent to being a model, it is a simplified version of reality. Assumptions are made that make the model workable but also leaves residual risk that is not transferred to the public authority. A 'gap' exists between the formula and reality. The result of this gap is that the actual cost change caused by volatile inflation is not perfectly followed by the inflation correction calculated with the index formula. The following five causes for this gap have been identified and will be described in this chapter;

- *Gap 1:* Inequality between aggregated index and composite maintenance activity
- *Gap 2:* Inequality between inflation correction spread over 5 years and maintenance expenses peaks
- *Gap 3:* Inflexibility of index formula regarding uncertainty of maintenance activities' timing
- *Gap 4:* use of outdated index figures in inflation correction
- *Gap 5:* strategic commercial choices

The five gaps are found by means of interview with experts (see Appendix C: List of interviews) as well as calculation tests. Small models have been used to research each component in the index formula to uncover the five gaps.
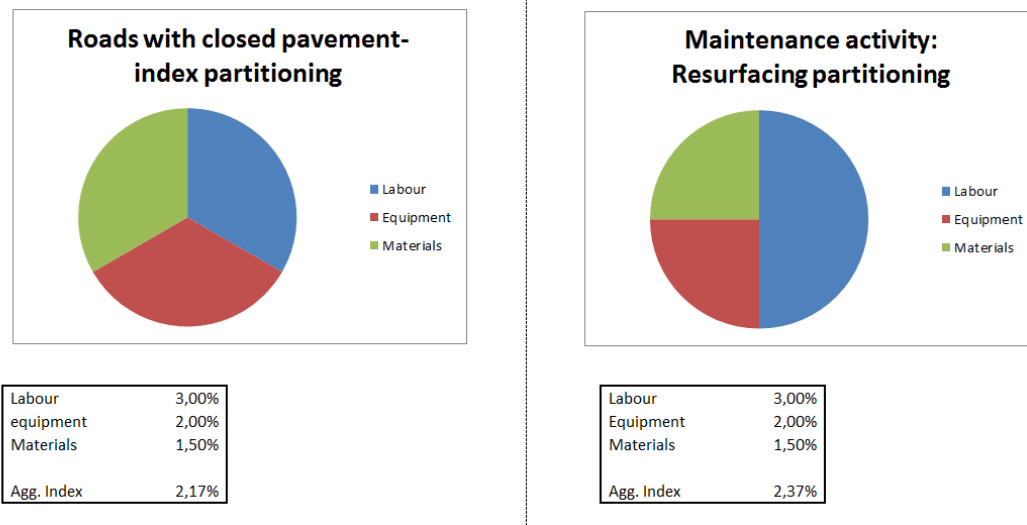
## 4.1 Gap 1: inequality between aggregated index and composite maintenance activity

The first imperfection is that of a mismatch between a grouped index and a grouped activity. Some indices are composed of different other indices (aggregated indices). The commonly used Consumer Price Index for instance, is composed of goods and services consumed by the average household. This 'basket' is filled with daily groceries, durable consumption goods like washing machines and cars, rent, educational fees and road tax (CBS, 2008). A household that does not own a car, will not be affected by inflation on road taxes, gasoline or cars. Because the CPI uses an average expenditure 'basket', individual cases will not perfectly match the inflation figure. The expenses of the carless household will have a lower inflation rate than the CPI when car-related expenses have a relatively high inflation rate compared to groceries and education fees.

This principle also goes for the infrastructure sector, where the composite index '*Roads with closed pavement*' is commonly used in indexation in DBFM contracts. The index is based on a budget of one kilometre of motorway and the budget of the matching four kilometres of guardrail. The shares of labour-, material- and equipment-cost in these budgets are used as factors to compose the '*Roads with closed pavement*' index (Elfering, 2008). Similar to the carless household, when a project's road repair expenses do not match the average factors in the aggregated index, a different index figure is applicable to the reality of the activity. Hence the gap between the model and reality. The formula in the indexation model uses a different index figure than reality, which results in a difference between actual expenses and actual correction of the annual payment.

Ideally, the private party would specify the activities to a very detailed, perfectly specified level. If the private party decomposes an asphalt maintenance activity into labour, bituminous products, gasoline, equipment, waste disposal, paint etc. the cost development of the activity is theoretically matched by the set of indices. However, this is very time-consuming and the model in the contract

limits the number of indices that can be used. These two reasons make it necessary for contractors to use composite indices like the 'road with closed pavement'-index.



**Figure 3 inequality between aggregated index and its composite maintenance activity. Aggregated index (left) has a different combination of shares of labour, equipment and materials than the maintenance activity it should represent. The result is a different inflation rate for the aggregated cost.**

The inequality between an aggregated index and its composite maintenance activity as depicted in Figure 3 creates a gap between the actual cost of inflation and the index-clause calculated cost of inflation. This gap results in extra cost or income for the private party and is the first of five index-gaps.

## 4.2 Gap 2: Inequality between inflation correction spread over 5 years and maintenance expenses peaks

The index formula (Equation 1) allows the contractor to choose six specific indices with a weight factor. Each 5-year period the weight factor may be set at a different level matching the expenses in that specific period, see Figure 4.
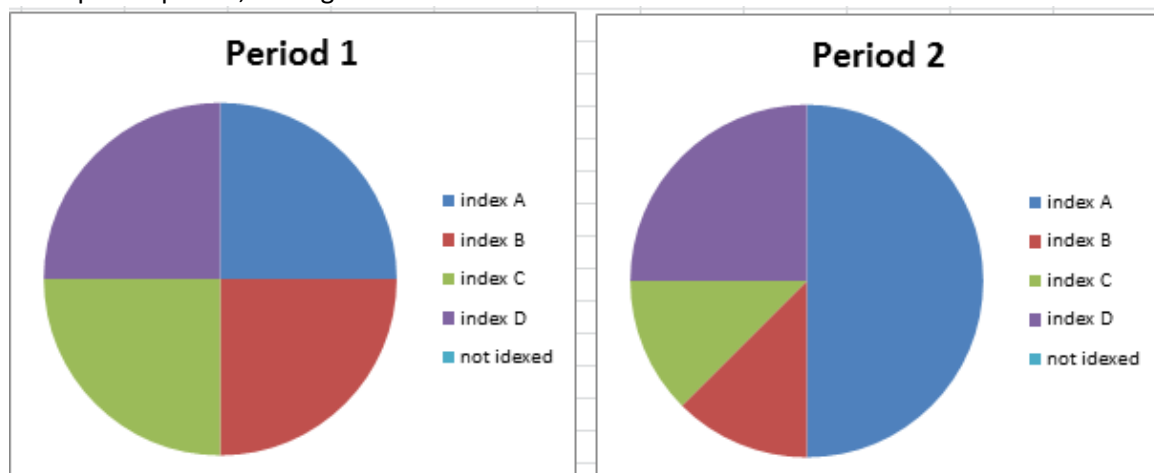
**Figure 4: Example of different weight factors per 5-year period**

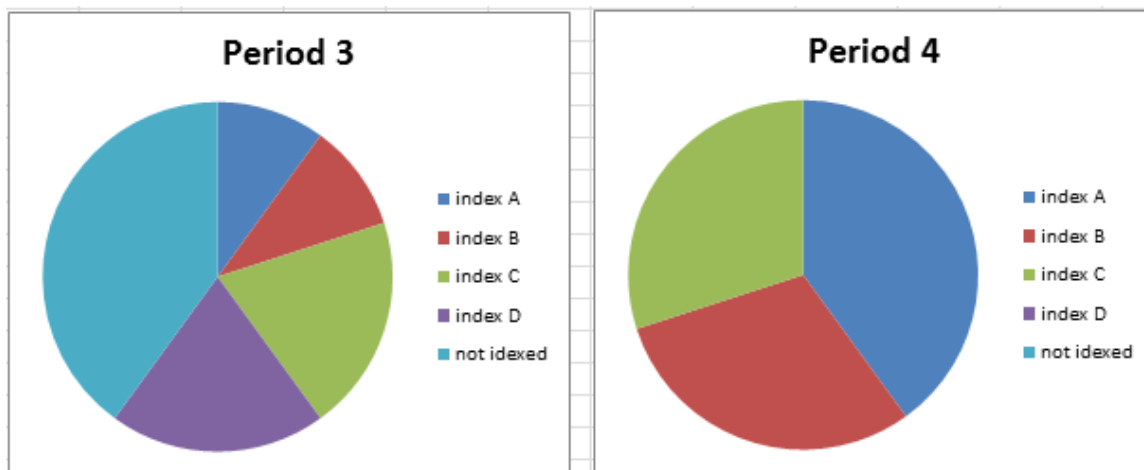With this mechanism in the model, it is assumed that the amount of expenses per index remains constant during the 5-year period. This assumption does not match reality, creating a second index-gap. This gap will be illustrated with an example.

**Example 2**

This example uses a 5-year project and will only have expenses in year 1 and 2, while the availability payment is spread over the 5-year period. During these years, the inflation percentage related to the expenses is constant at 5% per year.

The expenses in the first two years are repaid by the availability payments during the full five years. These are corrected for inflation using the index number calculated by the index formula for each respective year. Graph 6 shows the cashflow diagram of this case.
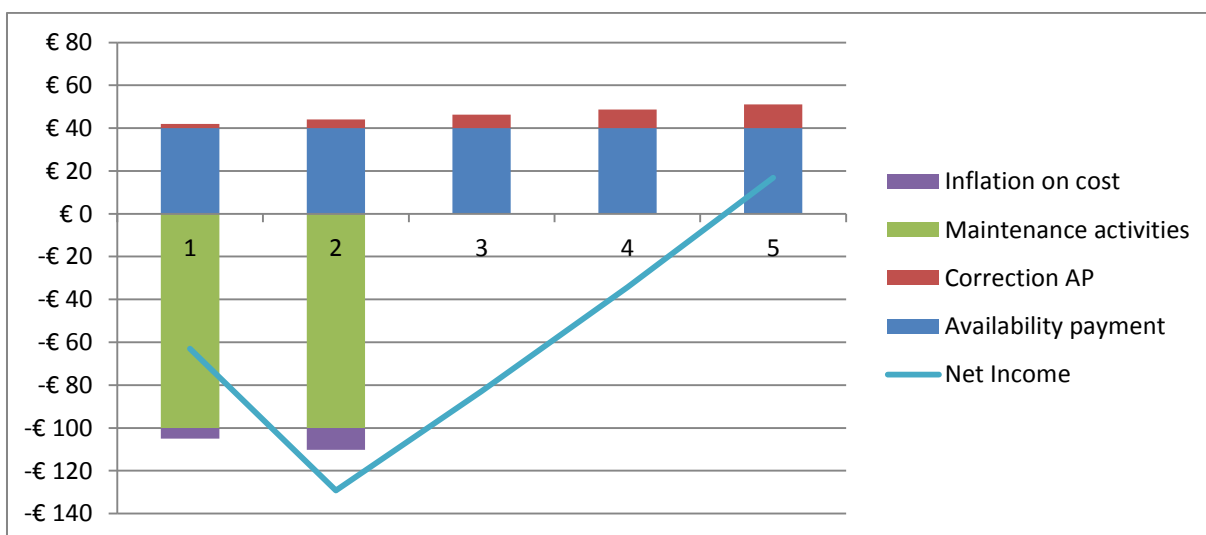
Because inflation is corrected over the entire 5-year period, inflation cost that have not been made by the contractor are repaid nonetheless. The correction is calculated with inflation over inflation, creating the mismatch. The averaging index formula does not accurately correct the spread-out availability payment. This results in a positive outcome for the contractor of €17, which is 8,5% of the

total project cost (€17/€200 * 100%). The outcome can be either positive or negative for the contractor, depending on the timing of the cost and the inflation rate of the cost component during the 5-year period.

Example 2 shows there is a residual risk for the contractor, in this case resulting in a positive profit. This gap between actual extra cost due to inflation and the calculated extra cost is caused by the assumption of the index formula that costs are spread evenly over each five-year period. This is called index-gap 2.

## 4.3 Gap 3: Inflexibility of index formula regarding uncertainty of maintenance activities' timing

The third index-gap is caused by uncertainty of the maintenance planning. The weight factors that have to be fixed in the index formula are based on the activities executed during the operational phase of the project. The contractor designs a maintenance planning that gives insight in the activities and their cost components. The maintenance planning is used as input for the calculation of the weight factors.

This maintenance planning however, is an overview of the expected activities at the expected point in time. Especially the timing is subject to change due to changing conditions in the assets' environment, manufacturing methods and lack of knowledge. A maintenance interval of resurfacing of an asphalt layer for instance, is highly dependent on the load it endures in the operational phase. furthermore, if the asphalt is laid during a rain shower, the technical lifetime is reduced as well (Moenielal, 2013). There is uncertainty in the planning of maintenance activities and therefore in the cashflow. These dynamics will be elaborated in Appendix B: Explanation of strategy performance model
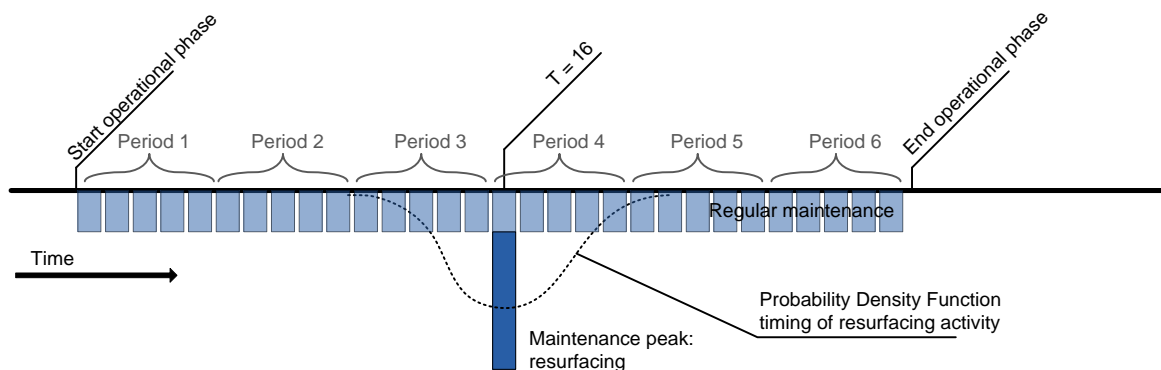


**Figure 5 uncertainty in maintenance planning. The peak in expenses due to resurfacing maintenance is uncertain and may vary from the budget.**

The figure above shows the uncertainty in a cashflow schedule. The resurfacing maintenance in year 16 gives a high peak in that year's expenditure. This expenditure is subject to inflation and therefore a large weight factor is fixed for the fourth period. But, as the probability density function of the resurfacing shows, it is very well possible that the resurfacing will be necessary in year 15 or 17. When the peak falls in year 15, it also falls in 5-period three instead of four. The inflation correction in this case does not match the actual incurred extra inflation cost.

So the basis on which the parameters for the index formula are chosen is uncertain. Because the model uses a 5-year period to spread the distribution of the inflation correction, planning shifts of activities within this five-year period does not introduce risk (except for the second residual risk described in the previous paragraph). But when activities are shifted outside the 5-year period they are planned for, there is room for a large mismatch between the composition of maintenance activities and the composition of the index weight factor-pie. Further clarity will be given in Example 3.

**Example 3**

This example uses a road maintenance project of ten years, divided in two periods of five years with different weight factors resembling the activities executed during a period. In this case, each year €100 is spent on grass mowing, and in year 6-7 a peak in expenses is present when the road is resurfaced. Because of the difference in expenses between the two periods, they have a different weight factor set, as can be seen in the pie-charts below.
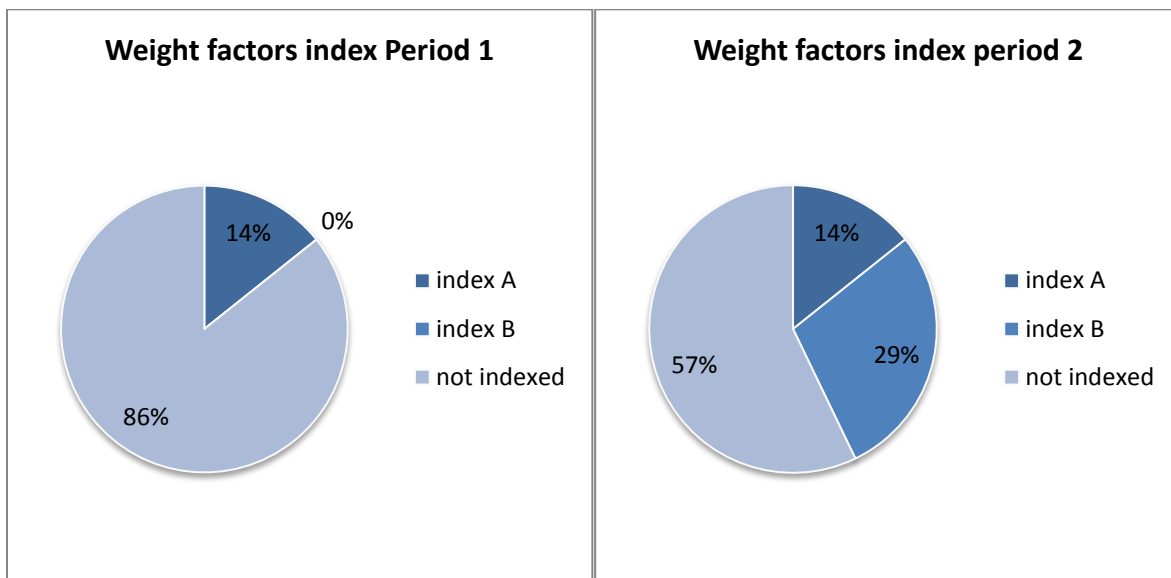


**Graph 7: pie charts of the different weight factors in the two periods of the example. Large maintenance is budgeted in the second period causing a big weight factor for index B which resembles the commodities for large maintenance.**

As can be seen in the cash flow graph, the cumulative income after ten years is 0; the income and expenses are in total balance. This is possible because the extra cost of inflation are met by extra income through the inflation-corrected Availability Payment. The yellow and red line represent these amounts and show that the surface below the red line and above the yellow line level each other out (except for the small deviation due to gap 2).
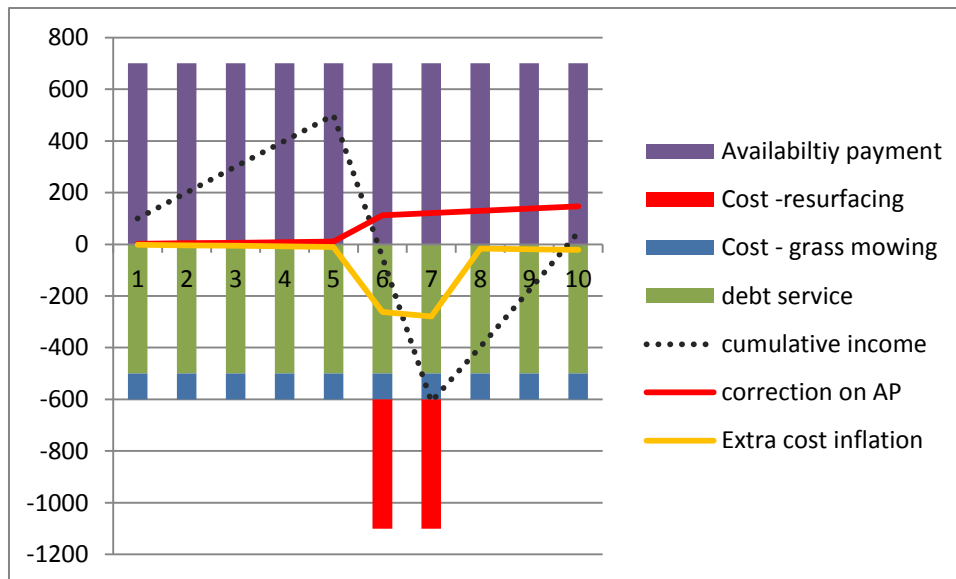
**Graph 8: the cashflow of the example project with the large maintenance cost in the second 5-year period; year 6 and 7. The extra cost due to inflation is depicted by the yellow line, and subsequently compensated by the red line, which shows the inflation correction payments. The dotted line shows the cumulative balance between income and cost, resulting in zero at the end of the project.**

These weight factors are fixed, but as stated before, the planning of the maintenance activities is subject to many factors and might change. The following graph shows the situation where the resurfacing peak is brought forward two years. In this case the inflation correction does not correspond to the weight factor-pie anymore.
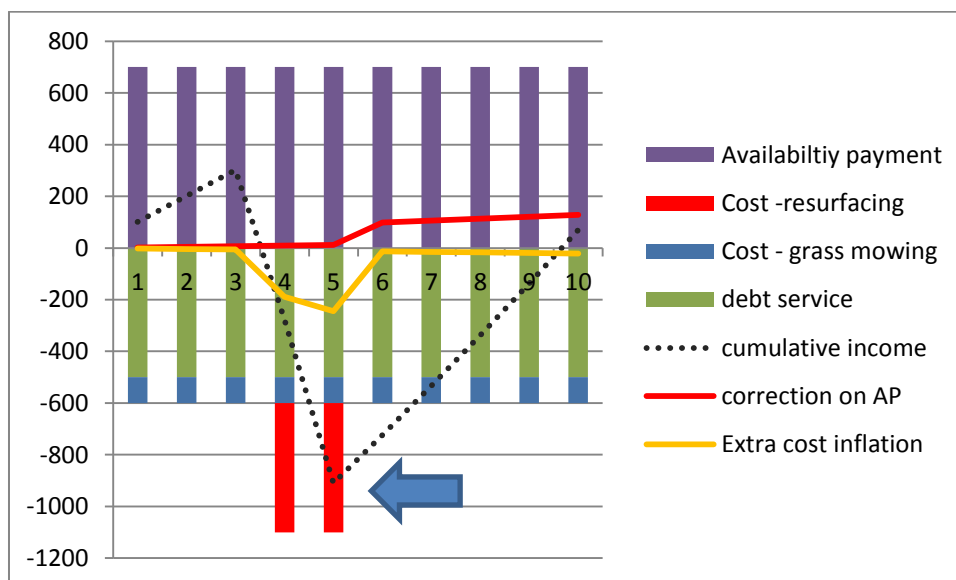


**Graph 9: this cashflow shows the same project as in Graph 8 but here the large maintenance is pulled forward, resulting in a mismatch between the cost of inflation and the inflation correction. The yellow and red line are not mirrored resulting in a deep dip of the cumulative income but eventually a positive value in year 10.**

In the second case, the cumulative income has a far larger dip which means extra money has to be available to pay for the resurfacing. It also shows a positive final balance (dotted line) because the extra cost incurred in year 4 and 5 due to inflation are corrected over the years in the second period, including the inflation in the previous years.

The difference between the inflation correction and the cost for inflation caused by the change of the moment cost are being made can be amplified by the volatility of price levels. If, in this example, the cost for large maintenance in year 4 and 5 are at a moment in which prices are very high, cost for inflation are increased. If the price levels fall in year 6 to 10, the amount of inflation correction is lower than necessary for the reimbursement of the inflation cost in the year 4 and 5. This results in a mismatch with negative implications for the private party.

Concluding, the assumption in the index formula that the maintenance planning is fixed creates a discrepancy between the real cost of inflation and the index-formula calculated cost of inflation. This is called the third index-gap.

## 4.4 Gap 4: Use of outdated index figures in inflation correction

The fourth gap is caused by the *annual* time scale used for *quarterly* inflation correction. The index clause states that the mutation in price level is calculated with the index of January of the year the inflation correction is to be paid. This mutation is then used to calculate the inflation correction over the four following quarters. When prices rise constantly, or prices change overnight or at least on a smaller timescale than a year, this method causes a mismatch between actual cost due to price rise and the correction paid by the public authority.
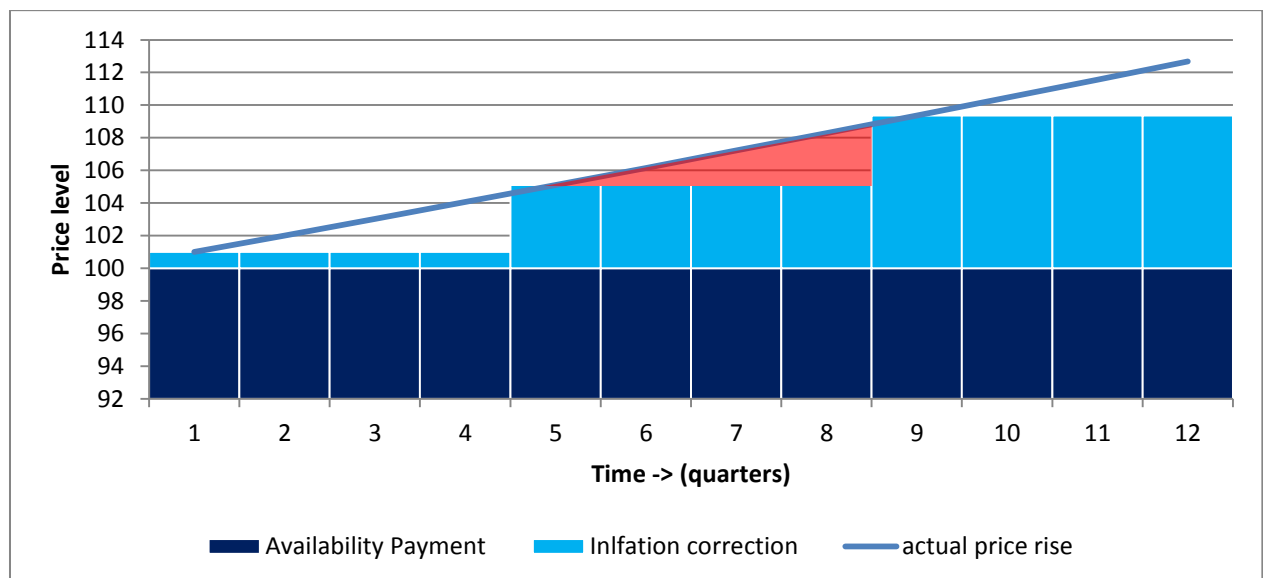


**Graph 10: Visualization of Gap 4; difference in quarterly and annual price level rise**

Graph 10 shows the mismatch between the inflation cost and the inflation correction over the course of a three year period. The red triangle between the inflation correction and the actual price level represents the mismatch of this gap. This is a simple example with a constant price rise over the timeline. With more volatile price levels, like materials such as bitumen and steel, the mismatch might even be larger.

In total there are four kinds of index-gaps. They have influence on both the tender bid and the actual exploitation budget. The gap size is not known but in large infrastructure projects even changes in percentiles can result in millions of difference because of the long time span and large amounts of money that characterize these projects. Besides that, tenders with bids of hundreds of millions are sometimes lost over a few thousand euros, so even the smallest changes in budget can influence the scoring of a tender.

## 4.5 Gap 5: strategic commercial choices

The index formula also allows for strategic commercial behaviour of the private party. Because the chosen weight factors per index are taken into account in the tendercompetition, they influence the tenderbid (see chapter 3: Indexation). There are different kinds of strategic behaviours that can be identified, generally resulting in higher risk for the contractor.

### Choose different index group

The first kind of strategic behaviour from the contractor originates from a different point of view on the development of an index over the years to come. The Public Authority estimates the average inflation rate per index group before the tender call is made (the reference value). When the private party thinks the inflation rate is different, the choice of index will also be different. This will be explained in the following example.

When index A is expected to rise with 5% p.a. and index B is expected to rise by 2,5% the influence on the tenderbid with expenses of €100 per year are shown in Graph 11.
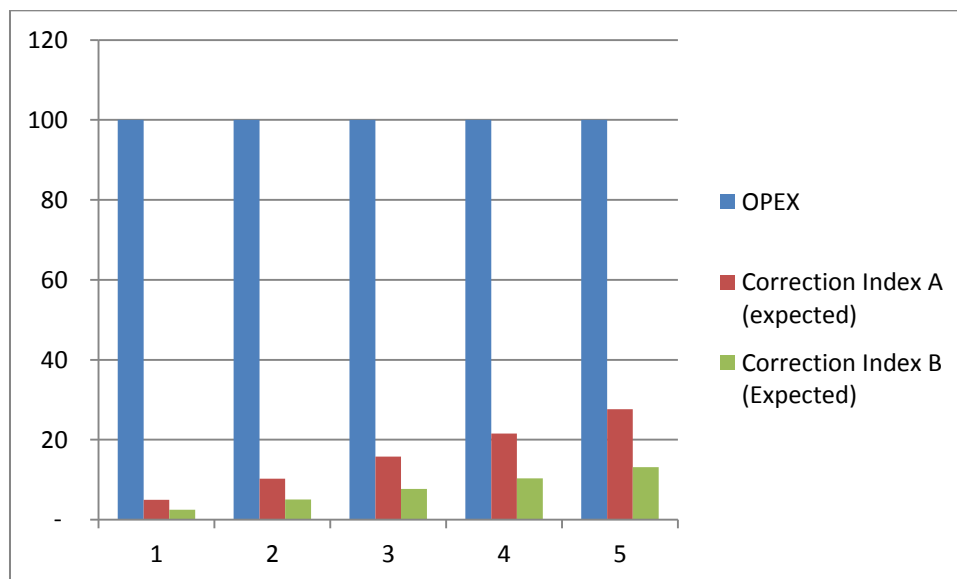


**Graph 11: Expected index correction with different index groups**

When choosing index B in the tenderbid, the final price, including the expected inflation correction, will be lower than in the case of choosing index A. When the private party expects the price of his total OPEX develops at 2,5%, that will be his index of choice. However, index B might resemble an entirely different kind of good or service than the components in the OPEX, so there is a difference in the actual price development of the OPEX and the chosen index, this is a risk for the contractor.

### Choose smaller factor

A second strategic choice of the contractor can be made in his choice for the second index parameter; the weight factor. The private party can choose a different weight factor (or zero) than is actually the weight of a specific good in his expenses. By doing so, the extra cost of inflation will not (or not entirely) be reimbursed by the Public Authority but on the other hand, the tenderbid will be lower as well. When the private party estimates a lower price rise than is laid down in the reference values a smaller factor can be chosen and a reservation for the expected price rise is laid down in the project budget.

These two ways of strategic behaviour cannot be objectively chosen and are subject to the entrepreneurial mind-set of the private party. Because of this subjectivity and opportunism, the influence of strategic behaviour on the choices of the index parameters will be excluded from this research.

# 5. Influential variables of the index gap

The size of the aforementioned index gaps is influenced by the variables of the index formula. These variables can all be traced back to the set-up of the maintenance activities during the exploitation phase and the price level development. The maintenance activities have a certain cost and a point in time when they are executed. This chapter will elaborate on the planning of the maintenance activities and its insurmountable uncertainty. To understand where this uncertainty originates from, one must first understand the principles of maintenance.

## 5.1 Principles of maintenance

There are numerous definitions of maintenance ranging from a more economical viewpoint to a more user-centred view. Most definitions agree that maintenance is done in the use-phase of the lifetime of a project. The European norm EN 13306 on maintenance terminology defines it as:

> *"Contribution of all technical, administrative and managerial actions during the life cycle for an item intended to retain it in, restore it to, a state in which it can perform the required function."* (CEN, 2001)

This definition aims on the functionality of an object. This suits the DBFM principle where the Public Authority describes her demands in a functional way, and the private party is charged with achieving this function during the lifetime of the project.

One can argue whether daily operations are also part of maintenance. With these activities one must think of ice control, emergency response and clearing of debris (Schoenmaker, 2011). Because these activities are also necessary for functionality of an object, some might include these activities in maintenance. However, in line with DBFM practice, these daily operation activities are separated from the undisputed maintenance activities in this research, because daily operations are the responsibility of Rijkswaterstaat in the current Dutch contracts.

Maintenance is necessary because objects deteriorate over time. In Rijkswaterstaat's maintenance model, ageing is modelled by a gamma deterioration process, where failure is defined as the event in which – due to deterioration – the condition at time $t$, denoted by the resistance $R(t)$, drops below the failure condition (see Graph 12). However, even with accurate knowledge of the deterioration curve $R(t)$, the deterioration process is uncertain because of external factors like weather and use. With this uncertainty included, the expected condition at a certain point in time is described by E(X)t. The time at which the condition drops below the failure condition is therefore uncertain as well. The maintenance interval, which is based on the time between construction and the point at which the failure condition is reached, is also an uncertain value described by a probability function. This probability density function (PDF) is influenced by the rate of deterioration, the uncertainty of the deterioration and potential use of life extending maintenance (J.M. van Noortwijk, 2004). The PDF of the maintenance interval is an important input for the maintenance planning and can be obtained by evaluating the maintenance intervals of similar objects, more about this in Appendix B: *Explanation of strategy performance model*.
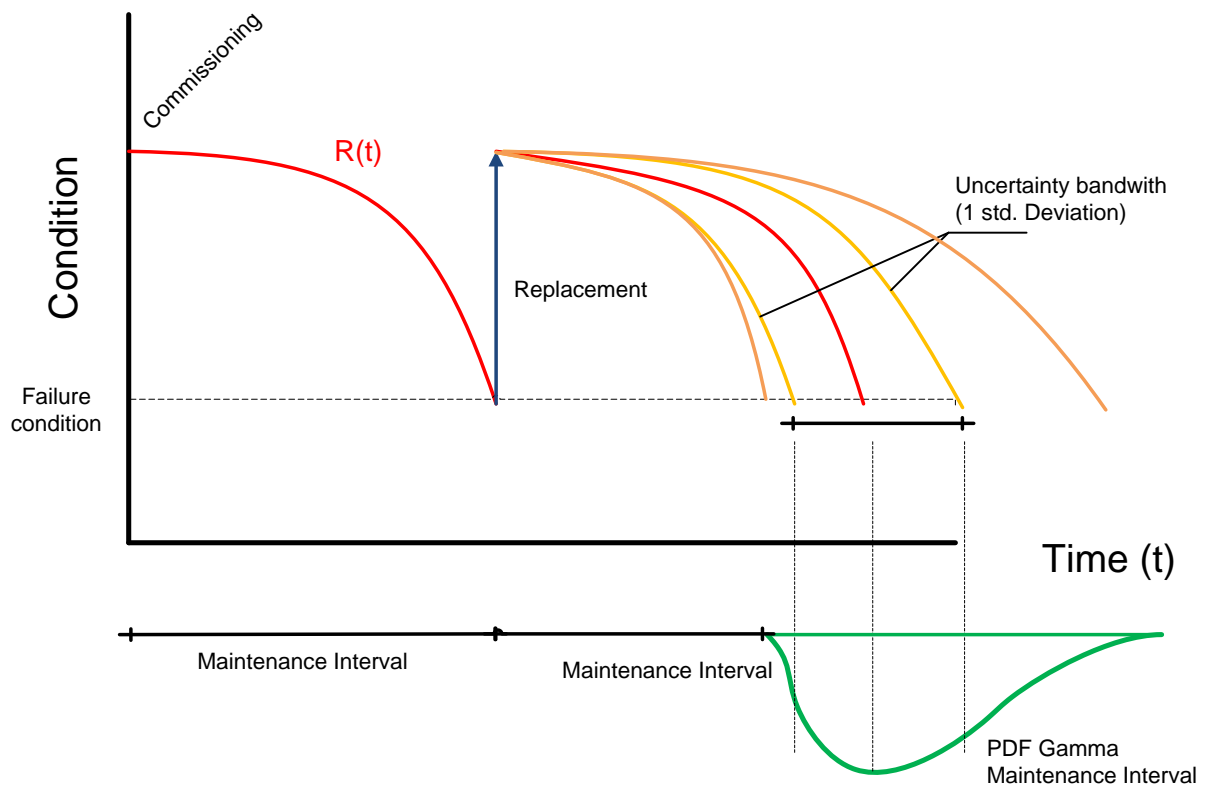
**Graph 12 Deterioration curve and maintenance activities in the Rijkswaterstaat Model. The maintenance interval is uncertain because of the uncertain degradation curve R(t). The uncertainty of the maintenance interval can be described with a Gamma-shaped probability density function.**

The rate of deterioration R(t), is dependent on the technical properties of an object. A traditional light bulb for instance, will fail earlier than an energy saving light bulb for instance. The uncertainty of the deterioration process can be reduced with inspections, because the uncertainty of the condition is eliminated by measurement. Furthermore, the replacement can be postponed by rejuvenating measures. The mechanisms of inspection and rejuvenating are visualized in Graph 13 and Graph 14.
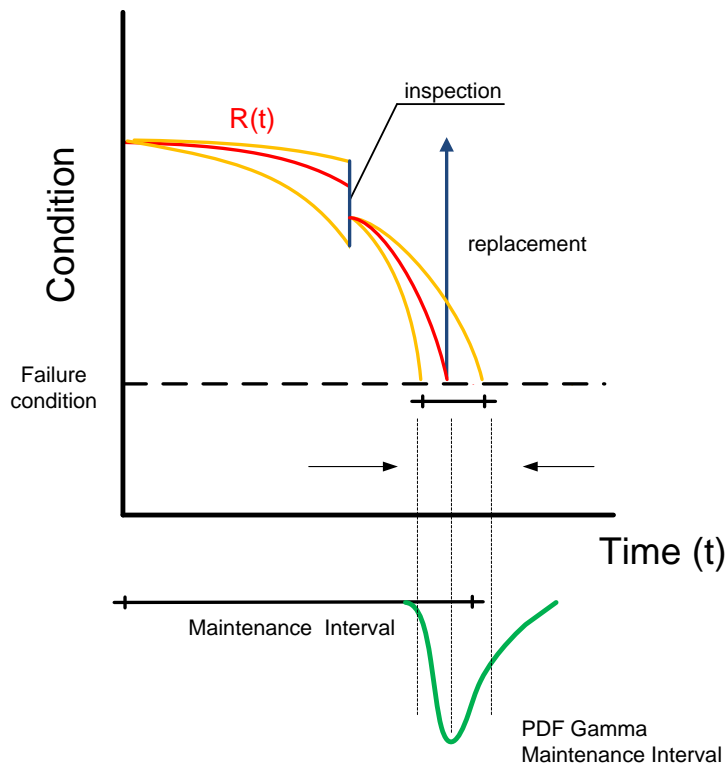
**Graph 13: uncertainty reduction through inspection; the PDF becomes more 'pointy' because the state of the asset is better known through inspections.**
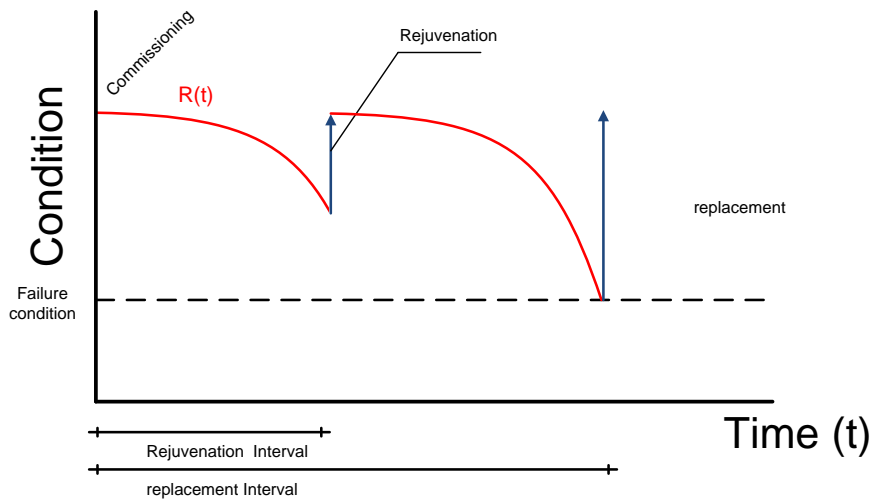


**Graph 14: Lifetime extension through rejuvenation. Quality is brought back to the original level to extend the lifetime.**

## 5.2 Largest impact on Index gap

We now know the origin and dynamics of uncertainty in the maintenance planning and that it has an important effect on the index gap. This chapter will define the most influential part of the maintenance budget on the index gap. The maintenance budget is cut-up into small pieces with each different properties on uncertainty, proportion of the budget and cost components.

Maintenance of road infrastructure can be spilt up in two types; periodical and variable. Periodical maintenance include activities that have a predetermined interval, for instance the mowing of the



**Graph 1: Maintenance budget per activity type. Periodical maintenance is the largest component, followed by resurfacing of the pavement and replacement of electro- an mechanical installations.**

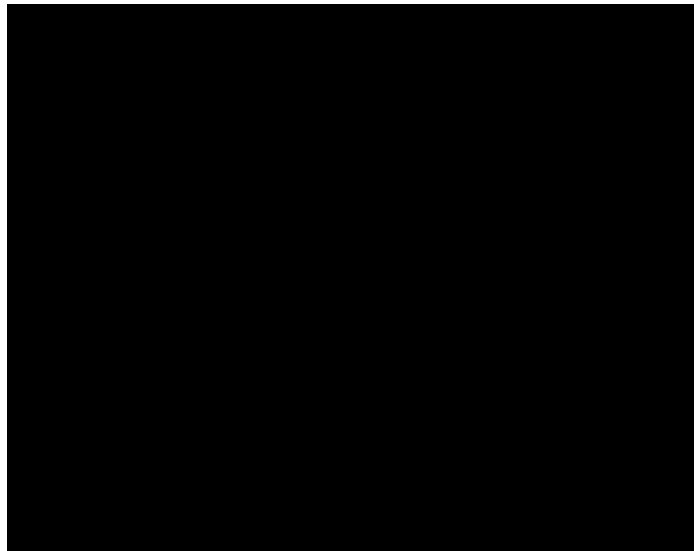grass or the cleaning of the signs. This type of maintenance has a small uncertainty in the planning because intervals are small (< 2 year) and deterioration curves are well-known. Graph 15 shows the cashflow of different maintenance activities for a DBFM road contract with a timespan of twenty years. The annual cycle is clearly visible as the spikes in the red block.

Variable maintenance on the other hand, lack this recursive interval in planning. Common variable maintenance in DBFM contracts include replacements of electromechanical installations (E&M) and resurfacing of the pavement. Maintenance in the form of replacement of the electromechanical components, are a large part of the maintenance budget (the green block in Graph 15) and have a small uncertainty in planning. This is because parts like lighting, pumps and dynamic signalling are produced in large volumes by specialist suppliers. These suppliers are able to test their products and accurately establish their deterioration curve. This is valuable information for maintenance engineers, who can use it to narrow down the uncertainty to a minimum.

The other large maintenance activity in the graph, the resurfacing of pavement, does not come with this accurate information on deterioration and therefore has a much wider bandwidth in the maintenance planning. In the case study, resurfacing comprises 40% of the variable maintenance budget, see the orange block in Graph 15. The large impact on the cost and uncertainty in planning make the resurfacing activity very influential to the index gap. This interesting component will be discussed in depth in the following section.

## 5.3 Resurfacing of pavement

The resurfacing of the pavement, also referred to as large asphalt maintenance, not only involves high costs and planning uncertainty, but also needs commodities with volatile price levels like bitumen and gasoil. For these reasons, the scope of this research is aimed at this type of maintenance. To get a better understanding of large asphalt maintenance, this section will explain why it is necessary in the first place.

## Function of pavement

The function of a road is threefold; a road has to accommodate a *fast*, *safe* and *comfortable* traffic flow (Molenaar, 2011). For a fast traffic flow, the capacity of the roads and connections between them has to be enough for the amount of traffic using it. The capacity is mostly influenced by the number of lanes and dynamic traffic control like dynamic signalling. Besides that, use of special porous pavement types can increase capacity during rain showers by improving motorists' sights with its strong draining capability.

The second function of a road; providing a safe traffic flow, is also dependent on the spatial design of the road system and furthermore dependable on weather conditions, driving behaviour and technical properties of the pavement. Of these aspects, the technical properties of the pavement are subject to deterioration and must therefore be preserved.

The third function, a comfortable traffic flow is dependent on several aspects like the traffic intensity, vehicle properties, weather conditions and technical properties like evenness of the road (Molenaar, 2011).

The technical properties of the pavement thus have an effect on the functionality of the road. Maintenance is done to preserve the technical properties of the pavement. The technical properties of the pavement that influence the functionality of a road are listed below:

- Load bearing capacity
- Consistency of pavement mixture
- Longitudinal evenness
- Transverse evenness          Technical properties
- Transverse banking
- Roughness
- Texture                                        (Wisgerhof, 2002)

The following step into the disentanglement of the degrading process of the pavement is the identification of damage forms, which are linked to the technical properties. The contract specifies the lower limit that cannot be exceeded during the exploitation period. The damage type of pavement are listed below:

- Crack formation (*craquelé*)
- Ravelling
- Unevenness
- Slipperiness                      Damage type
- Water nuisance
- Noise nuisance                                    (Wisgerhof, 2002)

These damages all have their own deterioration behaviour and are used by the contractor to design their maintenance planning. The maintenance planning aims to execute the maintenance activity just before the lower limit is reached. This lower limit is laid down rather specifically as can be seen in the DBFM contract of the N33 provincial motorway. The Longitudinal smoothness of the pavement for example, is functionally described as:

> *The presence of driven surfaces with a longitudinal unevenness damage larger than class 2, according to review technique [X] is unacceptable.*

This report will not elaborate more on the technical details behind these damage forms because it is sufficient to understand that these damages are the driving factor behind the demands in the contract and thus choices made in the maintenance planning. Further specification of the dynamics and classification of the damage forms is a research of its own. The next section will narrow down to resurfacing maintenance of a specific type of pavement used in the latest DBFM projects.

## 5.4 Maintenance of Double layer porous asphalt

In the Netherlands, Rijkswaterstaat commonly demands double layer porous asphalt (*tweelaags ZOAB*) because of its low noise properties and very good water drainage. *Double* layer porous asphalt is an innovation of its single layer counterpart with even better noise reducing properties. This innovative type is currently used in 10% of the Dutch motorways (Voskuilen, 2012). Rijkswaterstaat demands this type of pavement in dense urban areas with stringent noise requirements. Moreover, it is expected to be demanded in the DBFM projects in the near future which are located in urban areas (SAA 3/4/5 and A13/A16) (Rijkswaterstaat, 2012) (Rijkswaterstaat (2), 2012).

The distinctive principle of porous asphalt is that the granulate in the asphalt mixture has a large diameter resulting in open spaces between the stones. These spaces form small channels allowing water to drain downward, away from the road surface. Secondly, the channels reduce the closed character of the surface of the top layer, which reduces noise. A big shortcoming is that this type of asphalt has a relatively short lifetime (Voskuilen, 2012) (Schlangen, 2012). While the lifetime is shorter than normal porous asphalt or traditional dense asphalt (*DAB*), double layer porous asphalt is cost effective in the urban cases with stringent requirements because of the higher cost of alternative noise reducing measures like noise barriers (IPG, 2008).

The decisive damage form for motorway pavements in The Netherlands is ravelling (N. Verra, 2003) (Spaargaren, 2013) (VBW Asfalt, 2005) (Voskuilen, 2012). Ravelling is the loosening of the granulate in the asphalt due to the reduction of adhering strength of the bitumen. Over time, the bitumen becomes brittle and is unable to keep the granulate together. This results in inconsistent road surface and eventually holes. The abrasions reduce the surface area between tire and pavement, resulting in a reduction of roughness. The reduction of this technical property leads to longer breaking distance and eventually more accidents (Molenaar, 2011).



Figure 6: the decisive damage form in double layer porous asphalt; ravelling of asphalt

The degradation rate of the technical quality of the road is uncertain because it is dependable on unpredictable factors. Ravelling is influenced mostly by the traffic load but also by environmental influences like rain, frost, UV-light, pollution and cadavers. The influence of the traffic load can be observed in the driving tracks where the ravelling occurs first (Bochove, 2012). Because these

influences are uncertain and degradation predictability data is unavailable, the moment of execution of maintenance measure is uncertain as well.

To combat the damages of ravelling as well as unevenness, the pavement of a motorway is resurfaced after a number of years. With this maintenance measure, the top layer is milled out by specialized machinery. After the milling, new asphalt is laid down, rolled and provided with lines and markers. During this operation, the section is closed for traffic (VBW Asfalt, 2005).



Figure 1: first step of resurfacing of pavement; milling-out old top layer

Because the fines for insufficient quality of the pavements are very high, maintenance planning practice aims on asphalt planning at a 85% certainty interval. This means that, considering the uncertainty, the timing of maintenance activities is on or before the pavement quality dips below the required condition in 85% of the cases (Moenielal, 2013). Besides the high fines for the contractor, it is important to take into account that extended periods of neglect typically result in higher maintenance costs (Ng, 2009). Graph 16 shows an example of an 85% certainty interval given a specific probability density function. In this example, the expected year of the resurfacing is in year ten on average. But to be on the safe side, year eight (7,93) is chosen in the planning.
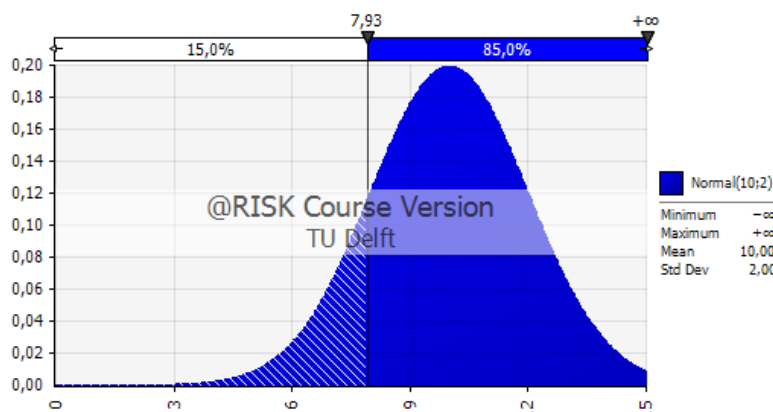


Graph 16: A normally distributed probability density function of a maintenance interval. The vertical line shows there is a 15% chance on an interval below 7,93 years. In a maintenance planning based on a 85% certainty, maintenance is planned in year 8.

For pavement maintenance, there are different options for the maintenance plan. Normally, there is at least one peak in maintenance cost due to resurfacing of the pavement during the exploitation period of 20 years. But different strategies are possible. The timing and combination of maintenance activities is estimated in the tenderphase and is subject to strategic choices of the contractor. For example; rejuvenating measures can be chosen to extend the lifetime of the pavement, in this way the resurfacing peak is delayed a few years. This could result in a maintenance planning with only one resurfacing activity necessary in the exploitation phase. Which results in lower maintenance cost and higher availability. This is an area of choice which is currently heavily debated in DBFM projects (Moenielal, 2013) (Spaargaren, 2013).

With asphalt maintenance on motorways it is important to differentiate the heavily loaded lanes and lightly loaded lanes. Heavily loaded lanes are the two lanes on the outer right side that are used by

trucks and other heavy vehicles. As stated before, degradation of asphalt pavements is dependent on the use. Therefore the heavily loaded lanes have a shorter lifetime than the lightly loaded lanes.

*"The heavily loaded lanes are being completely ruined by trucks"* (Spaargaren, 2013)

The resurfacing is therefore split into two parts with each a different planning. This is also beneficial to the availability because it allows for phasing in the maintenance planning; while resurfacing the heavily loaded lanes, the lightly loaded lanes can remain open for traffic.

This chapter described the mechanisms behind the most influential factor of the index-gap; resurfacing maintenance. Concluding on maintenance theory and practice, the uncertain character of the maintenance peak must be incorporated in the research. The different maintenance options must also be included. Further explanation of the uncertainty used in this research will be explained in Appendix B: *Explanation of Strategy performance model.*

# Part III – Inflation correction performance Research

This final part will describe the research on inflation correction and its relation to choices in maintenance regime. With the context and observations in mind, the problem can be defined. Then the method of the research is explained followed by the results and conclusions
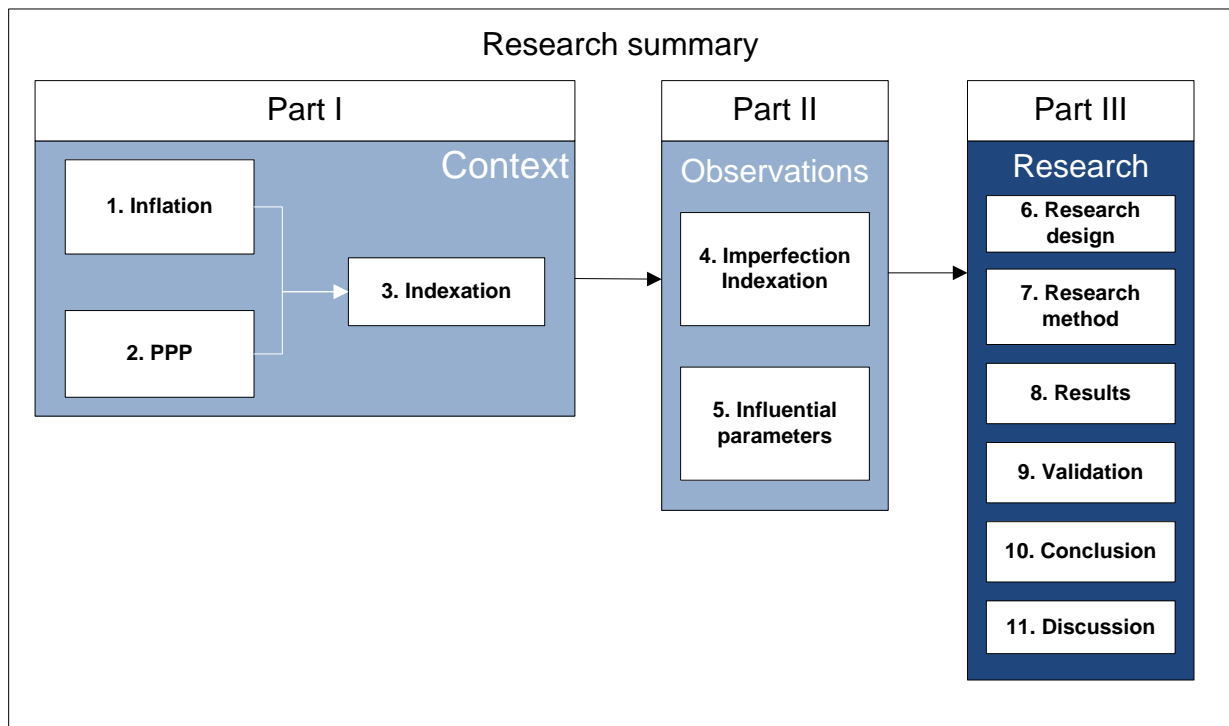
# 6. Research design

Summarizing the previous chapters describing the context of this research, the index clause is used to transfer the uncertain cost of inflation from the contractor to the public authority. In Dutch DBFM contracts, an index formula is used to transfer the escalating effect of inflation on a contractors maintenance cost. This formula is a rough approximation of reality and it does not perfectly match actual inflation cost. The difference between the approximation calculated with the formula and the actual cost of inflation is called the index-gap. The gap is influenced by the shape and uncertainty of the cashflow in the exploitation phase which is in turn influenced by choices made in maintenance regime. The dynamics behind the index gap phenomenon are the subject of this research.

## 6.1 Problem statement

The index-gap influences the tender bid as well as the exploitation budget and eventually the profitability of a project. However, according to experienced experts, this influence is not fully incorporated in the decision making process of budgeting, because knowledge of the index-gap and the potential impact it has on the project returns is lacking at the budget calculators. Interviews with experts from different kinds of private parties confirm that the size of the gap is unknown, whilst the existence of the gap is acknowledged (J. van de Ven, 2013) . By knowing how to deal with the index gaps, better choices can be made in the decision making process of the private parties.

The index-gap is created by the index formula in the DBFM agreement. This formula is affected by two variables; the programming of maintenance activities and price level development during the exploitation period. Contractors are unable to influence the latter[3] but do have the freedom of choosing a maintenance program. A maintenance program is designed by maintenance engineers in the tender phase, trying to keep the Life Cycle Cost (LCC) as low as possible whilst sustaining the required quality. Part of a project's life cycle cost are extra cost due to price-rise and the reimbursed inflation correction payments from Rijkswaterstaat, however this is not taken into account when making the technical trade-offs. This research therefore tries to seek the effect of a maintenance plan on inflation correction.

Within a project's maintenance plan, this research is narrowed down in order to keep the results comprehensible and workable. The scope of this research is focused on resurfacing of the asphalt because this is the most important part of the variable maintenance program (as explained in chapter *5. Influential variables of the index gap*) . This activity comprises over 40% of the variable maintenance budget in the case study (see Graph 15). 40% is a quite typical value for motorway maintenance projects in the Netherlands, it generally ranges between 35 and 50%, depending on the amount of viaducts, tunnel and installations (S. de Jong, 2012). Besides the big influence on the budget, there is much freedom to choose from different strategies. There are completely different kinds of maintenance plans possible that meet the requirements laid down in the contract.

A third factor makes the resurfacing activity even more interesting; the uncertainty of the length of the maintenance interval. Because degradation of the asphalt is influenced by weather conditions, asphalt quality, usage and construction method, the lifetime is hard to predict. This uncertainty must be taken into account in DBFM projects. The index formula lacks the ability to cope with this

---

[3] In small markets with little competition, the contractors áre able to influence the general price level by changing their own prices because they have a monopoly position. (Yescombe, Public Private Partnerships - Principles of Policy and Finance, 2007)

uncertainty, which is one of the reasons for the index-gap. Furthermore, large maintenance of asphalt uses products with highly volatile price levels, mostly due to the link with the global oil price. This volatile price level also influences the index gap.

Concluding, there is a lack of knowledge of the mismatch between a DBFM project's inflation cost and its inflation correction payments. Furthermore, the effect of different maintenance plans on this mismatch is unknown as well. The most influential component of the maintenance budget is the pavement resurfacing because of its financial weight, numerous maintenance strategies, planning uncertainty and unstable product prices.  It would be valuable to know how the resurfacing strategies perform on inflation correction in different scenario's. This is important because inflation correction influences the tenderbid as well as the profitability for the private party. When the parties in DBFM projects are more aware of the gap and how it can be influenced, the projects will result in a higher value for money for the government.

## 6.2 Research question

Having  defined the problem, the research question is composed to find the knowledge necessary to solve the problem. The research question is formulated as follows:

*Which resurfacing strategy minimizes the net present value mismatch between inflation correction and actual inflation cost in DBFM road projects in The Netherlands?*

- Which maintenance strategies can be identified in Dutch DBFM project budget?
- How do the resurfacing strategies influence the mismatch in Dutch DBFM projects?
- What recommendations can be made to reduce the mismatch in the standardized index clause?

With these questions insight in the index-gap will be given and recommendations can be made on how to handle the index-gap. This is an addition to the existing knowledge of the index-gap.

The mismatch is expressed in net present value (NPV), because this allows for a comparison of different cashflows in time. NPV is a major concept in investment choices.

The research uses present value calculations to take the time value of money into account. It uses an annual discount rate to calculate the current value of a future amount of money as if it existed today. The present value is always less than the future value because money has interest-earning potential, a characteristic referred to as time value of money. It can be simplified as: "a euro today is worth more than a euro tomorrow". Money can be invested in bonds or projects to generate income from interest  (Moyer, Kretlow, & McGuigan, 2011). This research uses an annual discount rate of 6,25% because this is the reference value used by Rijkswaterstaat.

### 6.3 Research goal

The goal of the research is to provide private parties with recommendations on which choice on maintenance regime when taking inflation correction into account.  The leading element on which

recommendations are made is the reduction of cost for the private party. This consequently results in a better value for money for the government.

A secondary goal is to provide a reason for maintenance engineers and financial advisors to improve their cooperation. With a subject on the interface between the two disciplines that can have a relevant impact on a project's success, the motivation to cooperate will grow.

A third goal is to evaluate the workings of the Dutch method of indexation. With the detailed knowledge of the mechanism necessary for this research, an assessment on the method can be given. This could result in recommendations to Rijkswaterstaat to change the formula or to private parties to change how they calculate their input parameters.

## 6.4 Relevance

With the research question answered, the contractors are more aware of the impact of technical choices on the index-gap and can make better choices. In the tenderphase, where the pavement and its maintenance plan are designed, the contractor aims for the lowest tender bid. When contractors would take the effect of technical choices on the index formula into account in their bids, they are able to make lower bids. The bids become lower either by a reduction in risk reserve or a cheaper design with lower quality. In the end, this is beneficial for the Value of Money and therefore the efficient use of tax money.

Secondary to the value of the answer to the research question is that this research promotes the use of probabilistic modelling. The use of probabilistic modelling in the road construction sector is not used to its full potential. The sector is conservative and is just starting to adopt modelling, mostly in the design of the construction planning. This research shows the value of probabilistic modelling on the interface of design, planning and finance, advocating the use in the sector.

Thirdly, the research proves the importance of the link between design, construction, maintenance and finance. DBFM contracts require an integrated approach between the four disciplines, but in practice they work largely separate. cooperation is improving and this research is another incentive that shows the connections between the different areas.

### Relevance test

To test whether or not the outcome of the research is relevant, an underlying hypothesis subscribing the relevance of this research must be defined. First of all, it states that different maintenance strategies have a different impact on the inflation correction mismatch.

Secondly, this research is executed because it is expected that the choice of maintenance strategy has an impact on the mismatch between inflation cost and inflation correction of such a magnitude, that it is relevant to the project.

To be able to check the relevance of the mismatch, a definition of relevance must be given. For this research, it is assumed that a relevant difference caused by the choice of maintenance strategy on the project budget must have a magnitude of over 2% of the total present value cost of the resurfacing maintenance. The present value cost for traditional resurfacing in the case study is on average ███████████ (including inflation and present value discounting). The threshold of 2% is based on current profit margins in the infrastructure sector in The Netherlands. Contractors in this sector are happy to see 2% profit on their projects. Times are rough in the construction sector and

contractors often make their offer based on a 0% profit, only to get the work in their portfolio (BAM, 2013) (VolkerWessels, 2013). The effect of resurfacing choices on inflation correction must therefore exceed ████████ to be relevant.  Hence the hypothesis:

> *It is expected that a choice between two maintenance strategies has a relevant effect on a project's budget, the choice results in a difference in the inflation correction mismatch of over* ████████ *PV .*

Whether this hypothesis is rejected or confirmed, will be described in chapter 10. Conclusion.

## 6.5  Relevance for Iter Fidelis

Iter Fidelis is a company that wants to be on the forefront of innovation within the construction management sector. The conclusion of this research is entirely new and directly usable in future tenders of contractors. At the time of writing, clients of Iter Fidelis have expressed their interest in this knowledge on the intangible and hard to comprehend indexation aspect. The methods used to answer the research question will also add to the skill portfolio of the company, improving the services to their clients. So with the knowledge and skills gained from this research the company has an innovative improvement to help their clients with better skills.

Besides this direct use of gained knowledge and abilities, this research is relevant to Iter Fidelis because it is beneficial to the Iter Fidelis product. The company has noticed that communication between their maintenance engineers and financial advisors from other companies is problematic. The two professions interact with each other in DBFM projects but lack the knowledge of each other's work and the interfaces between them. DBFM project teams often signal that the different professions "don't speak the same language".  Although this research aims at one specific part of the technical-financial interface, the insight in the necessary financial context will improve the financial knowledge of Iter Fidelis. The final benefit is that by fully understanding the financial aspects of DBFM projects, cooperation between professions is improved and a better, more competitive bid can be realized.

## 6.6 The gap in a larger picture

The index gap results in a different value at the bottom line of a project than would be expected with a perfect inflation correction. To understand the relevance, one must understand the other factors that influence the profit of the contractor as well.

The contractor's income, the availability payment,  is not only adjusted by a quarterly indexation escalation, but also by penalties and cuts. These penalties and cuts are based on the quality that is delivered each quarter and subtracted from the availability payment. This is a complex mechanism because it requires continuous monitoring of quality and uses a complex set of rules. The required quality and availability is laid down in the contract in terms of time slots of available lanes, noise production, ravelling and others.  The penalties and cuts have a significant effect on the profitability of a project because the contractor's income can be strongly reduced.

Besides changes on the income-side, the expenses can deviate from the tender phase estimation as well. Hidden technical difficulties can result in extra construction cost and time. Furthermore, the estimates of the maintenance budget might be off, because of the difficulty of estimating expenses

twenty years ahead. Contractors include extra budget reserve accounts for these risks but it is good to know that there are more deviations possible than the ones created by the index-gap.

## 6.7 Inflation risk transfer within the consortium

The DBFM agreement with the index clause is a contract between Rijkswaterstaat and a Special Purpose Company formed by the private party consortium. In principle, the index clause transfers risk of price level development from the SPC to Rijkswaterstaat but the allocation of this risk is more complicated than that.

The SPC makes contracts with other special purpose vehicles, generally an EPC (Engineer, Procure and Construct) and an Maintenance-company (M-Co). The EPC company is responsible for the construction and the M-Co  is responsible for the maintenance in the exploitation phase. The SPC makes contracts in such a way, that all remaining risks are transferred to subsidiaries like these. This also goes for the risk of price level change. The M-Co takes this risk and in return, receives the inflation correction payments. This is a so-called back-to-back contract in which the payments are directly channelled to the responsible party.

In this research, no differentiation will be made between the different parties behind the SPC. In this report, the SPC and her subsidiaries will be called 'the private party', see Figure 8.
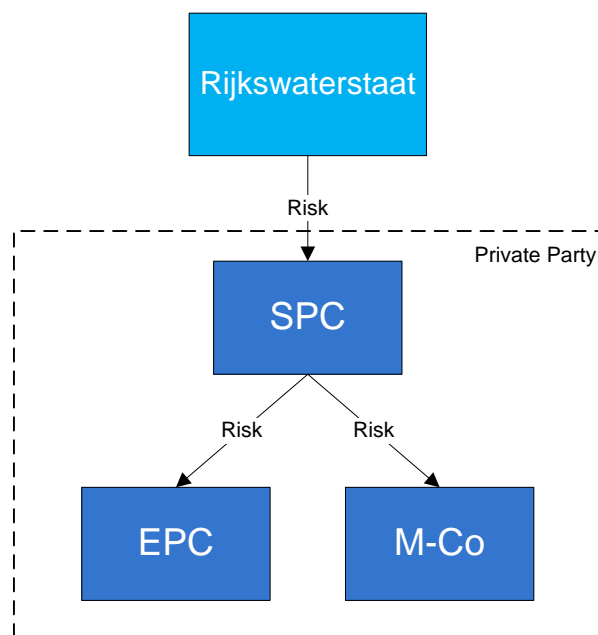


Figure 8: scheme of flow of risk of price level development from the SPC to subsidiaries

# 7. Research method

Ideally, to answer the research question, a comparison of an extensive number of project exploitations with different strategies would be made. The set of projects have had different circumstances with regard to price level development and timing of large maintenance. A comparison of the performance of these projects can identify the best way of dealing with the index gap. Unfortunately there are no finished DBFM projects in The Netherlands yet, let alone a number of projects to compare with each other.

Besides the fact that there are no finished projects to compare, this method has its drawbacks. For one, it is hard to compare unique projects because of difference in scope, duration, economic environment and payment mechanism. Furthermore, different projects initiated in different economic circumstances by different private parties involve different kinds of strategic behaviour. In a recent Dutch DBFM contract for instance, the entire maintenance budget was omitted just to get the job. Strategic behaviour like this would cloud the analysis.

Therefore, an alternative method is used. The two variables that influence the index gap have been identified as the price level development and the cashflow of the maintenance activities. To be able to answer the research question without a range of projects to compare, the two variables are simulated. With such a so-called Monte Carlo simulation, a large number of different future paths is created for one single project. For each future path, a different price level development and timing of maintenance is simulated, resulting in a unique set of performance indicators as output. Doing this for the possible resurfacing strategies makes it possible to compare the performance and answer the research question on how to deal with the index gap. An advantage of this artificial method over a real-life case comparison is that the scope, duration and payment mechanism of the project remain the same, resulting in more clear results.

The research method is a combination of a desk research and a case study (P. Verschuren, 2004). The Monte Carlo simulation is done with a model, where the construction of the model can be seen as the desk research using the theory of statistics and econometrics together with archives of price level developments and maintenance data. The different strategies that form the variable input of the model are different case studies, which are compared afterwards.
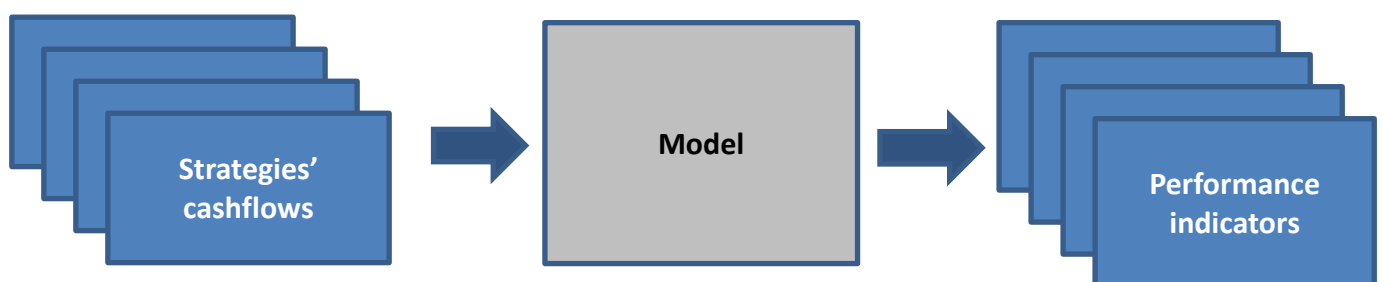


## 7.1 Strategy comparison model

The strategy comparison model will be the 'test-circuit' of the different resurfacing strategies. The model will simulate different kinds of price level developments and simulate the uncertainty of the timing of the resurfacing. The model outputs are performance indicators for each resurfacing strategy, which can be compared in order to answer the research question. The model uses two sets of stochastic inputs; the set of price level developments and the uncertain cashflow for each

resurfacing strategy. Appendix A and B describe in detail the mechanisms used in the model, this paragraph describes the way the model is used to answer the research question.

## Monte Carlo Simulation

This method is commonly used in the world of finance and uses statistics and computers to generate the different future paths. Variables are not fixed, instead, a probability density function (PDF) is assigned to each variable. The essence of the method is that, for all variables of the reliability function Z, one draws a value from the corresponding distributions in the function. Subsequently, one calculates the value of the Z-function out of the drawn values of the variables. By repeating the procedure numerous times, an estimation can be made of the probability of outcomes of the function. The result of the Monte Carlo method is a stochastic value itself with a mean and a standard deviation (Prof. Drs. Ir. J.K. Vrijling, 2011).

Because the model is such an important part of the research, it must be of good quality. The model is therefore constructed using the FAST standard. FAST is short for Flexible, Appropriate, Structured & Transparent and is developed by professionals in the field of financial modelling (Whitelaw-Jones, 2013). This standard prescribes how to build the calculation part of the model in such a way that it is possible to understand and audit it by other people. Before running the model, it will be checked by professional model-builders from Iter Fidelis. With their consent the model can be run and a comparison can be made.

The model is programmed in Microsoft Excel using the plugin @RISK from Palisade. @RISK is an extension of excel especially designed to run Monte Carlo simulations (Palisade, 2013). The Excel/@RISK combination is useful because of its graphical interface and its good compatibility with secondary users. A disadvantage of the combination is the difficulty of validating the inner workings in the model. The use of the FAST standard is meant to make this more easy.

## Drawbacks of the model

The method of using a model also has its drawbacks, which will be described here. Without the ability to look back, an artificial future is created. This research uses an econometric method to generate the future paths, described in Appendix A. The used method is a sophisticated method of extrapolation of historical values, which has a drawback. There is no way of being able to predict the future with certainty, especially a future of more than two decades. The development of price levels is subject to global economic climate, politics and technological advancements, neither of which is predictable over such a long time span. This means that the outcomes of the model, cannot be certain either.

But this uncertainty has less impact when the comparison between the outputs of the resurfacing strategies have the same uncertainty. It is still possible to conclude that one strategy is less vulnerable to the index gap than another. It is important to keep in mind that the absolute outputs are estimates, and the real world is free to differ.

## The incorporation of the index gaps

Chapter 4. *Imperfection of Indexation method* described the five index-gaps that influence the difference between extra cost for inflation and inflation correction. This section will discuss the used research method and describe for each gap whether or not its effect is taken into account.

The first index-gap was the result of a mismatch between the shares of cost components in the aggregated index and the shares of cost components in the actual activities. This gap is not taken into account in this research. Because the research is focussed on one type of maintenance activity (resurfacing maintenance), the cost components can be fully specified over five indices (see Appendix B: Explanation of strategy performance model). The difficulty in incorporating this gap is that the shares of aggregated indices change every five year, making the econometric inflation simulation less accurate.

The second index-gap comes forth from the assumption that the contractor's expenses are equally spread over a five-year period. This gap is taken into account by calculating the inflation cost at quarterly intervals. The quarterly calculation is then compared with the rough five-year method of the indexation clause.

The third index-gap is caused by the inflexibility of the formula with regard to a changing maintenance planning. This gap is taken into account by simulating the uncertainty of the execution of the maintenance activities.

The fourth index-gap is the result of the difference in the used interval in the calculation of the price level mutation. The index formula looks back at the price level of January to calculate the inflation correction in all four quarters,. The model calculates inflation cost using the price level of the corresponding quarter.

The fifth index-gap is caused by strategic choices of the contractor. This is not taken into account because they cannot be objectively simulated.

## 7.2 Resurfacing strategies

Through interviews with asphalt experts from both the public and private party together with literature on asphalt maintenance, four resurfacing strategies have been identified (see *Appendix C: List of interviews*). The nature of these strategies will be explained in this paragraph. To give the strategies a realistic context, they are applied on an existing DBFM project, the A15 motorway from the Maasvlakte to Vaanplein.

### Case Study – A15 Maasvlakte-Vaanplein

This motorway is an important connection in many respects. The road connects Europe's largest port with the hinterland while simultaneously facilitating the commuters to and from the area's industry. The road also is the main access to important residential and recreational areas in the Southwest of The Netherlands. With the completion of the second Maasvlakte and the expected growth of traffic expected to follow from that, Rijkswaterstaat initiated the project as a DBFM contract.

**Figure 9: overview of the A15 project (Rotterdam Vooruit, 2013)**

The consortium 'A-Lanes A15' won the tendercompetition and the contract was signed at the end of 2010. *A-lanes A15* is a private party consortium composed of Ballast Nedam, Strabag, John Laing and Strukton.

The project consists of the expansion of the capacity of the existing A15 from the Maasvlakte to the connection to junction Vaanplein. This is done by adding extra lanes in the form of a parallel structure where transit traffic is separated from commuting traffic. Besides adding extra lanes over 37 kilometers, the project includes the construction of a new Botlek bridge and 20 years of maintenance after the upgrade (A-Lanes A15, 2011). Key input parameters like pavement area as well as important milestones and payment mechanisms are retrieved from the scope document and DBFM agreement. With this information, the strategies following are projected on the case study;

- *Strategy A:* Traditional resurfacing
- *Strategy B:* Lifetime extension through Rejuvenation
- *Strategy C:* Aiming for innovation
- *Strategy D:* Innovative Asphalt

### Strategy A: Traditional resurfacing

In a traditional resurfacing regime of double layer porous asphalt (DLPA), the top layer of the pavement is resurfaced when the quality of the road nears the failure condition. With porous asphalt the resurfacing of the top layer of the heavily loaded lane is executed at 8 years after construction. 4 years later, the total DLPA package is replaced, both the top and secondary layer on both the heavily and lightly loaded lanes (IPG, 2008) (R. Hofman, 2008) (VBW, 2012) (TNO, 2011).

The uncertainty of the maintenance interval is described by probability density function $E(t)_A$. This function is build up from actual maintenance intervals together with expert estimations of future maintenance intervals for over 3000 road sections in the Netherlands (TNO, 2011).

The source of the cashflow data is the budget from the best and final offer from A-lanes A15. The cashflow in Graph 17 shows the budgeted cost for resurfacing in strategy A. The first peak is small, because only the toplayer is resurfaced. In the second activity, the entire pavement is resurfaced, resulting in a higher peak. Then in the final two years of the project, the toplayer is due for resurfacing again. The peaks are spread out in a 15-70-15% cashflow to include the difference in construction year and degradation within the road sections in the project (Moenielal, 2013). Total

budgeted cost for this strategy (at pricelevel 2008) is ███████ The present value of the budget comes to ███████. For calculation details, see Appendix B: *Explanation of strategy performance model*.
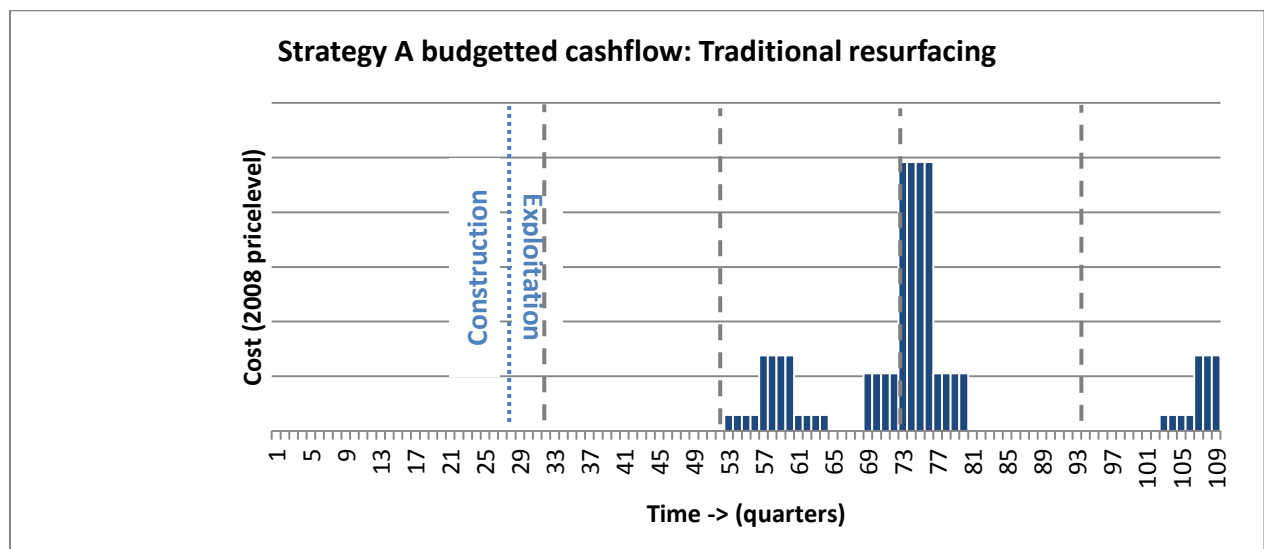


**Graph 17: Budgeted cashflow of strategy A: traditional resurfacing. With a small peak starting in quarter 54 for the heavily loaded lanes. The large peak represents the resurfacing of all lanes. A second resurfacing cycle is planned in the last two years of the project.**

## Strategy B: Lifetime extension through rejuvenating

This second strategy improves the first maintenance regime by extending the lifetime with rejuvenating measures. The embrittlement of the bitumen can be countered by spraying a new bituminous mixture in the porous asphalt, this technique is called 'sealing'. Sealing the pavement twice before the actual resurfacing extends the lifetime by two years on average. Besides the lifetime extension, it reduces the spread of the planning uncertainty (Moenielal, 2013) (Spaargaren, 2013).
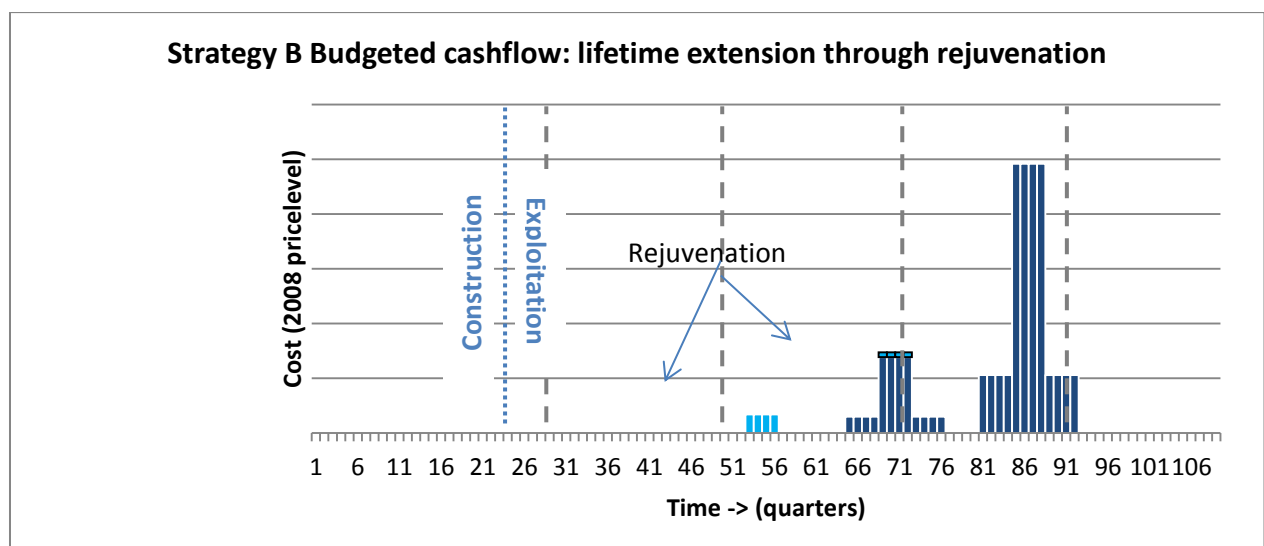


**Graph 18: budgeted cashflow of Strategy B: lifetime extension through rejuvenation. Two peaks are added to the traditional resurfacing strategy for the rejuvenating measures. This causes the dark blue resurfacing peaks to shift four years to the right, making a second cycle unnecessary.**

The entire resurfacing cashflow is set back two years, and two sealing peaks are added in year seven and during the resurfacing of the toplayer of the heavily loaded lanes. The second sealing activity has lower cost, because only the lightly loaded lanes are being sealed.

The cost of the sealing activities are based on the surface area of lightly- and heavily loaded lanes together with a price per m$^2$. This price has been taken from a budget from a recent DBFM project from the same contractor as the one from the case study.

The reduction of uncertainty in the maintenance interval is simulated by adjusting the PDF E(t)$_A$. To get the PDF more 'pointy', the 5$^{th}$ and 95$^{th}$ percentile are cut-off. The result is given in Graph 19, both the translation to the left and the reduction of uncertainty (pointiness) can clearly be seen. The budgeted cost for this strategy are €██████████, the present value is €██████████
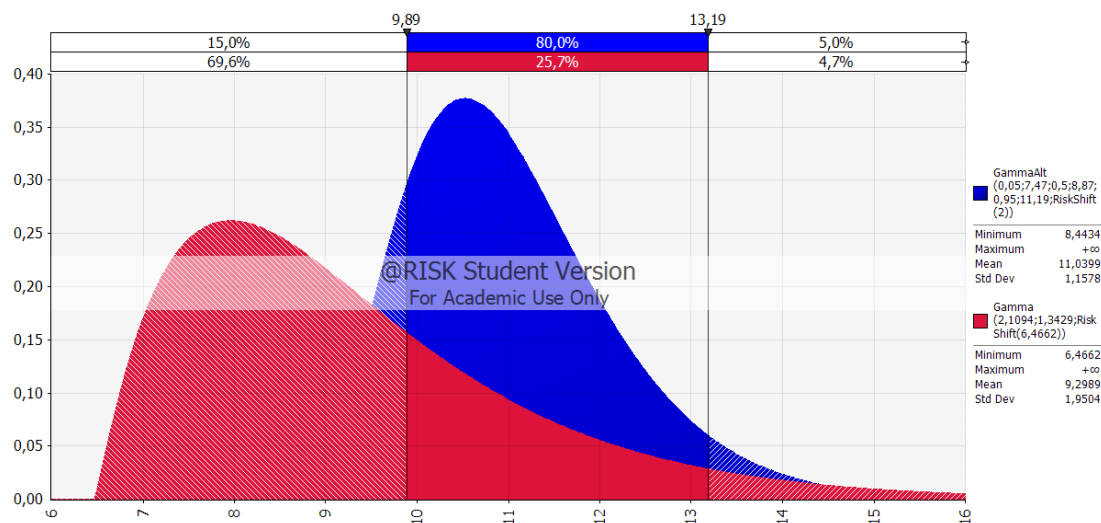


**Graph 19: PDF of strategy A (red) versus PDF of Strategy B (blue): the more shorter the interval between the rejuvenation measures and resurfacing causes a reduction of the uncertainty of the maintenance interval. This graph shows the uncertainty of the maintenance interval without (red) and with rejuvenating measures.**

### Strategy C: Aiming for Asphalt innovation

A more opportunistic strategy is to aim for technological advances in asphalt technology. In this strategy the budget is built on the assumption that after the first resurfacing in year 8, a more durable asphalt type has been developed. The durability of this new asphalt is such that it at least outlasts the contract period. With this strategy only one resurfacing is necessary resulting in a much lower tenderbid. This risk-taking is reality in the current market in which work is scarce (Moenielal, 2013) (Spaargaren, 2013).

The cashflow is a copy of strategy A, but without the second resurfacing cycle in the last years of the project. Also the PDF used to simulate uncertainty is a copy of the one used in strategy A.

The cost of this budget is €██████████ with a present value of €██████████
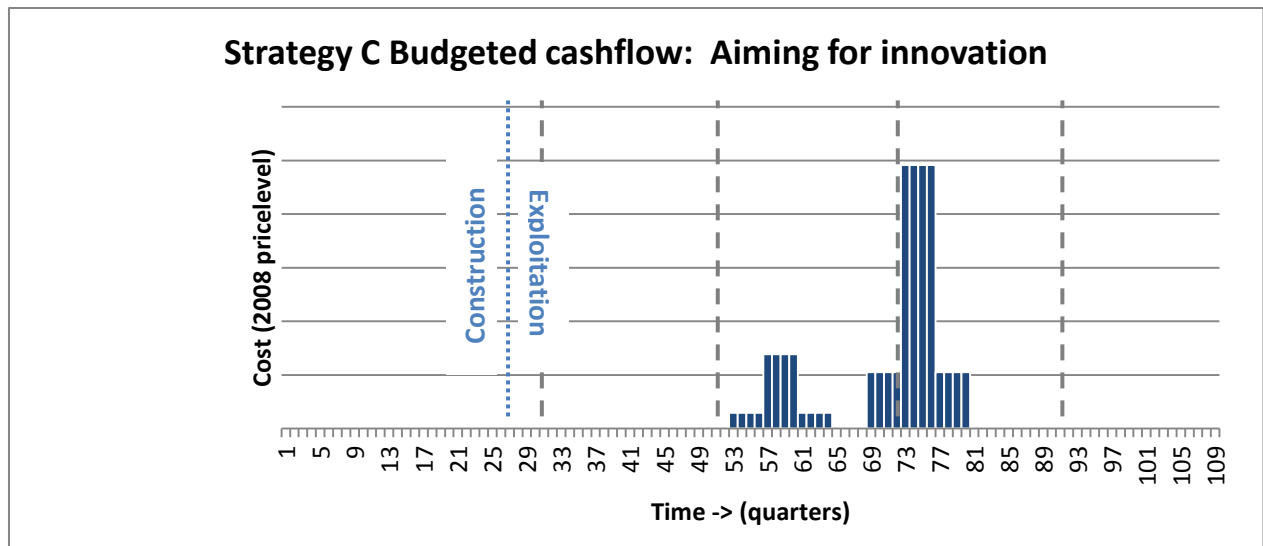
**Graph 20: budgeted cashflow of Strategy C: Aiming for innovation. In this strategy, the second cycle as seen in the traditional resurfacing strategy is removed because in this case, it is expected that new innovative asphalt with a longer lifetime will be on the market at the moment of the first resurfacing cycle.**

### Strategy D: Innovative Asphalt

The last strategy that is used in DBFM contracts also aims on only one resurfacing during the contract period. But instead of using a new asphalt type after using traditional pavement in the first phase of the contract period, this strategy starts with innovative asphalt right away. The exact details are commercially sensitive and therefore secret but it is a different pavement type than traditional double layer porous asphalt. This strategy is currently being used at the A15 project. A mayor disadvantage is that when introducing a new asphalt type in the Rijkswaterstaat network, the introducer is obliged to prove the quality of the pavement. These tests take time and money.

Based on experience abroad, the expected lifetime of this innovate asphalt is 12 years for both the heavily and lightly loaded lanes (Moenielal, 2013). Furthermore, there is no need to separate the heavily- and lightly loaded lanes; the entire pavement is resurfaced in one go. Exact cost are unknown so the cashflow is based on the following assumptions.

- The resurfacing cost are 20% higher than in a traditional double layer porous asphalt total resurfacing.
- The cost to get approval from Rijkswaterstaat are 20% of the cost of a total resurfacing.
- The uncertainty in the planning of the resurfacing is adopted from strategy A, and translated five years back.

Graph 21 shows the cashflow of this strategy.

**Strategy D Budgeted cashflow: Innovative asphalt**

*Cost (2008 pricelevel)*

Construction | Exploitation

*Time -> (quarters)*
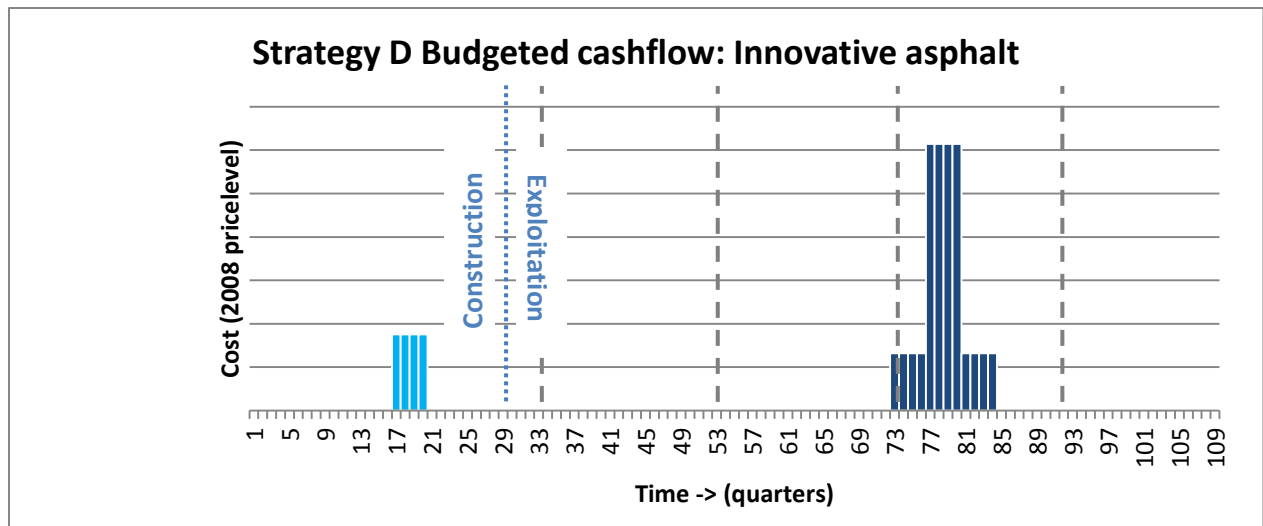
**Graph 21: budgeted cashflow of Strategy D: innovative asphalt. This strategy has only one resurfacing peak in which the entire road surface is repaved in one cycle. Because it is an innovative asphalt type, a small peak in the construction phase is added in which the private party is obliged to prove the quality of the asphalt.**

## Omission of penalty points

These four resurfacing strategies are the common options for maintenance engineers in current double layer porous asphalt maintenance design (Moenielal, 2013) (Spaargaren, 2013). The selection made from these strategies influences the cashflow of the project and subsequently influences the inflation correction. How this choice influences the inflation correction is unknown.

An important constant in all four strategies is that it is assumed that the execution of the maintenance work does not result in any penalty points or cuts in the Availability Payment. This assumption is valid because in practice, the maintenance is executed in the penalty-free time windows provided by Rijkswaterstaat (Moenielal, 2013). The result is that possible cuts are omitted from this research.

## 7.3 Model outputs

In order to answer the research question on the mismatch between inflation cost and inflation correction, a special performance indicator is designed to reveal this mismatch. The indicator is called the *Inflation Cost Cover Ratio* (ICCR) and describes the percentage of extra cost due to inflation that is compensated by the inflation correction. Because the time value of money is relevant in the comparison of the four strategies, the percentage is calculated with the present values of the inflation cost and inflation correction. In an ideal situation, where all cost for inflation are perfectly compensated by payments from the public authority, the ICCR would be 100% in every quarter.

$$ICCR = \frac{PV\ Inflation\ correction}{PV\ Inflation\ cost} * 100\%$$
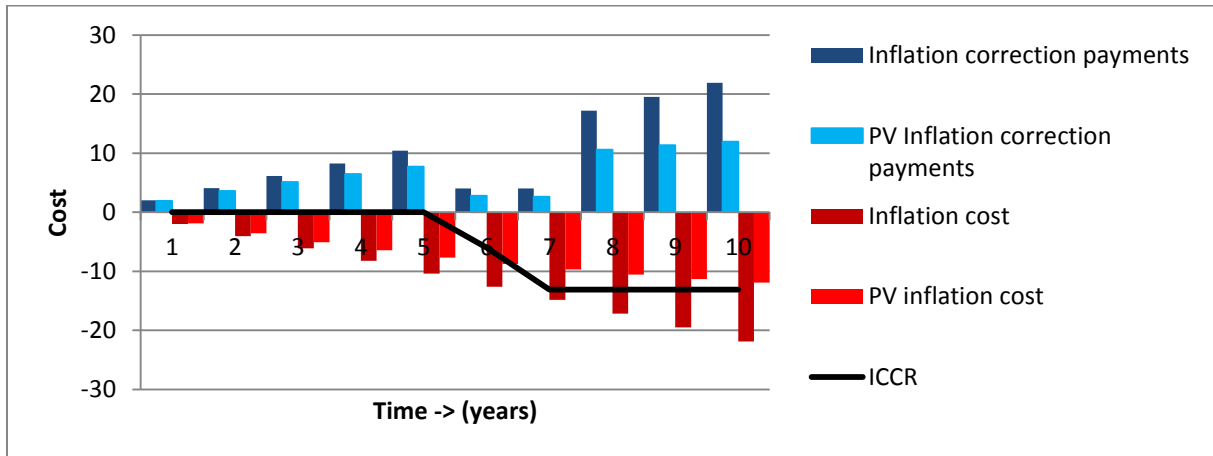


**Graph 22: ICCR development over time with insufficient inflation correction**

The graph above shows the workings of the ICCR. The red bars show the extra cost due to price rise that are to be paid on top of the expenses estimated at price level t=0. The blue bars resemble the inflation correction payments, provided by the public authority. When the two are in perfect balance, as is the case in the first five years, the ICCR is 100%. When the inflation correction payments are unable to cover the extra cost, the ICCR dips and remains at that level if no extra payments can be made to cover the cost. The mismatch between the blue and red bars is caused by the imperfections in the index formula.

### ICCR$_D$

The absolute ICCR must be compared to the base case ICCR because private parties incorporate the imperfection of the index formula to some extent (Grotenhuis, 2013). In this research, a derivative of the ICCR; the *ICCR deviation from base case* (ICCR$_D$) is designed to do so. The strategy comparison model calculates the inflation correction based on the index formula. The index formula has the inflation rate and weight factor per cost component as inputs. In this model, the weight factors are determined based on their share of cost per 5-year period. A base case calculation with deterministic planning of activities and deterministic price level change does not result in a 100% ICCR. This is due to the drawbacks of the index formula described earlier. So on the basis of a simple deterministic

calculation, the private party knows it is losing money over the period of the project. To combat this in practice, the weight factors are raised in such a way, that the base case has a 100% ICCR. Another method to get the ICCR to 100% is raising the Availability Payment. The raising of weight factors or the AP in order to get the ICCR to 100% is strategic behaviour because it makes the inflation correction more volatile than the inflation cost. The $ICCR_D$ is the ICCR minus the ICCR of the base case, exposing the deviation from the expected inflation correction.

$$ICCR_D = ICCR - ICCR_{base\ case}$$

A second performance indicator relevant to this research is the Net Present Value of the project. The NPV makes it possible to compare profitability of projects. When a project has a high ICCR but a low NPV, the project is still financially unsuccessful.

The third performance indicator is the reference value of the bid. Rijkswaterstaat estimates the inflation correction with pre-set reference values per price level index. This expected inflation correction is added to the payable Availability Payments. The Present Value of inflation correction, one-off payments plus the Availability Payments adds up to the reference value of the bid. The consortium that offers the lowest bid wins the tender.

# 8. Results

This chapter will briefly describe the results of the simulations run with the ICCR calculation model. In order to be able to compare the outcomes and stay concise, the results of the different strategies are combined. Detailed results of each strategy separately can be found in Appendix E: Simulation results.

## 8.1 ICCR: Inflation Cost Cover Ratio

The first performance indicator is the Inflation Cost Cover Ratio. It measures what percentage of the extra cost made due to price rise is covered by the inflation correction payments of the public authority. The ICCR gives the percentage of coverage at the end of the project and takes the discount rate into account by using the present values of the cost and correction. An ICCR of 100% means that the present value of the inflation cost is equal to the present value of the inflation correction after the project period. A lower value means that the cost for inflation are higher than the inflation correction payments and vice versa.
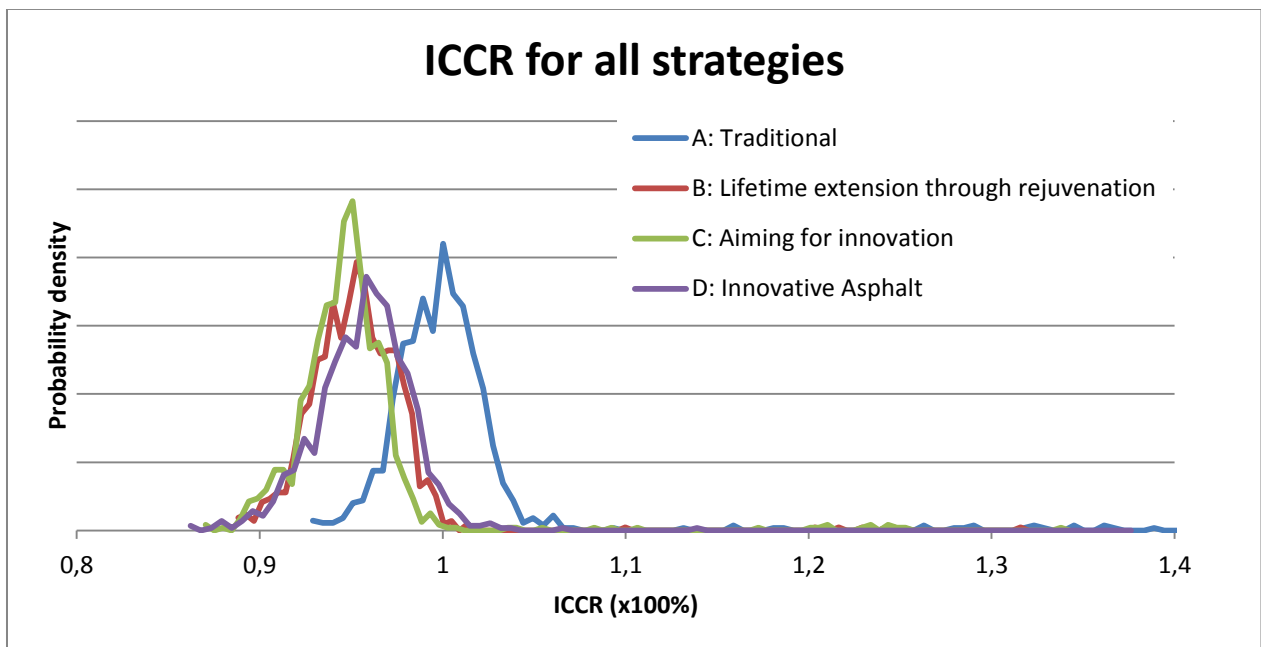


**Graph 23: overlapping PDF's of ICCR output of all four strategies, the inflation correction in traditional strategy A covers more than the inflation cost in half of the cases (mean > 100%) , the other strategies have much lower ICCR outcomes.**

The graph clearly shows that *strategy A: Traditional resurfacing*, gives the best results. All Probability Density Functions have a similar standard deviation, therefore their width and height are similar. Strategy A however, is clearly shifted to the right, giving a more positive result.

All four PDF's have a few outliers to the right, where extremely high ICCR values are generated. These cases are the result of simulations in which the resurfacing peak falls outside the project timespan. In such a case, inflation correction is received according to weight factors and price level development but no resurfacing cost are incurred, so no extra cost for inflation either. The result is an outlier with a very high ICCR. The differences between the outliers are caused by the different price level developments in these iterations. In simulations with high inflation rates, the inflation

correction payments are higher as well. When comparing situations in which no resurfacing cost are incurred, the simulations with high inflation rates have a higher ICCR value.

## 8.2 ICCR$_D$: incorporation of base case

As stated in section *6. Research design* the expected value of the ICCR in the deterministic base case should be taken into account to understand the unknown behaviour of the resurfacing strategies. This is done with the ICCR$_D$ which is the ICCR of the simulation minus the ICCR of the base case.

The base case of each strategy is the reference point in the ICCR$_D$. In the base case, the ICCR is calculated without variable inputs, but deterministic expected values. So, the calculation uses the timing of maintenance activities from the budget, and uses a fixed price level development percentage. The result is shown in Table 3. These values show an initial index gap, that can be foreseen by the contractor in the tenderphase. The values of A, C and D are very close, while strategy B clearly has the worst inflation correction coverage.

| Base case | ICCR |
|---|---|
| **Strategy A: Traditional** | 97,54% |
| **Strategy B: Lifetime extension through Rejuvenation** | 95,65% |
| **Strategy C: Aiming for innovation** | 97,44% |
| **Strategy D: Innovative asphalt** | 97,27% |

Table 3: deterministic base case Inflation Cost Cover Ratio per strategy

Graph 24 shows the Probability Density Function of the ICCR$_D$ for the four strategies. Again, strategy A has the most positive output; the mean ICCR calculated by the model is 3,1% higher than was expected in the base case. The high value is in this case again caused by the conservative budgeting, which expects higher costs than probable. Without these extra cost items in the last two years however, the deviation from the ICCR in the base case becomes much lower, as is displayed by the green line of strategy C. The other two ICCR$_D$ outputs deviate less from their expected value, -0,5 and -1,2% for strategy B and D respectively.
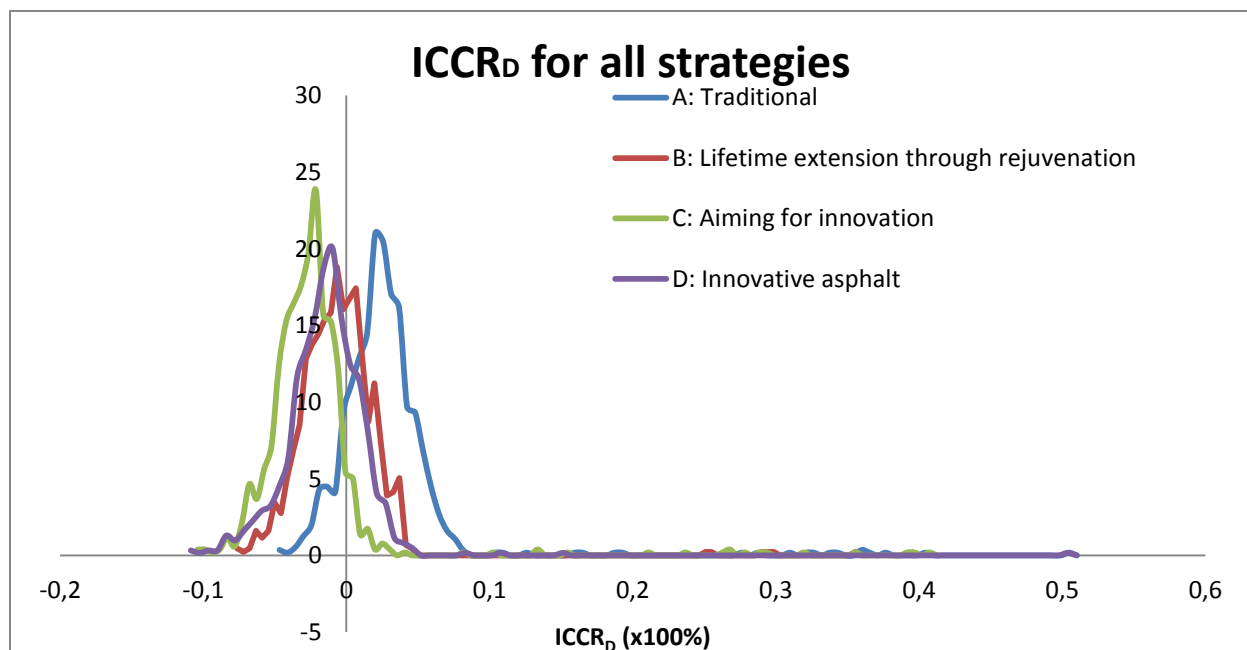


Graph 24: PDF of ICCR$_D$ overlay: the traditional strategy has the most positive performance

## 8.3 NPV: Net Present Value

When looking at the Net Present Value of the strategies, there is a different order of performance. In this output, strategy D scores highest closely followed by strategy A. The other two strategies are very similar and both have a mostly negative NPV.
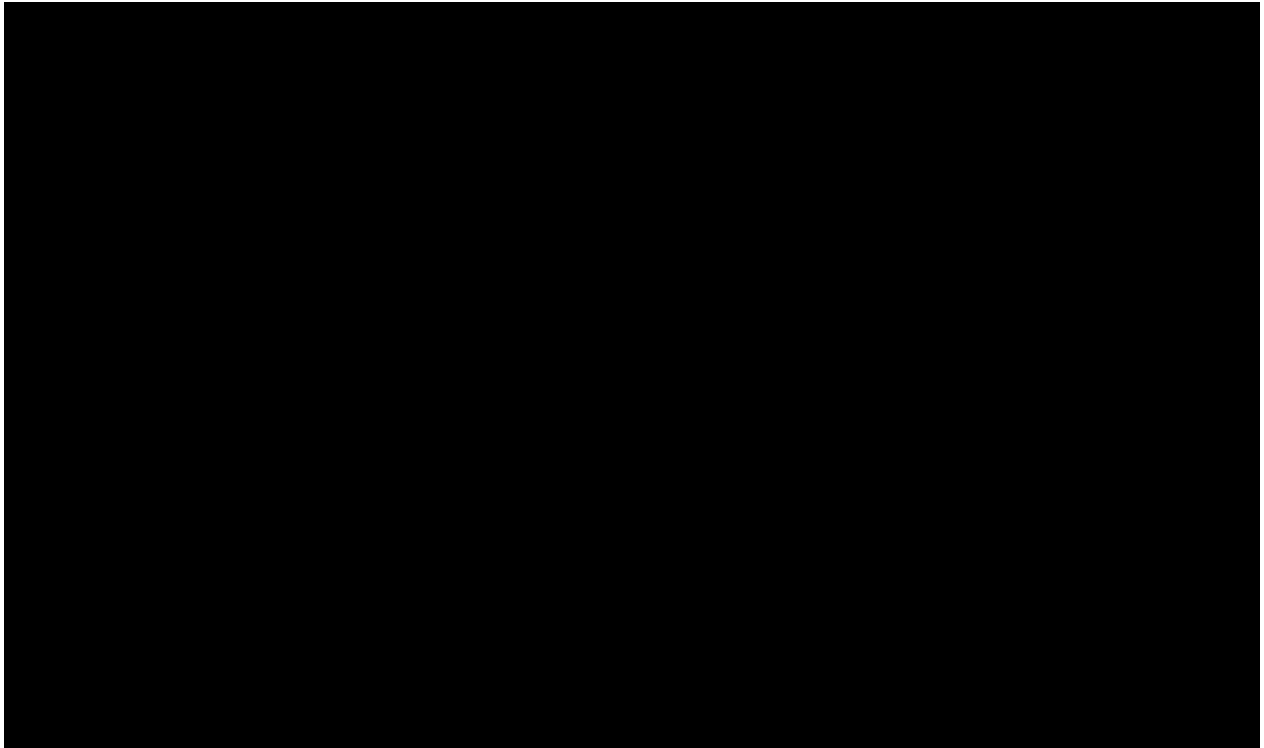


Again, the outliers to the left appear. These have the same cause as the outliers in the ICCR graph. Budgeted cost fall outside the project time span while the Availability Payment is calculated assuming these cost will be made. The difference in actual cost and expected cost causes a very positive NPV. A positive NPV means that the Availability Payments can be lowered.

## 8.4 Result overview

| Strategy | mean ICCR | ICCR base case | mean ICCR$_D$ | mean NPV | reference value bid | budgetted cost resurfacing |
|----------|-----------|----------------|---------------|----------|---------------------|----------------------------|
| A | 100,6% | 97,5% | 3,1% | | | |
| B | 95,2% | 95,7% | -0,5% | | | |
| C | 95,1% | 97,4% | -2,3% | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| D | 96,1% | 97,3% | -1,2% | | | | |

Table 4 shows an overview of the different performance indicators per strategy. A gradient from red to green is used to show which output value is better than another. Means are used to illustrate the outcomes of the simulations because the spread is similar for each strategy. It is clear that strategy A has the best ICCR output. The big difference in ICCR is caused by the fact that strategy A has a maintenance peak in the last two years of the project. Because the planning is done with a 85% certainty interval, chances are very high that this last peak will not be necessary at all. When the peak does not occur, no cost for inflation are made on these expenses but the index correction is paid, this causes a high ICCR.

Graph 25 shows the effect of this safe budgeting method. The two resurfacing peaks resemble one resurfacing cycle (a small peak for the heavily loaded lanes and a large peak for the total resurfacing). The second cycle is budgeted in the last two years, so weight factors are calculated accordingly. The effect of the weight factors in the last 5-year period is the inflation correction payments in this time slot. The graph shows an iteration in which the second cycle falls off the project time horizon entirely. This causes a positive mismatch betv **Table 1: overview performance indicators** high ICCR.
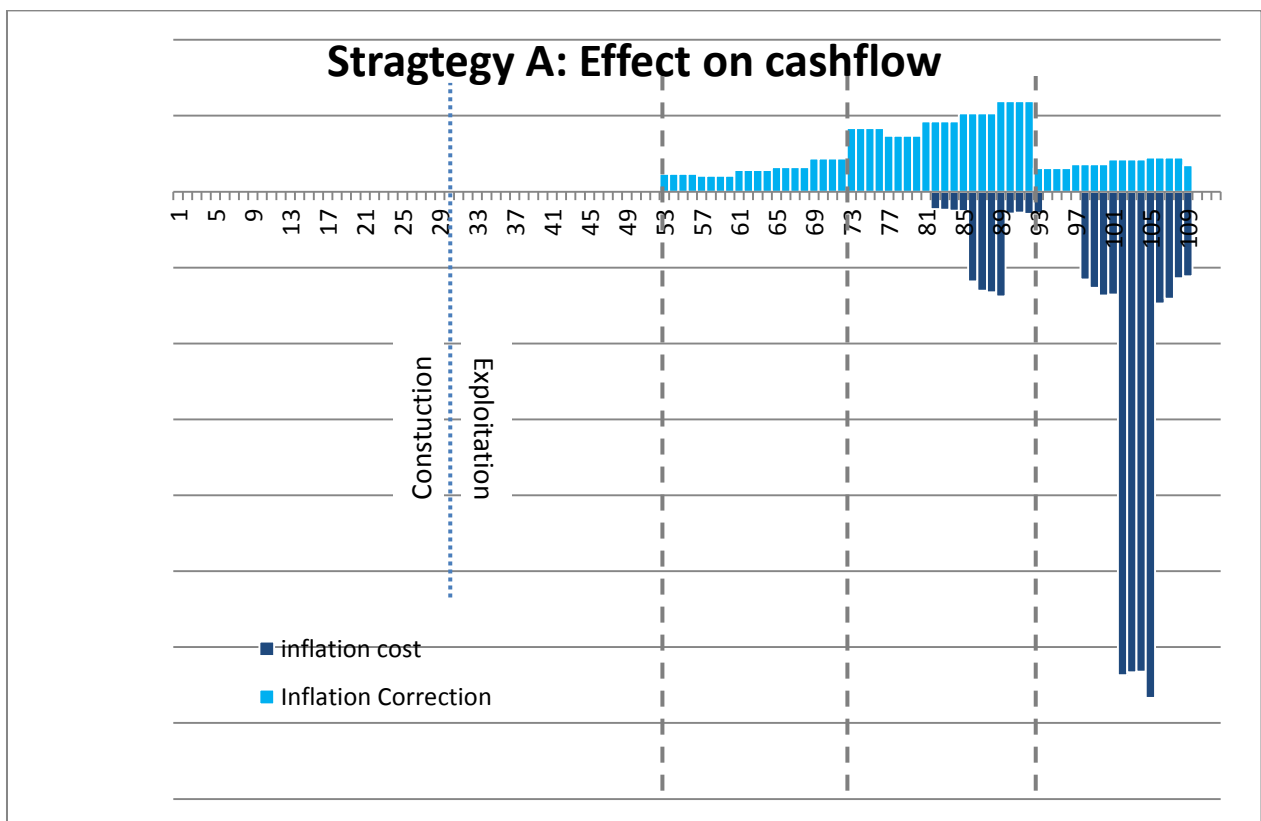


**Graph 25: example of inflation effects on cashflow of one iteration. The light blue bars represent the inflation correction payments from Rijkswaterstaat. The shape of this cashflow is based on the weight factors laid down before financial close. The budget expects a small peak in the third 5-year period, a big one in the fourth and a small peak in the last period. When the peaks shift in time, the expenses below the horizontal axis aren't mirrored anymore.**

When the second cycle is ignored, in both the budgeting and the exploitation, the strategy is identical to strategy C. It would bring strategy A's ICCR back into the range of the other strategies.

Table 4 also shows that strategy A's mean NPV is high, albeit not the highest value, which is reserved for strategy D. There are a few mechanisms at work here; the later in the project period expenses are paid, the higher the Net Present Value of the entire project. This is because expenses further away from t=0 weigh less in the NPV calculation, decreasing the total sum of the PV cost of the project. In contrary to this mechanism, the later cost are made, the higher the cost due to inflation. Prices get higher over time. With a perfect inflation correction, this wouldn't be a problem, but due to the index-gaps, private parties face the risk to pay the difference. This difference becomes larger over time and has a negative effect on the project's NPV from the private party's point of view.

In general, the annual discount rate weighs stronger than the inflation rate, but in specific cases like the price rise on asphalt bitumen, the average inflation rate is higher than the discount rate. In this simulation, the used discount rate is set at 6,25% p.a. and the average price rise of asphalt bitumen is 7,19%. Considering that the latter is only an average price rise, one must note that some simulations might have a much higher price rise rate. When this coincides with the timing of the resurfacing activity, the NPV is influenced negatively, even though it is executed later than budgeted. Graph 26 shows this effect in an example.
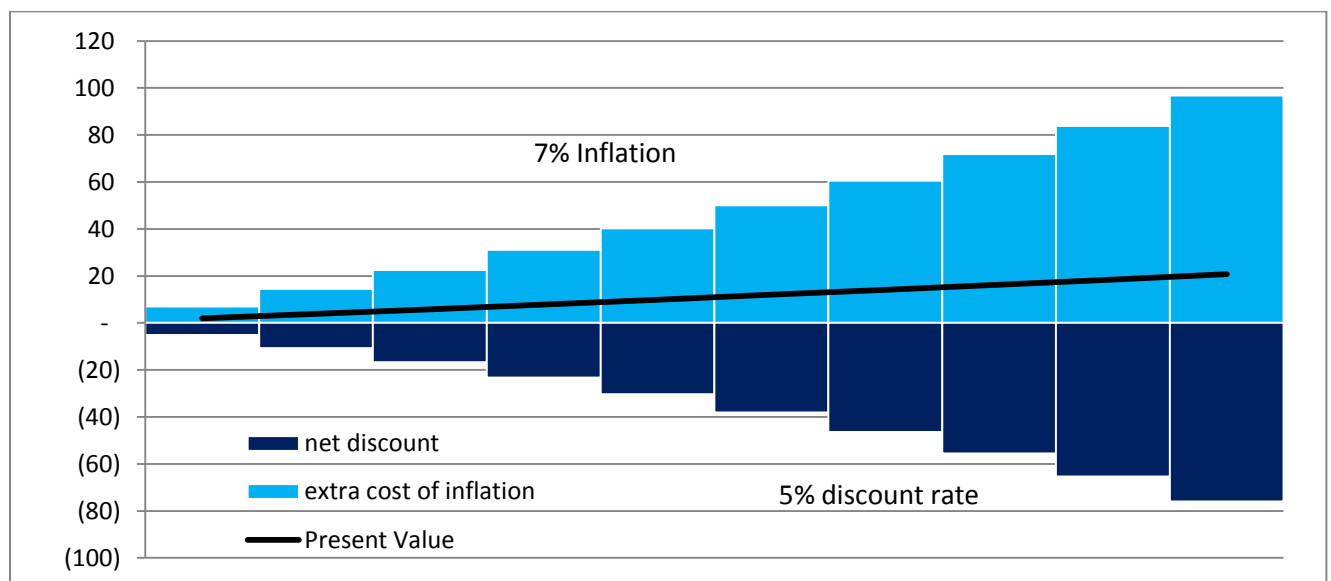


**Graph 26: effect of higher inflation than discount rate on Present Value**

These positive outcomes come at a cost; the reference value of the bid. Both strategies with a positive NPV (A and D), have a high reference value of the bid. If these four strategies would compete in a tender, strategy B would get the project, but it is very likely this would result in a negative NPV in the end resulting in a financially unsuccessful project.

# 9. Validation

In order to evaluate the conclusions, the assumption on which the conclusions are based, as well as the results themselves require validation. In interviews with experts, the important assumptions and results are presented and their opinions are reported in this chapter. Furthermore, the soundness of the model is validated as well, this is described in Appendix B.

## 9.1 Validation interviews

The model must match the processes from reality as well as possible. Assumptions made on calculations and practice are checked with the relevant experts. The calculations used in the model and the inflation simulation is validated by Rutger te Grotenhuis and Maysam Hamdan both from Financial advisor Rebel Group and Kees Vermeij, index specialist at Ballast Nedam.

The assumptions on the different strategies; the stochast used for the maintenance intervals and the shape of the cashflows is checked by Mahesh Moenilal , asphalt expert at Ballast Nedam.

Finally, the  assumptions in the model are checked by Stef de Jong, modeller at Iter Fidelis and daily supervisor of this research.

### Rebel Group - Financial advisor

The first interview was held with Rutger te Grotenhuis and Maysam Hamdam from Rebel Group. In this session, a thorough walk-through of the calculation steps in the model took place. All steps correspond to practice according to the interviewees except for the calculation of the Availability Payments (AP). In the model, the AP is calculated with the assumption that the sum of the expenses at price level 2008 is equal to the sum of the AP at price level 2008 (also including bullet payments). This is an assumption that deliberately excludes the effect of price level development but includes the present values of the cashflows. With this method, the private party assumes a perfect correction of price level changes by the indexation formula which is not true. An imperfection exists and results in a mismatch; the subject of this research.

However, practice shows that the imperfection is incorporated to some extent in the calculations of the AP. The assumption that excludes the effect of price level development does not correspond to the calculations in reality. The expected price level rise and expected price level correction are added to the equilibrium resulting in a higher AP. In the deterministic budget of the base case, enough inflation correction is paid to cover the price level changes.

After this interview, the $ICCR_D$ has been introduced to incorporate this incorporated imperfection in the base case while, at the same time, showing this imperfection. The AP is still calculated with the method without inflation correction. When the ICCR of the deterministic budget with expected price rise is calculated, the result is the deterministic imperfection of the indexation formula in the base case. The $ICCR_D$ adds uncertainty to the calculation and shows the unexpected deviation from this point, which was the goal of this research.  In this configuration, the comment of the interviewees from Rebel Group has been incorporated in the research.

### Ballast Nedam - contractor

A second validation interview was held with Kees Vermeij, head of the estimating department at Ballast Nedam and self-proclaimed indexation-hobbyist. The assumptions in the model were presented and were confirmed one-by-one by Kees Vermeij. There was one point of critique; the choice of the *GWW algemeen* index for the non-resurfacing activities. In the model, the total maintenance expenditures are separated between resurfacing- and non-resurfacing activities, and both have their own index weight factors (for further details see Appendix B: Explanation of strategy performance model). The activity group for non-resurfacing activities is represented by the *GWW-algemeen* index in the model.

This aggregated index is meant to be used for construction of new edifices in the infrastructure industry (*Grond-, Weg-, en Waterbouw*). The composition of this index includes commodities like concrete, labour, groundworks, gasoil and also bitumen. Especially the bitumen component is troublesome, because the asphalt maintenance is separated from the non-resurfacing activities, leaving few cost for bitumen in the non-resurfacing activities. Furthermore, concrete is a cost component in the *GWW-algemeen* index but does not appear as a cost component in the maintenance budget. Concluding; the structure of the GWW index does not match the structure of the non-resurfacing maintenance cost.

But when Kees Vermeij was asked which index would match the non-resurfacing maintenance activities more accurately, he concluded the *GWW-algemeen* was still the best of the CROW indices.

Furthermore, he expressed his opinion on the results. The fact that the ICCR-outputs were close to each other and close to 100% made him confident about the correct inner workings of the model.

### DIBEC – Engineering firm

The third validation interview was held with asphalt specialist Mahesh Moenilal from DIBEC. He is responsible for the asphalt maintenance plan in the A15 DBFM project. The findings and method of the research have been presented and he commented with the following notions.

Just like mr. Vermeij, mr. Moenilal thinks the extra cost for the tests for proving the innovative asphalt in the fourth strategy is too high. In the model it is set at 20% of the total resurfacing cost, while 5% is a better estimate. Furthermore, this cost component can be assumed even smaller when the subsidies of Rijkswaterstaat are taken into account. Rijkswaterstaat wants to stimulate innovation and supplies subsidies to make it more attractive to private parties to use new technologies. The effect of lower cost for these proving tests are not reflected in the inflation correction or cost in the research model. However, the effect is reflected in the NPV and reference value of the project because it changes the CAPEX. It is not expected that a smaller cost for the tests will change these two parameters considerably, because it is only a very small portion of the total CAPEX (<1%).

Secondly, he notices that the third strategy; aiming for innovation is the most commonly used strategy among Dutch contractors in DBFM projects (Moenielal, 2013). The asphalt industry has seen many innovations over the last decade and will continue to develop new mixtures. Besides new asphalt mixtures, the industry is developing new methods to extend the lifetime of the pavement like

in the strategy B: *lifetime extension through rejuvenation*. Remarkably, the most widely used strategy: aiming for innovation, has the worst performance when it comes to $ICCR_D$.

Thirdly, mr. Moenilal confirms that ravelling is the decisive damage form in double layer porous asphalt pavements. The other likely damage form is unevenness of the road surface but the repair cost of this damage form is so high, that the road is constructed in such a way that this does not happen. Unevenness of the road surface is caused by settlement of the sand bed on which the asphalt rests. To mitigate the risk of settlements the sand bed is strengthened in risky areas. With the risk of unevenness excluded, the remaining damage form is ravelling.

Overall, mr. Moenilal thinks the results are explainable and thinks the research is a good example of the bridge between finance and technology. He acknowledges the difference in language and the fact that both parties are unaware of the effect on each other's work fields. This research gives him a tangible example that shows the necessity of a better understanding of this interface between finance and technology.

## 9.2 Model run with historical values

Running the model with historical values of price level developments tests whether or not the inflation simulation is doing what it was designed to do. In this check, the uncertainty of planning of the maintenance activities are kept variable while the price level developments are fixed at the historical values. The historical values are the price level developments from '97 to '12. The output values of the calculation with historical values are inside the range produced by the simulation which affirms the way price level development is simulated, see Table 5.

|          | historical data | simulation |
|----------|-----------------|------------|
| **Strategy** | mean ICCR    | mean ICCR  |
| A        | 100,60%         | 100,60%    |
| B        | 94,45%          | 95,20%     |
| C        | 95,45%          | 95,10%     |
| D        | 97,18%          | 96,10%     |

**Table 5: ICCR calculated with historical data compared to simulation results**

# 10. Conclusion & Recommendations

This research was aimed on finding an answer to the research question. The research question was defined as; *Which resurfacing strategy minimizes the net present value mismatch between inflation correction and actual inflation cost in DBFM road projects in The Netherlands?* By means of a simulation of multiple future paths, four different strategies are tested and compared. The answer to the research question is:

> Because strategy B deviates least from the expected outcome of the ICCR, the strategy of *Lifetime extension through rejuvenation* is the best resurfacing strategy when it comes to the net present value of the mismatch between the inflation correction and inflation cost in Dutch DBFM projects.

## 10.1 Conclusion

The research uses a simulation of inflation based on historic data and a simulation of planning uncertainty based on maintenance intervals of existing double layer porous asphalt pavements. Besides these suppositions on future paths, this research assumes a budgeted equilibrium between income and cost and a base case incorporation of imperfection of the index formula. The budget and quality goals are confined by the project time horizon of the case study. The $ICCR_D$ (Inflation Cost Cover Ratio) is the designed performance indicator which houses these assumptions and makes different strategies comparable. The following conclusions can be made based on the results of this output parameter.
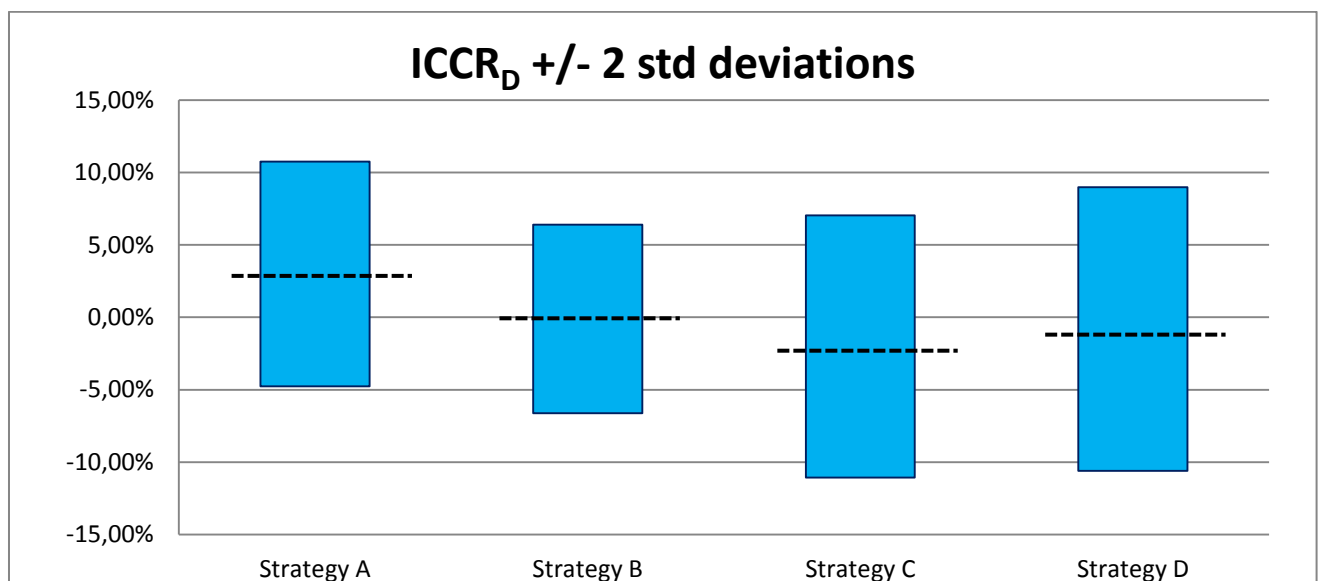


**Graph 27: $ICCR_D$ 95<sup>th</sup> percentile of all four resurfacing strategies. The dotted black line shows the mean simulated value of the $ICCR_D$ and the blue block shows the 95<sup>th</sup> percentile created by taking tow standard deviations above and below the mean value. 0% means that the inflation correction behaves exactly as expected in the base case calculation.**

As seen in Graph 27, the traditional resurfacing regime, Strategy A: *Traditional*, performs best for the budget of the private party. With a positive mean $ICCR_D$, the inflation correction paid by Rijkswaterstaat, minus the inflation cost is more than expected in the base case. This is good for the project balance but this strategy outperforms the expectations which makes the tender bid

commercially not very competitive. This is due to the safe method of budgeting in this strategy which assumes a peak in maintenance cost in the final two years of the project. The strategy's cashflow is constructed with maintenance theory, degradation data and engineering practice. However, in a competitive market, the bid resulting from this strategy is very safe. It is so safe, that the cashflow never occurs exactly as budgeted in the simulation. This causes the inflation cost to be much lower than expected, which benefits the $ICCR_D$. The safe maintenance strategy is reflected in the high reference bid, making this strategy the losing one in the tender.

Strategy B: *Lifetime extension through rejuvenation* performs almost exactly as expected. The mean of the $ICCR_D$ outputs is very close to zero and besides that, the spread of the 95th percentile is much smaller than the other two strategies C and D.

Conversely, strategy C: *Aiming for innovation* and D: *Innovative asphalt* on average perform worse than expected ($ICCR_D < 0\%$). In most simulations, the inflation correction is insufficient to cover the cost of inflation, causing negative financial outcomes for the private party at the end of the project.

Because strategy B deviates least from the expected outcome of the ICCR, the strategy of Lifetime extension through rejuvenation is the best resurfacing strategy when it comes to the net present value of the mismatch between the inflation correction and inflation cost in Dutch DBFM projects. This is the answer to the research question.

## 10.2 Relevance test

To prove the relevance of the inflation correction a hypothetical statement is formulated as follows in Chapter *6. Research design*:

> *It is expected that a choice between two maintenance strategies has a relevant effect on a project's budget, the choice results in a difference in the inflation correction mismatch of over* ▮▮▮▮▮▮ *PV .*

Graph 27 shows the different outcomes of $ICCR_D$ for the four different maintenance regimes, the difference of the outcomes confirms the first part of the hypothesis; the maintenance strategies perform differently on inflation correction. The largest difference in inflation correction is between the *traditional* strategy A and the *Aiming for innovation* strategy B. The difference between their mean $ICCR_D$ is 5,3%, which comes down to ▮▮▮▮▮▮ in present value in this simulation.
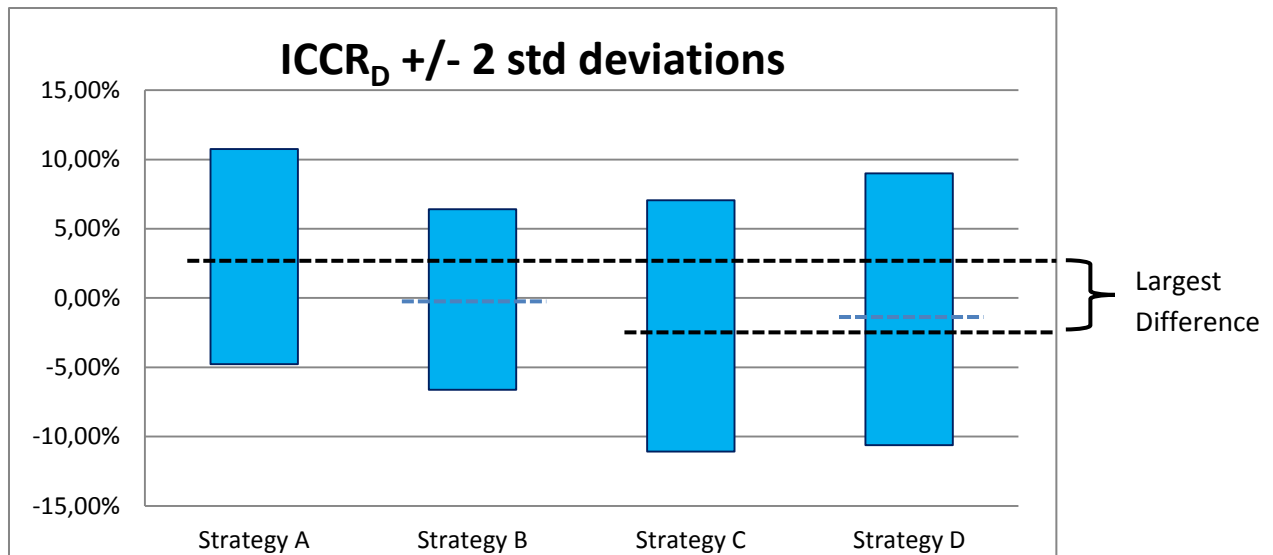
**Graph 28: showing the largest difference between the means of the strategies' ICCR simulation results**

In other words, the choice in maintenance strategy changes the budget of the resurfacing maintenance more than 2% in present value cost. Therefore, the hypothesis is accepted.

This research shows that inflation correction should be taken into account in a variant study because it has a relevant impact on the budget. This means that if contractors take the mismatch of the indexation formula into account, they can make offers with a better mitigation of risk resulting in better value for money for Rijkswaterstaat in DBFM projects.

## Relevance to society

The research gives a better insight in the dynamics of the index formula and the mismatch between inflation correction and inflation cost.

With the understanding of the mismatch of the index formula, the risk  on the mismatch can be better identified by the contractor. Without this knowledge of the size of the effect of the risk, it is likely to be overrated, resulting in a risk reserve that adds to a costly offer. This reduces the Value for Money from Rijkswaterstaat's  point of view. Rijkswaterstaat will have to pay for this high offer with tax payers money. Conversely, if the risk is not recognized at all, and the risk is not mitigated,  the private party will have to make an appeal to her risk reserves. This is probably what happens in the current DBFM projects.

In the current situation in the construction sector in The Netherlands, where margins are very thin, contractors will go very far to avoid using the risk reserve. The result is a constant battle between the contractor and Rijkswaterstaat about responsibilities, unknown risks and changes in contracts.

This is bad for the image of construction sector, which is notorious for delays and cost overruns. The consequences are paid with tax-payers money, making the construction sector infamous. An improvement of the risk mitigation before the project has started, will result in fewer delays and cost overruns, which improves the public opinion on the construction industry. This research makes it possible to better mitigate one of many risks in construction projects.

Besides the benefit to the efficient use of tax money and the improvement of the image of the construction sector, this research provides an argument to improve the cooperation between maintenance engineers and financial advisors. As stated in paragraph *6.4 Relevance¸* the collaboration between these two parties is not very strong, while this research suggest the interface between the two; indexation, is relevant to a project.

## 10.3 Other findings and recommendations

Besides the answer to the research question and the relevance test, several other findings can be noted. This paragraph describes these other findings.

### Two sorts of mismatches

The research also shows there are two sorts of mismatches in inflation correction. The first mismatch is caused by imperfections of the index formula even when the cashflow behaves exactly as expected in the deterministic budget (gap 2 and 4). This mismatch is taken into account in DBFM projects at the moment. The second mismatch occurs when the cashflow deviates from its expected path. This deviation may occur in the price development or the timing of expenditures. This second mismatch is not taken into account in the current DBFM projects. The research suggests the private party must take this into account in the tenderbid because it causes variations in the cashflow of a maintenance plan.

### Evaluation of index formula

First of all, the private party should be thankful for the existence of the index formula, the formula is a helping hand for the private party that takes away a lot of uncertainty. A strong property of the formula is that there is little room for strategic behaviour. The index formula is constructed in such a way that when commercial parties try to use it for strategic behaviour, it either leads to more risk or a higher offer.

This research shows the index formula is somewhat unrefined in its calculations, resulting in a mismatch. The rough level of detail is chosen for ease of calculation, changes can be made to the formula in order to reduce the mismatch, but this would introduce discussion as explained hereafter.

*Gap 2; inequality between inflation correction spread over 5 years and maintenance expenses peaks* can be removed as follows. The spread-out of the inflation correction over a five year period could be refined to a correction calculated annually or even quarterly in order to reduce the mismatch. In this way, the inflation correction and inflation cost profiles are mirrored better which strongly reduces the mismatch. However, due to the uncertainty of the timing at which the peak expenses are made, fixed weight factors for each year could result in even larger mismatches than with a spread-out over 5 years. If a peak expenditure is made earlier than budgeted, the fixed inflation correction does not match the expenses because the weight factors are based on the budgeted timing of expenses. Thus, the current method in which the weight factors are spread over a 5-year period is a protection against the mismatch cause by flexibility.

To make use of this build-in protection, the peaks must be budgeted in year 3 of the five-year period in order to have the biggest chance that the peak expenses remain inside the period.

*Gap 3; Inflexibility of index formula regarding uncertainty of maintenance activities' timing* can also be reduced. An improvement of the formula could be done by introducing flexibility; giving private

parties the possibility to change the weight factors as their maintenance activities change from what was budgeted. The drawbacks of this is that it will give room for discussion and strategic behaviour. In the current index formula everything is fixed and undebatable. If weight factors can be changed after the tender offer is made, the client and private party will be debating constantly whether or not the change is reasonable. And with the current state of heavy debates in DBFM projects, an additional point of debate is not welcome.

*Gap 4: use of outdated index figures in inflation correction* can be reduced by using quarterly indices in the calculation of the index figure. In the current state of affairs, the formula uses the indices from January, also to calculate the inflation correction for the third, second and fourth quarter. It is possible to use the indices publicized in each respective quarter, but because there is a big delay between the moment of measurement and the moment of publicizing, calculations delay inflation correction payments. Figures of January are publicized two to three months later, making it only possible to calculate the inflation correction in a later stage. With the time value of money in mind, a delay in inflation correction payments is unwanted.

Concluding, the index formula can be improved to reduce the mismatch. However, this introduces debates and slows down the process of inflation correction payments. The current index formula has a good balance between workability and precision, therefore I recommend Rijkswaterstaat to keep the current indexation method untouched.

## Use more likely budget for weight factor calculation

One reason for the mismatch between inflation correction and inflation cost is the fact that the weight factors in the calculations are based on a budget designed with a 85% certainty interval. I recommend to use two budgets, a safe one, and a more probable one to be used to define the weight factors.

The second one will have the maintenance peaks planned at a 50% certainty interval, making the match between the out- and inflowing cashflow more probable. This improvement has been tested on Strategy C; aiming for innovation with an improvement of the ICCR from 95,1% to 95,7% (€ ▮▮▮▮▮ present value benefit).

Figure 10 shows the difference between the calculation with the same budget for the weight calculation and the use of an secondary adjusted budget for the weight factor calculation. The difference can most clearly be seen in the bar charts that show the arrangement of the weight factors. In the second method, a large part of the weight factor set of period 2 are shifted to period 3. Because it is also more likely that the expenses will occur in period 3, this set of weight factors is more likely to be more accurate. The result is an improvement of the Inflation Cost Cover Ratio.

This improvement has been tested for strategy C, where it results in a better performance from a private party point of view. It is recommended that the private party runs simulations like these to test whether the weight factor calculation can be improved.
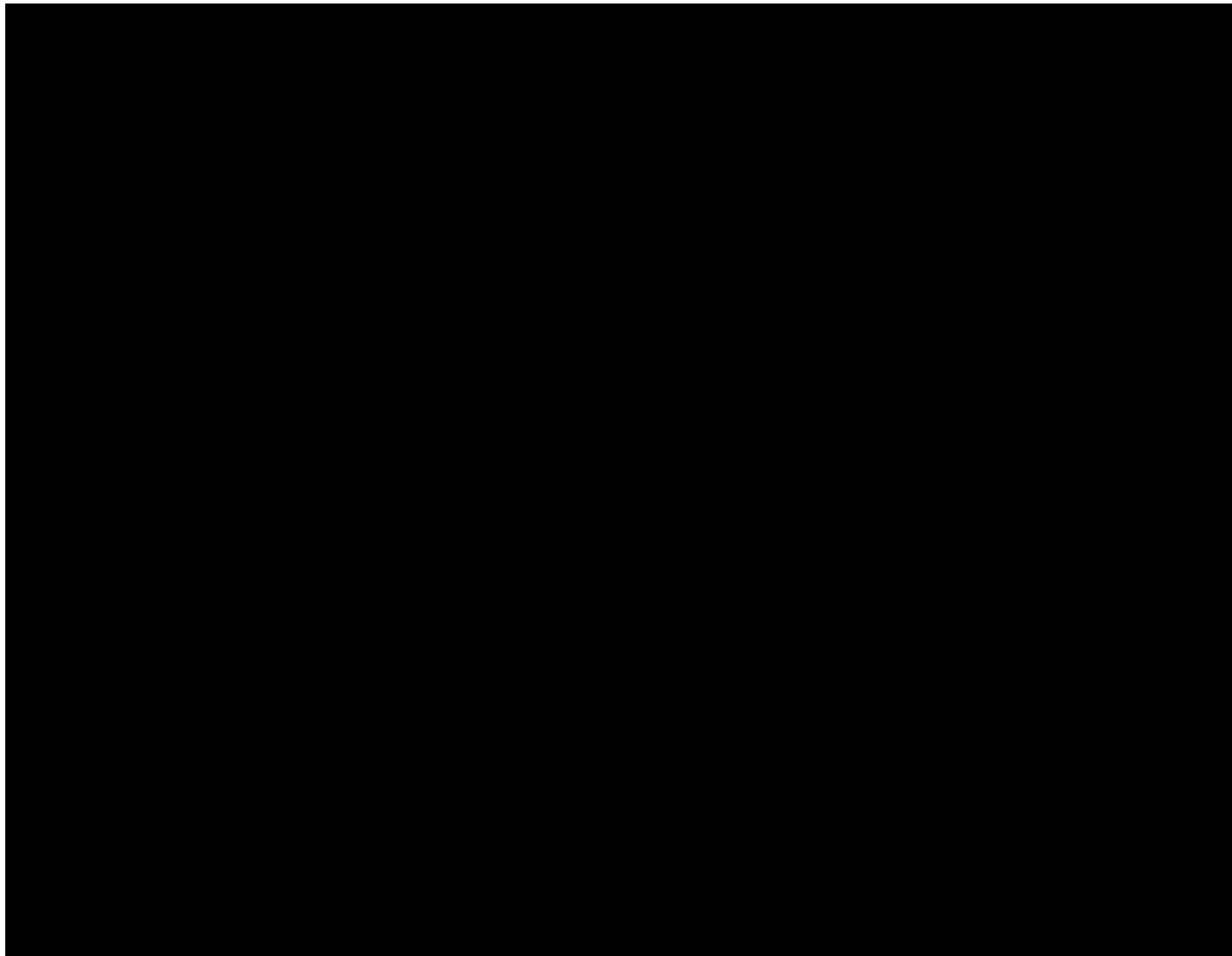
**Figure 10: overview of improvement of weight factor calculation. The cashflow is better matched by the weight factors**

## 10.4 Recommendations for further research

This research has only focussed on a small portion of the dynamics of indexation. This paragraph will discuss option for further research that result in usable knowledge for both Rijkswaterstaat and the private party.

### Size of influencing parameters

The simulation results endorse the statement that the larger the spread in planning uncertainty, the larger the spread in ICCR. Strategy B is the only strategy with a different Probability Density Function that simulates the timing of the resurfacing activities. Strategy B has a 'pointy' PDF, resulting in a more certain planning, this might be the cause of the small standard deviation in the $ICCR_D$.

| ICCR(D) | std deviation |
|---|---|
| **Strategy A** | 3,88% |
| **Strategy B** | 3,26% |
| **Strategy C** | 4,53% |
| **Strategy D** | 4,90% |

However, the difference in standard deviation of the $ICCR_D$ is not that distinctive, considering the other variables within the strategies. It might be interesting to do further research on which factors within the strategies are leading. Is it the spread of the cashflow or the PDF? Knowing this results in rules of thumbs that can be used in the design phase of a  project.

### Pre-financing pressure
The index gap results in a mismatch between income and cost for price rise. The calculations made in this research are focused on the result of the index gap at the end of the project. But the gap changes over the timeline of the project. In negative cases, the private party is forced to pre-finance the extra cost for inflation because the correction is paid in the following quarter.

Graph 29 shows the effect of the spread of inflation correction over the project timespan. At some moments in time, the balance is tipped in the positive direction, but when resurfacing activities are executed, high cost for inflation are incurred and the balance tips to the negative side. In the quarters following this strong dip, the balance restores back to the final ICCR value.

The entire surface of the graph below the horizontal  needs to be pre-financed with money from either equity or debt, this is costly and therefore unwanted. It would be interesting to research how the pre-financing pressure can be reduced. This research would have to look into the height of bullet payments, the size of a contractor's reserve account and the repayment structure of the debt.
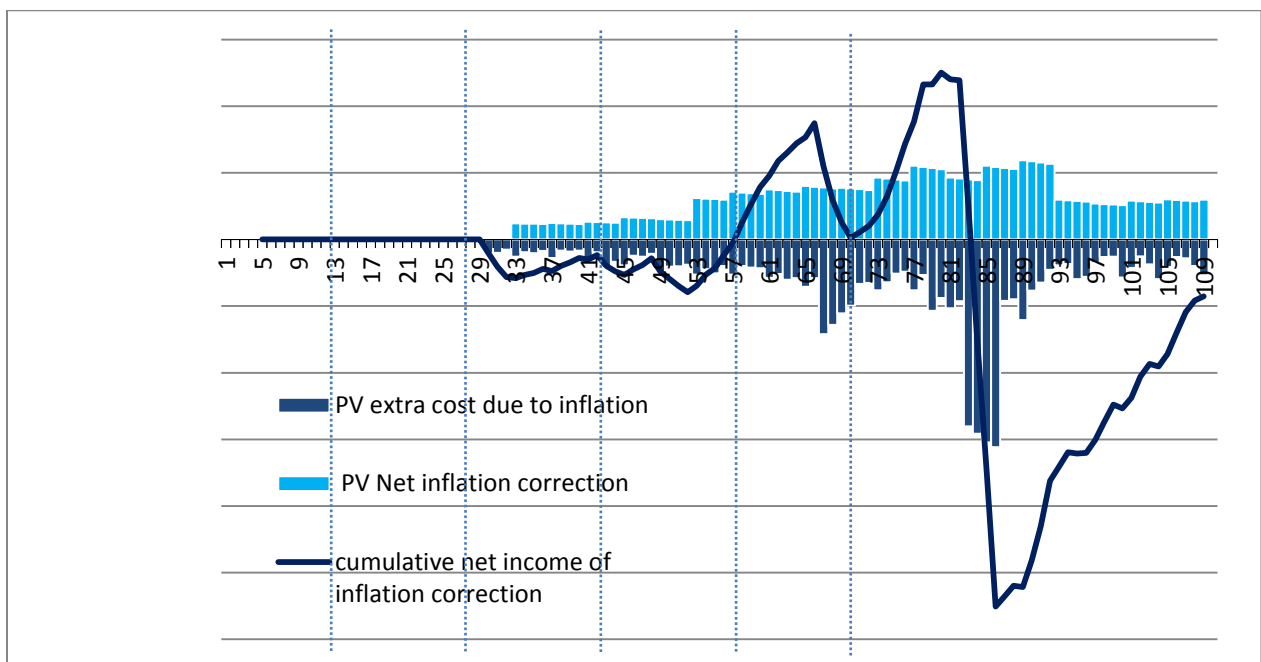


**Graph 29: Balance of inflation correction and inflation cost**

## 10.5 Limits to conclusions
It is important and necessary to note that the conclusions are based on assumptions. Especially the assumption on the future development of inflation is debatable.  The price level development is based on an extrapolation of historical behaviour of data, but there is no certainty at all that the future will resemble history. Major shifts in geopolitical relations or technological advances may

change price level drastically. Also, events like hyperinflation, which occurred not that long ago in Latin America in the 90's, are not taken into account. Therefore, the conclusions remain confined to a specific assumption on the future.

Furthermore, the assumptions on the lifetime of the pavement is based on historical behaviour of double layer porous asphalt. But a series of very cold and wet winters or a new law allowing heavier trucks would change the degradation of the pavement insofar, that it would fall outside the probability density function expected of the maintenance interval. Therefore, the conclusion must be used with care by taking the assumptions into account.

The incorporation of these two uncertainties oblige the reader to be careful with the interpretation of the results. Especially the quantitative values must not be seen as exact truth, because they are all forecast of the future based on assumptions.

# 11. Discussion and Reflection

This chapter will reflect on the choices made in the process that have led to this final report. Choices made in inputs, research method and interpretation of results are discussed.

### Forecasting with historic values

History cannot always predict future: using relations derived from historical data to predict the future implicitly assumes there are certain steady-state conditions or constants in the complex system. This is almost always wrong when the system involves people.

The simulation of inflation is done by a sophisticated extrapolation of historical values. The timeslot chose for these historical values is as large as it can be, since there is no older data on the specific indices used in DBFM contracts. The result is a dataset of index figures from 1997 to 2012 that is used to simulate possible future price level developments until 2035.

One might argue that the dataset is too small to contain all possible changes in price levels. Furthermore, the largest part of this dataset is part of the Great Moderation; a period of unmatched economic stability from '85 to the crisis in 2008. It is debatable whether this is the right dataset to base the future economic circumstances on. But because this is the only dataset available, it is the best option.

Besides the individual development of price levels of different commodities, the same dataset is used to define the correlation between the prices of products. There is no guarantee for this correlation to stay the same in the future.

### Method of Availability Payment calculation

The method of the AP calculation does not incorporate the inflation correction. The calculation principally assumes a perfectly working inflation correction. Afterwards with the $ICCR_D$ the difference between expected and simulated inflation correction is introduced.

Another method to calculate the AP incorporates the inflation correction which would result in a higher AP and thus changing the NPV. The first method is used because it uncovers the full index-gap.

### Not incorporated in model:

The strategy comparison model is used to expose the imperfection of the model behind the index formula. The strategy comparison model is a model itself, and inherent to being a model, it has it's imperfections.

Firstly, the model takes price levels at quarterly intervals, while some prices change every minute. Taking a quarterly interval reduces the accuracy of the model.

Furthermore, the *GWW-Algemeen* index is modelled with the assumption that the shares of the cost components will remain the same. This makes it possible to apply the ARIMA extrapolation method. However, the shares of cost components change every five years, which could result in large adjustments of the index.

### Other damage forms

The maintenance interval in for the resurfacing of the pavement is based on data from existing road sections. This data is based on ravelling as decisive damage form. This research assumes ravelling is

the decisive damage form because it assumes the system of the case study behaves the same as the road sections from the reference data. However, other damage forms like unevenness of the pavement, especially due to the heavily loaded trucks or longitudinal unevenness due to settlement of soft soil might cause shorter maintenance intervals.

## Cost for buying 'maintenance time'

This research method assumes that all four resurfacing regimes perform equally on the time necessary to execute the maintenance activities. In most DBFM projects, the contractor has to pay 'rent' per closed lane on a motorway. The closure of lanes is necessary for resurfacing maintenance activities.

Rijkswaterstaat offers a number of rent-free hours of lane closures, which are expressed by Vehicle Loss Hours (*Voertuig Verlies Uren, VVU*). The contractor is allowed to use a maximum number of VVU's for free, before 'rent' has to be paid. Experience shows that this maximum is never exceeded, because the rent is very expensive, and Rijkswaterstaat sets the maximum at an acceptable level.

Whether or not the maximum of VVU is exceeded or not is not incorporated in the model, because the model of calculating the use of VVU's is very complex. There are differences in maximum speed, nightly closures and location of road sections. To keep the research simple, this has been omitted. In a consideration of maintenance plans in a real tender however, it is vital that this is incorporated in the variant study.

# Bibliography

A. Meyler, G. K. (1998). Forecasting Irish Inflation using ARIMA models. *Research Technical Paper 3/RT/98*. Central Bank of Ireland.

A-Lanes A15. (2011, maart 1). Scope-document ROADS Project A15 Maasvlakte - Vaanplein. Nieuwegein.

Algemene Rekenkamer. (2013). *Contractmanagement bij DBFMO-projecten.* 's Gravenhage.

Asian Development Bank. (2008). *ADB Public Private Partnership Handbook.* Manilla, Philipines: Asian Development Bank.

B. Bernanke, F. M. (1997). Inflation Targetting: A New Framework for Monetary Policy. *Journal of Ecnomic Perspectives*, Volume 11, number 2, 97-116.

BAM. (2013). *halfjaar cijfers*. Retrieved 25 8, 2013, from www.bam.nl

Bochove, G. v. (2012). *Rafelingsonderzoek op ZOAB boorkernen: het effect van Levensduur Verlengend Onderhoud [LVO] op de levensduur van ZOAB.* Rosmalen: Breijn.

Buelens, C. (2012, March). Inflation forecasting andd the crisis: assessing the impact on the performance of different forecasting models and methods. *Economic paper 451*. Brussels, Belgium: European Commission Directorate-General Economic and Financial Affairs.

Canova, F. (2007, 11). G-7 Inflation Forecast: Random walk, Philips curve or what else? *Macroeconomic Dynamics*, pp. 1-30.

Cate, M. t. (2013, 1 3). Msc. MA. Senior advisor Infrastructure Finance at PriceWaterhouseCoopers. (D. Vervoort, Interviewer)

CBS. (2008). *Onderzoeksbeschrijving Statistiek Consumentenprijsindices.* Centraal Bureau voor de Statistiek.

CBS. (2011). *Basisverlenging prijsindexcijfers Grond-, weg- en waterbouw van 2000=100 naar 2005=100.* Den Haag/Heerlen: Centraal Bureau voor de Statistiek.

CBS. (2013). *Grond-, weg- en waterbouw (GWW); inputprijsindex 2005 =100 toelichting.* Heerlen: CBS.

CEN. (2001). *EN 13306 Maintenance Terminology.* Brussels: CEN.

Cobouw. (2013, 9 19). Prijsstijgingen knabbelen investeringsruimte op.

Coentunnel Company B.V. (2008, februari 20). Indexeringsformule. *07_4070_R0539H_Indexeringsformule*. Amsterdam.

CROW. (2012, 1 1). Indexen ten behoeve van Risicoregeling GWW 1995. CROW.

De Volkskrant. (2013, 7 27). Geldcreatie is een gevaarlijk privilege, zowel in private als in publieke handen. *De Volkskrant*, p. 37.

Eaves, E. (1976). Indexed escalation: inflation damper of danger? *Engineering and process economics 1*, 41-50.

Elfering, S. (2008). *Methodenbescrhijvin prijsindices GWW.* Den Haag: Centraal Bureau voor de Statistiek.

Encyclopedia Americana. (1976). Volume 15. Americana Corporation.

Ende, D. v. (2012, 1 5). Bespreking Problem statement. (D. Vervoort, Interviewer)

Eynde, G. v. (2013, 4 15). Financial manager Coentunnel Company - Financial manager Locorail - Vinci concessions. (D. Vervoort, Interviewer)

Flyvbjerg, B. B. (2003). *Megaprojects and risk - an anatomy of ambition.* Cambridge: Cambridge university press.

Friedman, M. (1977). Milton Friedman Speaks. *Free to Choose television programme.* San Diego: Idea Channel.

Grotenhuis, R. t. (2013, augustus). Adviseur Rebel Group. (D. Vervoort, Interviewer)

INGENIUM Association of Local Government Engineering New Zealand. (2006). *International Infrastructure Management Manual.* Thames.

IPG. (2008). *Eindrapportage IPGWegdekken Monitoring.* Delft: Rijkswaterstaat Dienst Verkeer en Scheepvaart.

J. Koppenjan, H. v. (2002). *Publiek-private samenwerking bij transportinfrastructuur.* Utrecht: Lemma.

J. van de Ven, m. K. (2013, 14 3). (D. Vervoort, Interviewer)

J.H.W. Koster, W. H. (2008, 1). DBFM handboek - een verkenning van contractonderdelen. *Pps bij het rijk*. Den Haag: pps bij het rijk.

J.M. van Noortwijk, D. M. (2004). Deterioration and maintenance models for insuring safety of civil infrastructures at lowest life-cylce cost. *Life-Cylce Performance of Deteriorating Structures: Assessment, Design and Management*, 384-391.

Kennedy, P. (2003). *A Guide to Econometrics 5th edition.* Blackwell Publishing.

Klijn, E. v. (2007). Publiek-private samenwerking in Nederland - overzicht van theorie en praktijk. *M&O*, 156-170.

M. Diron, B. M. (2005). *Forecasting the central bank's inflation objective is a good rule of tumb, ECB Working paper 564.* European Central Bank.

M. Siemaiatycki, N. F. (2012). Value of Money and Risk in Public Private Partnerships. *Journal of the American Planning Assosiation*, 286-299.

Ministry of Finance. (2012, 12 3). Voortgangsrapportage DBFM(O) 2012.

Ministry of Finance. (2013). *Overheidsfinancien*. Retrieved 5 14, 2013, from www.rijksoverheid.nl

Mishkin, F. S. (2001). *The economics of Money, Banking and Financial Markets.* New York: Columbia University.

Moenielal, M. d. (2013, 4 19). Senior Materiaal Technoloog. (D. Vervoort, Interviewer)

Molenaar, P. d. (2011). *CT2800 Wegen en Spoorwegen.* Delft: TU Delft.

Moyer, C., Kretlow, W., & McGuigan, J. (2011). *Contemporary Finacial Management.* South-Western Publishing Co.

N. Verra, M. v. (2003). *De Levensduur van ZOAB - gemiddelde levensduurbepaling op basis van MJPO-2003.* Dienst Weg- en Waterbouwkunde Rijkswaterstaat.

Ng, M. L. (2009). Optimal Long-Term Infrastructure Maintenance Planning Accounting for Traffic Dynamics. *Computer-Aided Civil and Infrastructure Engineering*, 459-469.

P. Verschuren, H. D. (2004). *Het Ontwerpen van een onderzoek.* Utrecht: Lemma.

Palisade. (2013). *@RISK*. Retrieved 4 22, 2013, from www.palisade.com

Palisade. (2013, 2 28). *knowledge base Palisade*. Retrieved 6 19, 2013, from kb.palisade.com

Peijs, K. (2005). *Kamerstuk: Resultaten Taskforce PPS/infrastructuur.* Den Haag: via: www.minfin.nl.

PPS Netwerk. (2012). *Publiek Private Samenwerking Netwerk Nederland*. Retrieved 1 7, 2013, from Projecten Database: www.pps.netwerk.nl

Prof. dr. E.H. Klijn, v. T. (2008). *PPS in Nederland: retoriek of bloeiende praktijk?* Rotterdam: Erasmus University.

Prof. Drs. Ir. J.K. Vrijling, I. d. (2011). *Financial Engineering Reader.* Delft: TU Delft.

R. C. Merton, Z. B. (2000). *Finance.* University of Harvard.

R. Hofman, W. v. (2008). *Kennis update tweelaggs ZOAB, eindrapport van de verbeteringen aan dit product.* Delft: Dienst Verkeer & Scheepvaart.

Rebel Group. (2011). Seminar DBFM in het echt. *DBFM in het echt - wat kunnen we leren van de praktijk?* Rotterdam: Rebel Group.

Rijksgebouwendienst. (2012, 3 19). DBFMO Overeenkomst. *Bijlagen modelovereenkomst DBFMO Huisvesting* .

Rijkswaterstaat. (2010). *DBFM agreement.* Rijkswaterstaat.

Rijkswaterstaat. (2012). *A9/A10/A1/A6 Schiphol -Amstedam -Almere*. Retrieved 4 26, 2013, from Rijkswaterstaat: www.rijkswaterstaat.nl

Rijkswaterstaat. (2012). *Missie en kerntaken - Publiek-Private Samenwerking*. Retrieved 01 07, 2013, from Rijkswaterstaat: www.rijkswaterstaat.nl

Rijkswaterstaat. (2012, 03 28). Schedule 2 Payment mechanism. *Rijkswaterstaat DBFM Agreement Standard 3.0*, p. 92.

Ross, S. R. (2005). *Corporate Finance.* New York: McGraw-Hill.

Rotterdam Vooruit. (2013). *Rotterdam Vooruit*. Retrieved from www.rotterdamvooruit.nl

Ruding, H. (. (2008). *Op de goede weg en het juiste spoor.* Den Haag.

S. de Jong, D. v. (2012, 1 5). Bespreking problem statement. (D. Vervoort, Interviewer)

Schlangen, E. (2012, October). 'Zelfhelend Asfalt'. *TEDx Delft*. Delft: TED.

Schoenmaker, R. (2011). *De ingeslagen weg - een empirisch onderzoek naar de dynamiek van de uitbesteding van onderhoud in de civiele infrasstructuur.* Delft: Next Generation Infrastructures Foundation.

Schöndorff, P. d. (2000). *economie - 1500 temren van A tot Z.* Utrecht: Spectrum.

Sieswerda, S. (2013, 3). Director of Iter Fidelis. (D. Vervoort, Interviewer)

Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations.* The Electronic Classics Series.

Spaargaren, T. (2013, 4 11). Asfalt expert. (D. Vervoort, Interviewer)

TNO. (2011). *Levensduur 2L ZOAB.* Delft: TNO.

VBW. (2012). *Richtlijn tweelaags ZOAB .* Zoetermeer: Vakgroep Bitumineuze Werken - Bouwend Nederland.

VBW Asfalt. (2005). *Asfalt Onderhoudstechnieken - Vereniging tot Bevordering van Werken in Asfalt.* Breukelen: VBW.

VolkerWessels. (2013). *halfjaar cijfers volker wessels*. Retrieved 8 25, 2013, from www.volkerwessels.nl

Voskuilen, J. T. (2012). *Onderzoek naar levensduurverlengend onderhoud van (TL)ZOAB(+).* Delft: Rijkswaterstaat, Dienst Verkeer en Scheepvaart.

Vrijling, J. V. (1997). *Probability in Civil Engineering. Part 1: Th theory of probabilistic design.* CUR.

Whitelaw-Jones, K. (2013, 01 22). FAST Standard Organisation Launch Event. Rotterdam: Rebel Group.

Wisgerhof, A. (2002). *Optimalisatie aanleg en onderhoud snelwegen.* Delft: TU Delft.

Woltjer, G. (2002). *De economische manier van denken.* Bussum: Uitgeverij Couthino.

Yescombe, E. (2007). *Public Private Partnerships - Principles of Policy and Finance.* Oxford: Elsevier.

Yescombe, E. (2007). *Public-private partnerships, Principles of Policy and Finance.* Oxford: Elsevier.

# List of Definitions

|  | abbreviation | *Dutch translation* | Description |
|---|---|---|---|
| **Availability Payment** | AP | *Beschikbaarheidsvergoeding (BBV)* | Periodic payment of PA to contractor for the delivered service. |
| **Commencement date** |  | *Startdatum* | Date at which the DBFM agreement starts |
| **Cost component** | ccp | *kostencomponent, productgroep* | a portion of a cashflow that can be attributed to a specific product or service. E.g. labour, steel or asphalt bitumen. Each cost component has it's own index publicised by CBS or CROW |
| **Debt Service** |  | *Betalingen voor lening* | Repayment of debt + interest payments |
| **Design Build Finance Maintain** | DBFM | *DBFM* | A project organized in such a way that the private party is responsible for the Design, Construction, Financing an Maintenance of an asset. The private party is reimbursed by periodical payments based on the delivered quality |
| **Double Layer Porous Asphalt** | DLPA | *tweellaags ZOAB, 2L ZOAB* | Asphalt type with a toplayer of fine granulate and a secondary layer with a large granulate. This type is required in the recent Dutch DBFM projects |
| **Government building service** |  | *Rijksgebouwendienst (RGD)* | Governmental organization responsible for the housing needs of governmental institutions |
| **Index** |  | *Index* | a series of index figures used as a measure of expressing a price level of a certain commodity at a specific point in time compared to the reference point in time. |
| **index clause** |  | *indexeringsclausule* | section of DBFM agreement that contains the inflation correction method |
| **Indexfigure** |  | *Indexcijfer* | one of the figures of a series corresponding to a specific commodity and a specific point in time |
| **Inflation correction** |  | *inflatiecorrectie* | The inflation correction is the amount of money the private party receives on top of the Availability Payment to compensate for price rise in a quarter |
| **Maintenance interval** |  | *levensduur* | time between completion and replacement |
| **Motorway** |  | *Autosnelweg* | dual lane road with a maximum speed of >80 |
| **Overall indexation** |  | *algemene indexering* | escalation of cashflow using one general index group |
| **Public Authority** | PA | *Publieke authoriteit* | Governmental organization able to enter into contracts for infrastructure needs. The Dutch PA is Rijkswaterstaat |
| **Public Private Partnership** | PPP | *Publiek- Private Samenwerking* | structured collaboration between public and private parties for the provision of public services and facilities |

| | | | |
|---|---|---|---|
| **Ravelling** | | *Rafelling* | damage form of asphalt where the pavement loses granulate due to weakening of the bituminuous binding material. |
| **Reference value** | | *referentiewaarde* | Values used by Rijkswaterstaat to make assumptions on the price development over the contract period. Part of the tender documents |
| **Rijkswaterstaat** | RWS | *Rijkswaterstaat* | Executive body of the Dutch Ministry of Infrastructure and the Environment. |
| **Selective indexation** | | *selectieve indexering* | Escalation of cashflow using specific index groups |
| **Subscription guide** | | *Inschrijvingsleidraad* | document released by the public authority containing all relevant information for subscriptors to complete a tenderbid |
| **Tenderbid** | | *Aanbieding* | Bundle of documents describing the offer of a consortiom. The tenderbid includes a price, planning, kwalitative documents and the index parameters. (alos known als Best and Final offer, BAFO) |

# Appendix A: Inflation simulation

## Research on price level simulation

The Monte Carlo analysis used in the research requires a simulation of the price level indexes used in the indexation formula. To be able to do this, a research in econometrics and time series forecasting has been carried out. This appendix describes the results of this research and explains the mechanism behind the used model.

## Requirements of simulation result

A major assumption is that the Future price level development is similar to  historical price level development. One should note that predicting the future is impossible, however, one can assume developments based on historical data of the same developments. For example, if a bread costs €1 in year one, it is likely that the next year, the same type of bread will cost €1,02. Furthermore, it is *un*likely that the bread will cost €3,00 after a year. This 'gut feeling' of likelihood is made on the basis of historical behavior of price level development.

The properties of the historical data have to be incorporated in the simulation results. These properties will be explained in this section.

**Property 1**: *Price development will follow an exponential trendline*. The indexfigure datasets, which are to be generated, are based on quarter-on-quarter price level change. This change is expressed in percentages. A constant inflation percentage would result in an exponential growth of the indexfigure.

The historical data have an exponential path, but drops up and down the exponential line in cycles of different lengths. An exponential line is chosen over a linear line because of a better fit with an exponential regression line as opposed to a linear regression, see Graph 30. Both the linear and exponential regression lines are estimated using the least-squared estimation method. The measure of goodness of fit, $R^2$, is best when closest to 1. The $R^2$ values of the two regression lines lie close to each other, but the value of the exponential line is closer to 1, thus the price level index is assumed to follow an exponential path.

$R^2$ is the coefficient of determination and is frequently used in econometrics. It represents the proportion of the variation in the dependent variable "explained" by variation in the independent variables (Kennedy, 2003).

This assumption is in accordance to the assumptions in Rijkswaterstaat's reference values for DBFM contracts. These values assume a certain percentage of annual growth, resulting in an exponential line. The assumption is also backed by the European Central Bank's (ECB) inflation target, which is around 2% annually, also resulting in an exponential development.
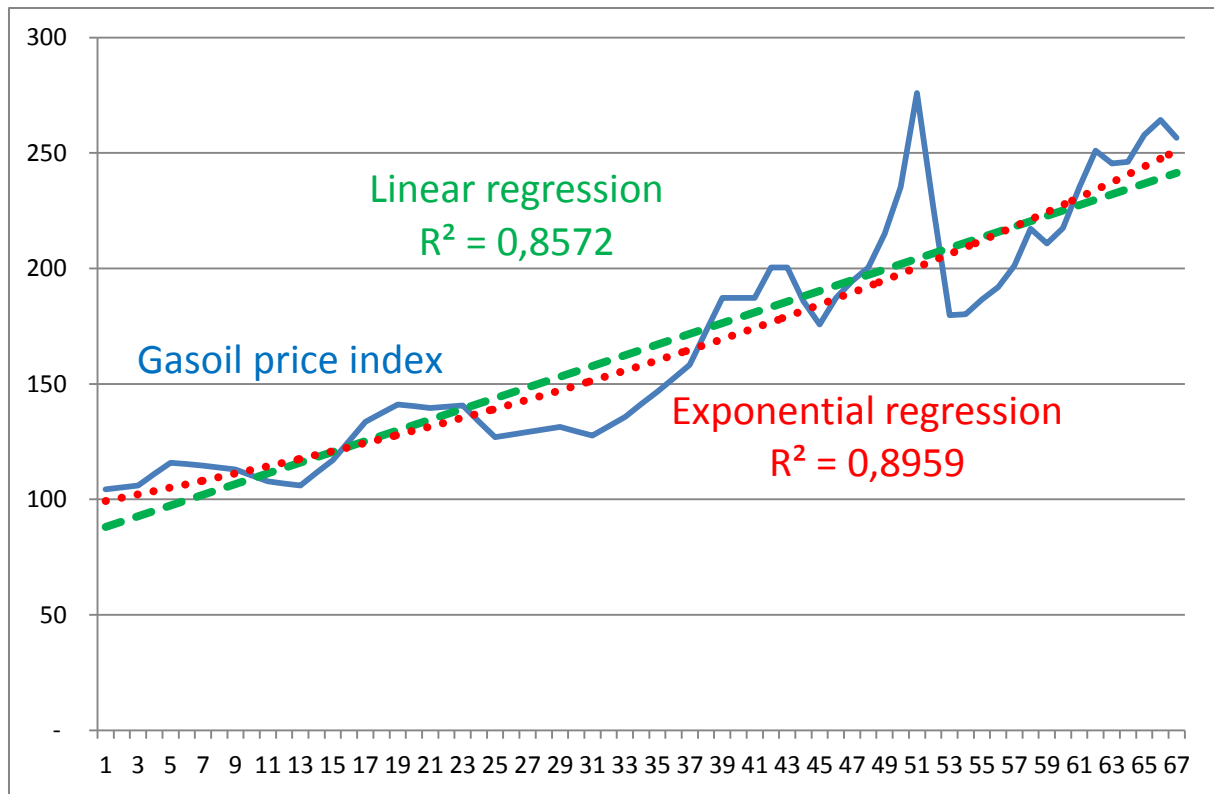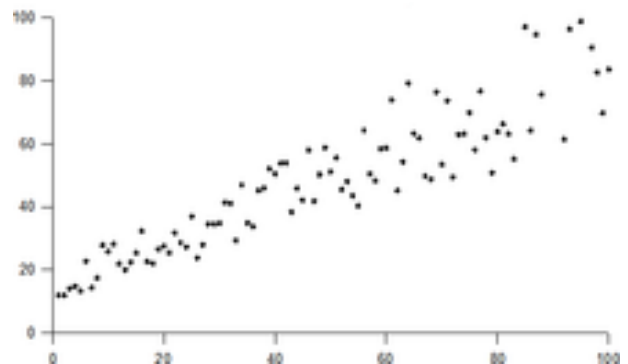
**Graph 30: Exponential and linear regression on historical data of gasoil price index**

**Property 2:** *The price level index deviates around it's trend line*. As mentioned above, the index line dips up and down from the line created through regression analysis. This behavior can be seen clearly in Graph 30. Furthermore, the duration of these cycle varies and cannot be attributed to seasonal influences.

**Property 3:** *The price level index is heteroskedastic*. This means that the spread of datapoints becomes larger over time (see Graph 31). This is a result of the mechanism behind price development. In price level measurements, the annual price level change is given in percentage of the old price level. Index figures use a base value to show the effect of the price level change in percentage. If the base value is 100 on t = 0, a 2% price level rise would give a value of 102 at t=1. If 20 years later, when the price level index has risen to 200, the same inflation rate of 2% is observed, the



**Graph 2: Heteroskedasticity**

absolute change in price level index rises. With the price level index figure is 200 at t = 20, a 2% increase results in an index figure of 204 at t = 21.

|  | Year x | Price level change % | Index figure | Index figure year x+1 | Absolute change |
|---|---|---|---|---|---|
| Example I | 0 | 2% | 100 | 102 | 2 |
| Example II | 20 | 2% | 200 | 204 | 4 |

This shows that absolute residuals do not remain constant with constant price level rise in percentages. But proportional residuals, measured in percentages, are assumed to stay in the same bandwidth over time. Residuals are mathematical transformations used to extract specific properties from a dataset. This is in line with assumptions of both Rijkswaterstaat and the EIB, who use annual percentages.

The proportional deviation from the trendline is given in Graph 32.
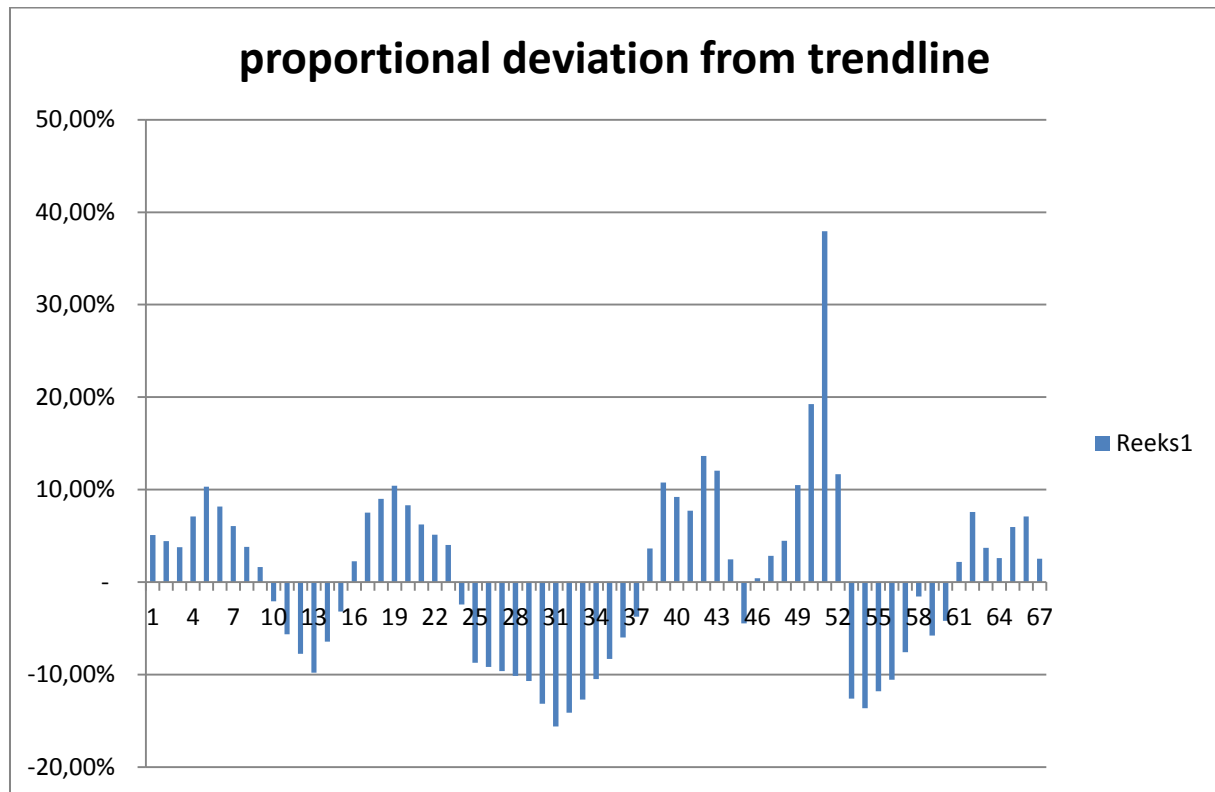


**Graph 32: Proportional deviation from trendline in of historical gasoil price index**

**Property 4:** *Sample points have a positive serial autocorrelation*. The historical data of the price level index in Graph 30 show a positive serial correlation between the data points. This means that when the value at *t* is above the regression line, the value of *t+1* is likely to be on the same side of the regression line as well. In this case, the first transformation is the subtraction from the trendline, followed by a conversion from absolute values to proportional values.

$$Y'_{Gasoil\ Price} = \frac{y_t - y_{t-1}}{y_t}$$

Plotting the value against their previous value gives the following scatterplot and shows this positive and strong correlation.

**Property 5:** different price level indexes are mutually correlated. The price level index of bitumen for instance, is strongly correlated with the index of gasoil. This can be easily explained with the fact that bitumen and gasoil are both oil-based product. Graph 33 shows the price level development of these two products and it is clearly visible that the price level movements follow each other. Furthermore, they are more correlated to each other than to the third price level index, which is in this example labour.
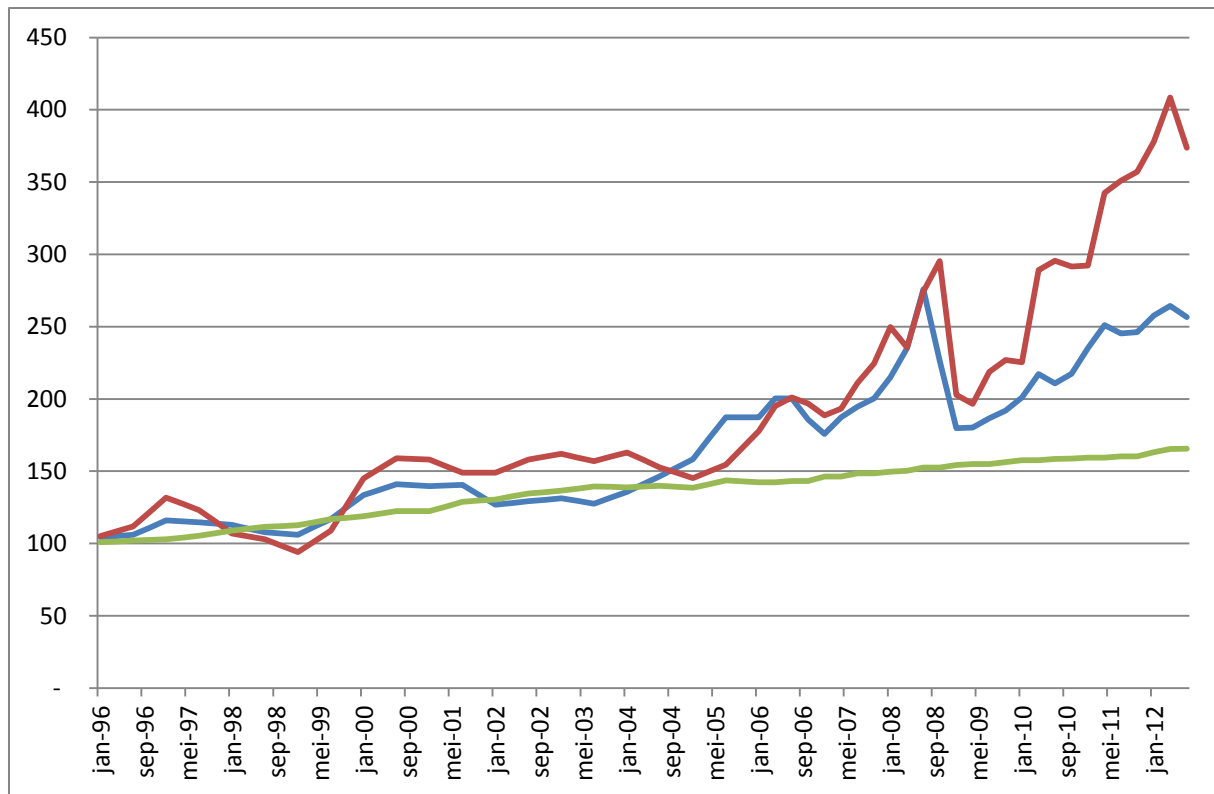
**Graph 33: Historical price level indexes of Gasoil, Bitumen and Labour cost**

## Simulation model

With the properties that are to be included in the simulation, a method has been chosen. The forecasting and estimating of economic measures lies in the field of econometrics. This paragraph will describe the handles provided by this field of study and will culminate in the chosen model method.

## Existing forecasting models

The science of econometrics has developed numerous mathematical models to forecast the inflation rate. These forecasting models can be arranged in three groups. The first group is the least sophisticated one and uses simple numerical benchmarks or "rules of thumb". For example, in these forecasts, the inflation target of a central bank can be used as forecast. In the case of the European Central Bank (ECB), the annual inflation rate (HCPI) is defined as 1,9% (M. Diron, 2005).

The second group of models consists of *Univariate models.* These models forecast inflation of a specific point in time based on values of previous values. The most common models of this type are Random walk-, Autoregressive- (AR), Autoregressive Moving Average Models (ARMA) and Vector Auto Regressive (VAR) models. These models use the properties of historical data to forecast future data. This way of forecasting is purely mechanical rather than fundamentals-based, and can therefore in some ways be criticized as simplistic (A. Meyler, 1998). Nonetheless, these models have the practical advantage that data requirements are limited to the series of interest (Buelens, 2012).

The third group consists of *multivariate models* in which the information set is extended to potential exogenous predictors of inflation. These exogenous indicators may include unemployment, industrial

production, exchange rates and household surveys.  Each indicator has their own impact factor on the inflation (Buelens, 2012).

## Choice of model

For the Monte Carlo analysis, a choice has to be made on which type of model is used to simulate different inflation developments. The research requires the simulation results to have the 4 properties mention above .

The benchmark-type is unsuitable because it produces exponential developments without volatility. This volatility is one of the required properties and is important to the research. Volatile price levels affect the difference in inflation cost and inflation correction. When a contractor buys asphalt at a peak, the high cost of inflation are only partly reimbursed by the public authority because the inflation rate is averaged over five years.

The other types, univariate and multivariate models, do have the ability to produce volatility. Multivariate models are not chosen because they are mostly used for short-term forecasting. Long-term forecasting with multivariate models would require more assumptions on how the exogenous variables like unemployment would develop. These extra assumptions are unnecessary in the univarate models, therefore this is the method of choice in this research.

## Univariate models

The method of modeling time series with univariate models comes down to an extensive variant study of the different types of possible models with different parameters. By creating a range of models and subject them to tests, the best model can be identified. This can be done by specialized software, in this case Palisade @Risk.
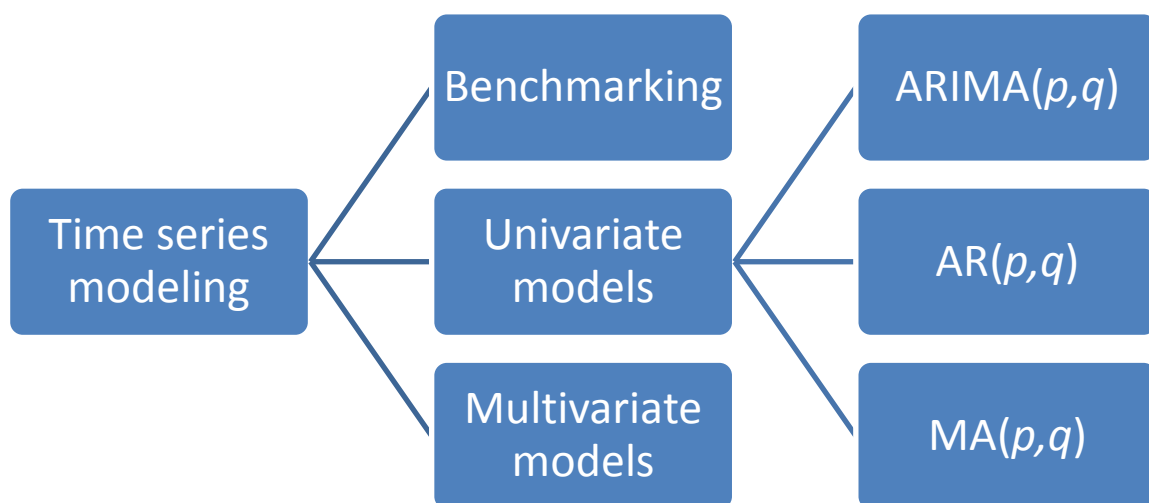


The most sophisticated univariate modeling technique is best known as the ARIMA model. ARIMA is the abbreviation of *Autoregressive integrated moving average* and is also known as the Box-Jenkins model. It was developed in 1970 for forecasting purposes and relies solely on the past behavior of

the variable being forecasted. The model creates the value of $x_t$ with input from previous values of the same dataset. In formula it looks like:

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \cdots + \Phi_p Y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q}$$
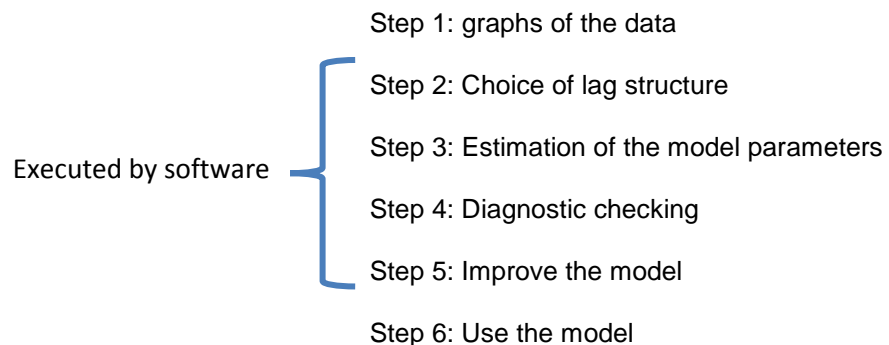
With $\Phi$ and $\theta$ as unknown parameters to be found in the variant study. The $\varepsilon$ are independent and identically distributed normal errors with zero mean. This stochastic error term is called the innovation or white noise. The number of historical values used to generate value $t$ is $p$, and is called the number of lags. The number of innovations incorporated in in value $t$ is expressed by $q$. The theory speaks of ARIMA($p,d,q$) models to describe the lag structure.

The $d$ determines the number of deformations of the data necessary to be able to use the ARIMA model. The ARIMA method is only possible when the dataset to be generated has specific properties, deformations are used to gain these properties. For one, the model assumes the data to be stationary. This means the stochastic properties are invariant with respect to time, also known as homoskedastic. Furthermore, stationarity means that the mean of the series doesn't change over time. If these requirements are not met, the dataset must be differenced, usually by taking logs. The number of deformations used is expressed in $d$ (Kennedy, 2003).

The other univariate models, Autoregressive (AR) and Moving Avarage (MA), are simplified versions of the ARIMA model. AR models only use the $\Phi_p Y_{t-p}$ lag component and AM models only use the $\theta_q \varepsilon_{t-q}$ construction.

## Model construction

The econometric theory provides a step-wise method of establishing the best simulation method. The 6 steps are listed hereafter.

Step 1: graphs of the data

Step 2: Choice of lag structure

Step 3: Estimation of the model parameters

Executed by software

Step 4: Diagnostic checking

Step 5: Improve the model

Step 6: Use the model

The steps have a feedback loop between step 5 and step 2. This is an iterative process that can be executed by specialized software. The software tests XXX variants of the ARIMA(p,d,q), AR(p,d) and AM(q,d) models and tests a range of possible $\Phi_p$ and $\theta_q$ parameters. The quality is measured with the Akaike Information Criterion (AIC). AIC deals with the trade-off between the complexity of a model and the goodness of fit of the model.

$$AIC = 2k - 2\ln(L)$$

Where k is the number of parameters in the model and L is the maximized value of the likelihood function of the estimated model. The preferred model is the one with the minimum AIC value.

## *Deformations*

As mentioned above, univariate models can only be used on stationary homoscedastic datasets. Therefore, deformations are necessary to gain these properties.

Exponential regression

The exponential growth property of the data (property 1) is extracted by subtracting the exponential regression line from the sample points. The exponential regression line is obtained using the least squares estimation method. The result of this deformation for dataset 'gasoil price index' is given in Graph 34.
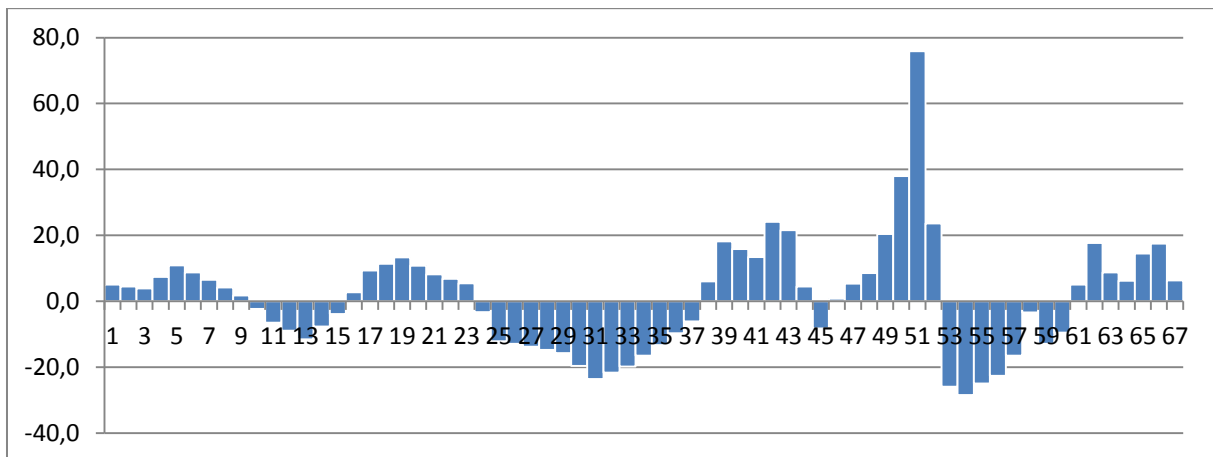


**Graph 34: result after transformation of dataset**

The heteroscedastic property is still apparent and must be eliminated. This is done by transforming the absolute deviations from the trendline in proportional deviations from the trendline. The result is shown in Graph 35.
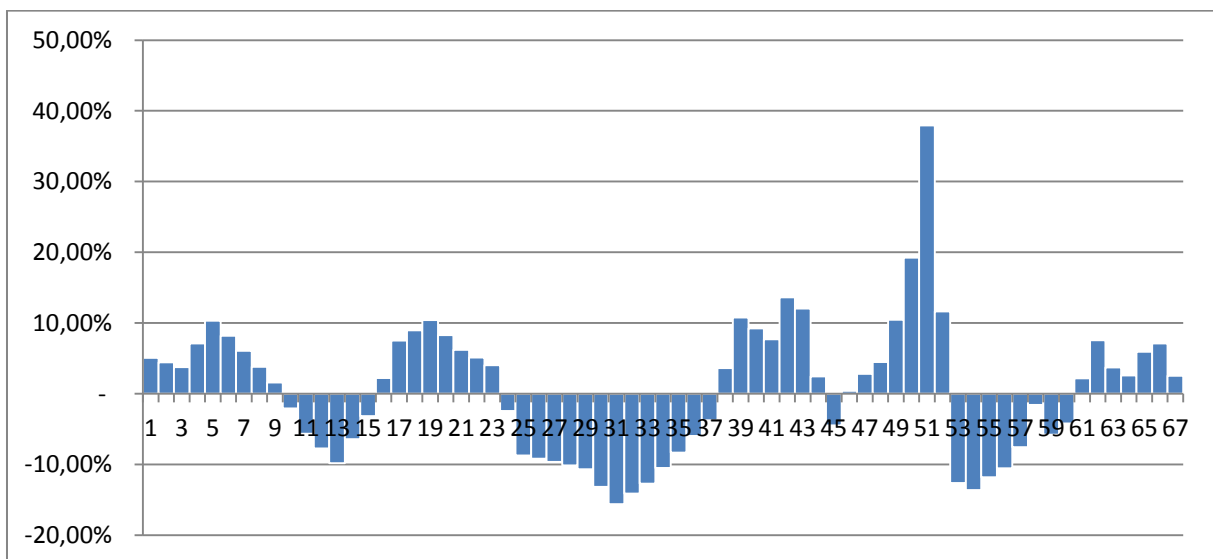


**Graph 35: result after second transformation of dataset**

With these transformations the dataset is both stationary and homoscedastic. This is the input for the software.

In addition to the 6-step guideline, the software takes another step; step 1b. In this step, the correlations between different datasets are defined using the Spearman method (Palisade, 2013). These correlations are included in the different models incorporating property 5 into the simulation.
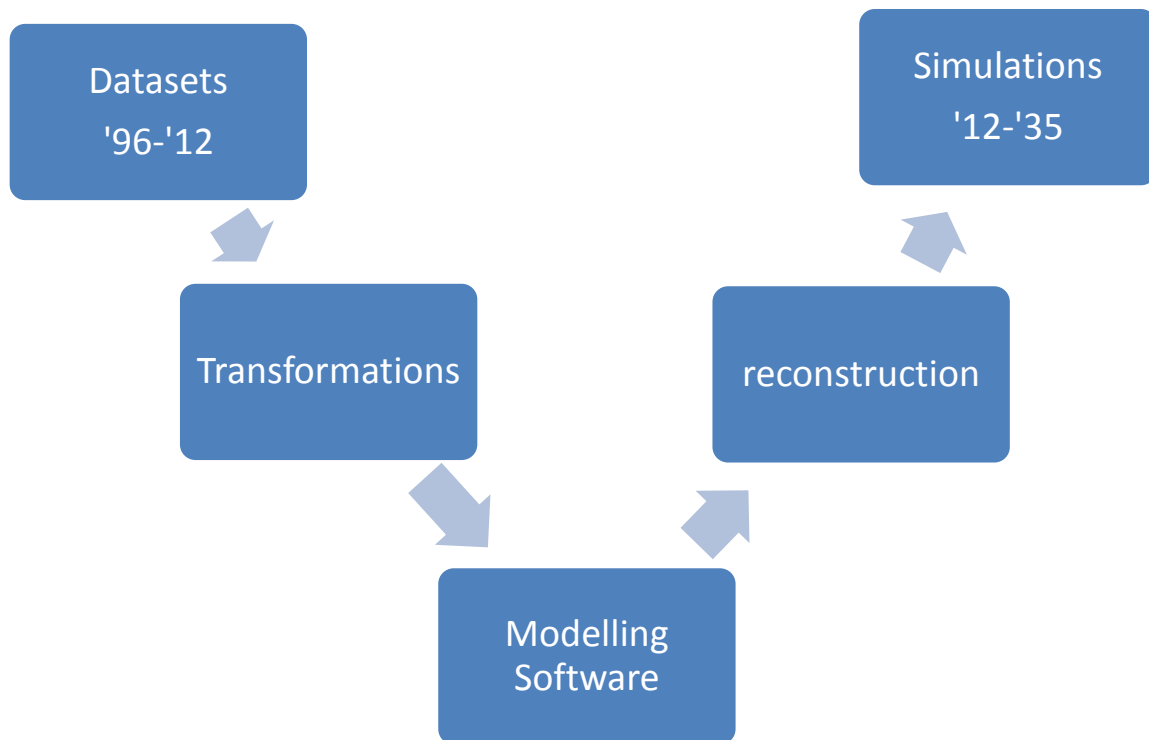


## Results

The method results in a model with different outputs meeting the 5 required properties. Graph XX shows the historic values and one sample of the simulated values. As a reference, the assumed values of Rijkswaterstaat are included as dotted lines in the graph. These reference values are estimates laid down in the DBFM agreement, see table 1.

For further insights in the model and live simulations, digital Appendix D: Model which contains the excel sheet.
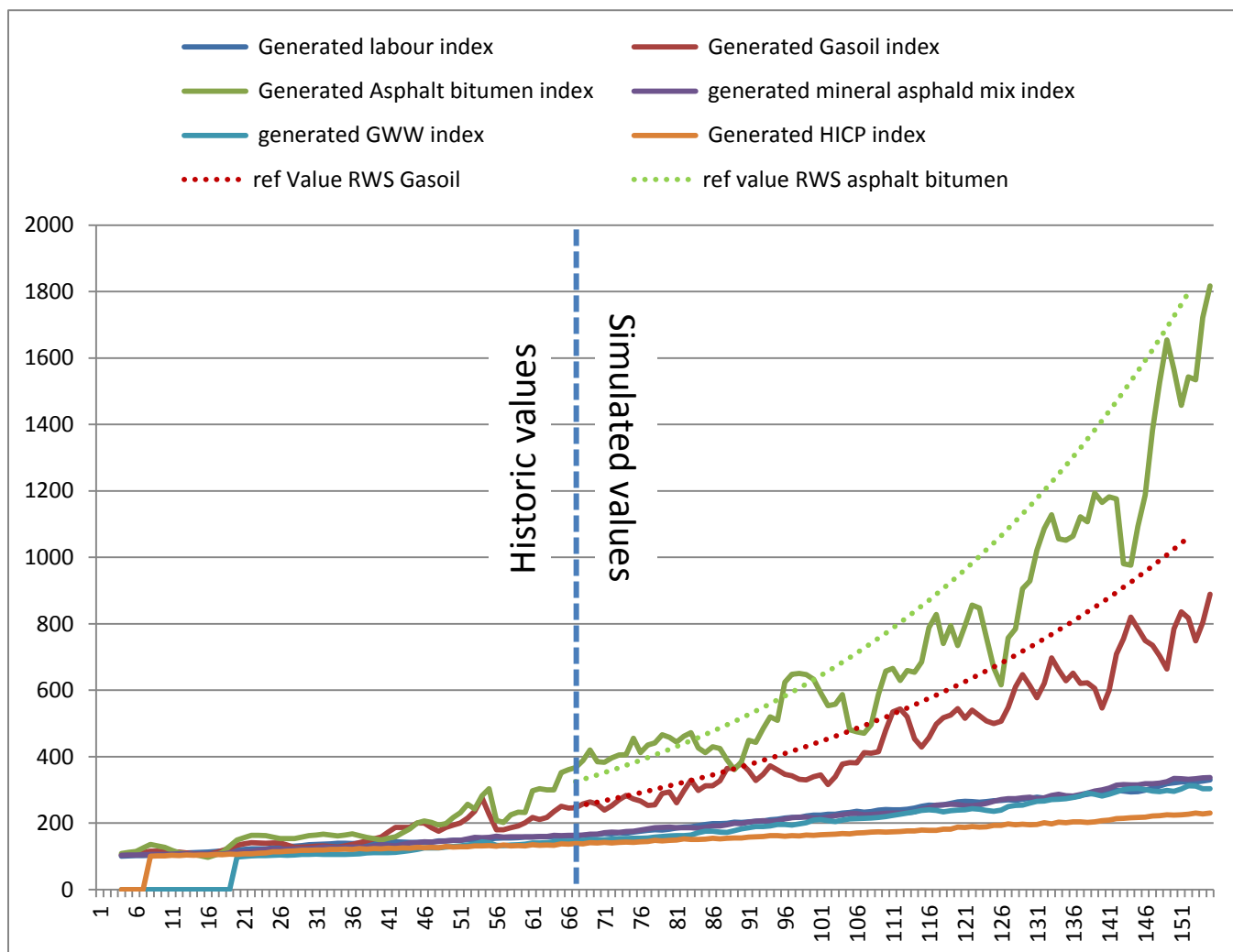
Tabel: Limitatieve lijst indexen voor Indexeringsformule

| CBS | GWW totaal Januari | 3,24% |
|---|---|---|
| CBS | Riolering Januari | 2,44% |
| CBS | Wegen met open verharding Januari | 2,25% |
| CBS | Wegen met gesloten verharding Januari | 3,69% |
| CBS | Grondverzet Januari | 3,16% |
| CBS | Waterbouwkundige werken Januari | 3,76% |
| CBS | Kunstwerken Januari | 2,66% |
| CBS | Spoorwegen Januari | 3,86% |
| CBS | Electrotechnische voorzieningen Januari | 3,39% |
| CBS | CPI alle huishoudens Januari | 1,85% |
| CBS | Nederland, HICP Januari | 1,89% |
| CBS | Eurozone, MUICP Januari | 2,01% |
| CBS | Europese Unie, EICP Januari | 1,97% |
| CBS | Metaal/elektrotechn. Industrie 27-35 (CAO lonen) Januari | 2,58% |
| CBS | Bouwnijverheid 45 (CAO lonen) Januari | 2,25% |
| CROW | Loonkosten Januari | 3,34% |
| CROW | Gasolie hoog accijns Januari | 7,03% |
| CROW | Gasolie laag accijns Januari | 7,09% |
| CROW | Gasolie excl. Accijns Januari | 11,35% |
| CROW | Electriciteit Januari | 3,62% |
| CROW | Grind- en industriezand Januari | 3,42% |
| CROW | Steenslag en brekerzand Januari | 2,85% |
| CROW | Betonmortel Januari | 3,23% |
| CROW | Betonproductie Januari | 2,11% |
| CROW | Cement Januari | 1,06% |
| CROW | Breuksteen Januari | 2,62% |
| CROW | Kunststof incl. pvc, excl. Geosynth. Januari | 2,94% |
| CROW | Betonstaal Januari | 3,54% |
| CROW | Staal excl. Betonstaal Januari | 4,25% |
| CROW | Wegenbouw bitumen Januari | 8,38% |
| CROW | Bitumen.bindmiddelen Januari | 9,09% |
| CROW | Mineraal asfaltmengsel incl. brandstof Januari | 3,57% |
| Eurostat | HICP excl.Tobacco (00X TOBAC) (EA) Januari | 1,88% |

# Appendix B: Explanation of strategy performance model

This research uses a model to calculate outputs that can be compared. This appendix will describe the mechanisms of the model. Figure 11 shows a schematic representation of the steps in the model and the order in which the calculations are performed.
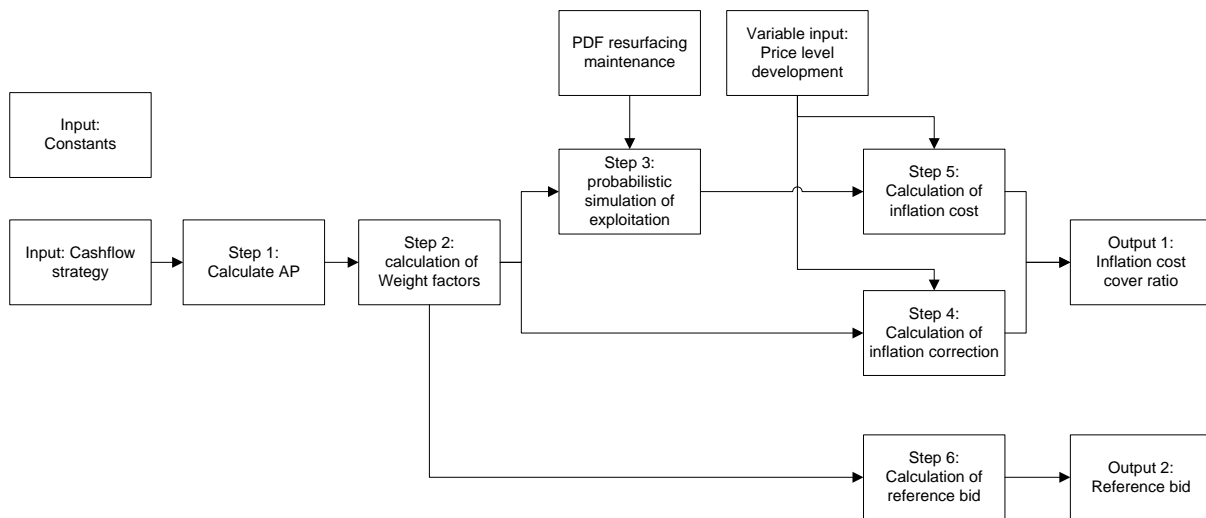


**Figure 11: Schematic representation of the inflation cost calculation model**
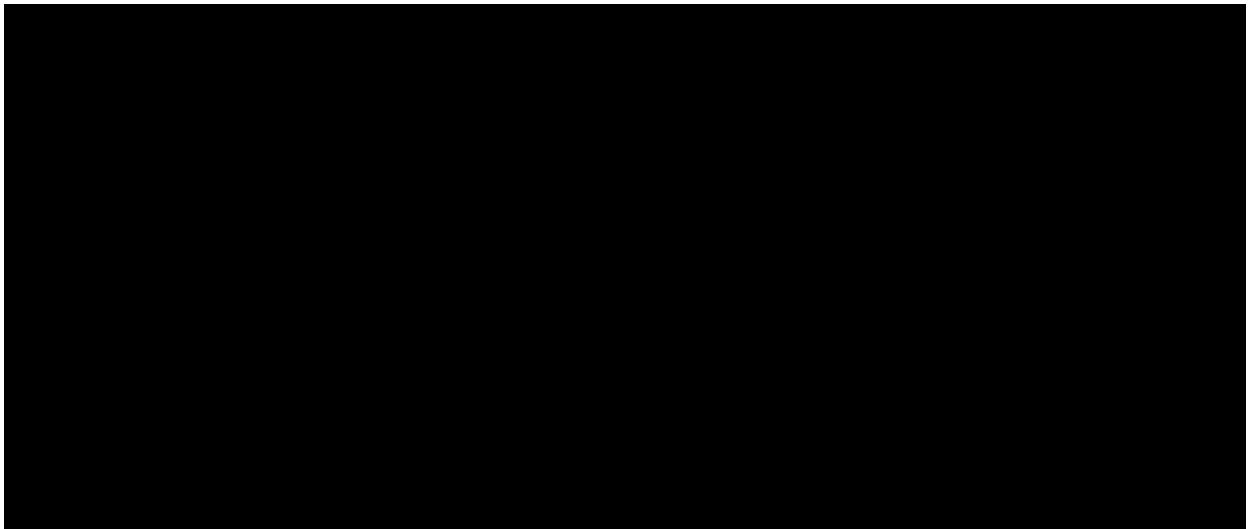
## Inputs

The model is used to calculate performance indicators for specific resurfacing strategies. Each strategy is fed into the model in the form of a cashflow. A cashflow carries information about how much is spend at which moment in time. This information is retrieved from the budget of the case-study which was used for the best and final offer. The budget is cut-up into three parts, for ease of calculation. Table 6 shows the three different components and their indexation properties.

| Cashflow component | Project phase | Indexation |
|---|---|---|
| CAPEX+M | Construction phase | Not indexed |
| OPEX non-resurfacing (α) | Exploitation phase | Overall-indexation |
| OPEX resurfacing (β) | Exploitation phase | Selective indexation |

**Table 6: three different components in the cashflow**

The first cashflow component is the largest, and comprises all cost in the construction phase including design, project management, construction cost and maintenance of the existing infrastructure. The second component is build up from all maintenance activities during exploitation phase excluding resurfacing activities. It includes inspections, routine maintenance, replacements of electromechanical installations and small pavement repairs. OPEX non-resurfacing is indexed using the *GWW-algemeen* index, which is designed to resemble all different cost components in the infrastructure construction sector. In the calculations, the two indexed cashflows will be referred to as the α- and β-cashflow. The β-cashflow is the focus of this research; the resurfacing activities. The cashflow comprises all cost incurred for the resurfacing of the pavement and is indexed using a specific set of cost components. To give an idea of the cashflow magnitude and separation, Graph 36 gives a visual representation.

**Graph 36: Cashflow separated in three components**

The model uses variable inputs to generate different future paths for the calculation. One of these variable Monte Carlo inputs is the OPEX resurfacing cashflow. The timing of this cashflow component is defined probabilistically and shifts back and forth along the horizontal time axis. The size of the cashflow; the cost, remains constant. More about this in

Step 2: Calculation of Weight factors. This probabilistic input is only used on the β-cashflow, the other two cashflows are fixed in both timing and size.

Besides the cashflow as input, the calculations require several other constant values. An important factor is the discount rate *r.* The choice of *r* is subjective because it contains a risk estimation.  In this research a rate of 6,25% is used because it is the standard Rijkswaterstaat value. Rijkswaterstaat uses this value to calculate the present values of the different tenderbids and choose the one with the lowest value.

# Calculations

In this paragraph, the calculations will be explained in a step-wise fashion according to the scheme in Figure 11.

## Step 1: Calculation of Availability Payment

An essential input of the index formula is the availability payment (AP, *Beschikbaarheidsvergoeding*). This quarterly payment from the Public Authority to the private party is escalated each quarter in order to compensate for the price rise. To calculate the AP, the following assumption is made:

$$\sum_{n=1}^{110} PV\ (cost_n) = \sum_{n=1}^{110} PV\ (income_n)$$

The sum of the cost is equal to the sum of the income, while taking the time value of money into account. The discount rate *r* is used to calculate the present value (PV) with the following formula:

$$PV_C = \frac{C}{(1+r)^t}$$

$PV_C$ = Present Value of C
C = Cost in quarter *t*
*r* = discount rate
*t* = quarter

All costs can be retrieved from the cashflow together with the quarter in which the cost are made. The income is comprised of two parts; the Availability Payment and the one-off peak payments. The case study has two large peak payments from the Public Authority to the private party. Both are €250 million and are paid when the intermediate- and full availability certificate are handed over. In the model the time at which these payments are made are fixed on the date of the construction planning.

The availability payments increase in size when specific milestones are reached. At the start of the project, the private party receives 20% of the AP, after the intermediate availability date, it rises to 40% and after the full availability date it rises to 100%. The income cashflow is presented in Graph 37, mind that the vertical axis jumps to 250 million to be able to show the one-off payments.21-7-2013

**Graph 37: cashflow of income**

With this set of cost and income for each quarter, together with the assumption of the equilibrium, the unknown height of the Availability Payment is found using Goalseek in excel. In this case, the quarterly availability payment is just over seven million euros.

## Step 2: Calculation of Weight factors

Another essential input for the index formula are the weight factors per cost component. Weight factors describe how much is spend on a specific cost component in the first five-year period as a portion of the Availability Payments in the same period. The weight factors resemble the proportional share of the cost component over a five year period (20 quarters) because this is the method used in the index formula. To calculate the weight factor of cost component $n$, the following formula is used:

$$a_{n,p} = \frac{ccp_{n,\alpha} * \sum_{t=1}^{20}(Cost_{\alpha,t,p}) + ccp_{n,\beta} * \sum_{t=1}^{20}(Cost_{\beta,t,p})}{\sum_{t=1}^{20}(AP_{t,p})}$$

With:

$a_{n,p}$ = weight factor for cost component $n$ in period $p$

$Cost_{\alpha,t,p}$ = cost of non-resurfacing maintenance activities in quarter $t$ period $p$

$ccp_{n,\alpha}$ = cost component proportion of cost component $n$ for non-resurfacing activities ($\alpha$)

$Cost_{\beta,t,p}$ = cost of resurfacing maintenance activities in quarter $t$ in period $p$

$ccp_{n,\beta}$ = cost component proportion of cost component $n$ for resurfacing activities ($\beta$)

$AP_{t,p}$ = Availability Payment in quarter $t$ in period $p$

This formula excludes the CAPEX cashflow because this part is not indexed. The index formula is not meant to cover the price risk of the CAPEX because this falls in the first years. For this short period the price levels can be estimated more accurately, resulting in a low risk the private party is able to carry. Furthermore, the weight factor of the cost of the CAPEX in proportion to the Availability Payments in the first period would be well over a thousand percent, whilst it is limited to 50% in the payment mechanism.

For each of the other two cashflows, α and β, a separate set of cost component proportion is defined. Cashflow α is indexed by an overall-type indexation, which means a general aggregated price level index is used to resemble the price level development. In this case, the index of *GWW-algemeen* is used because it is meant to resemble all different kinds of activities in the infrastructure construction sector. So the $ccp_{n,\alpha}$ for *GWW-algemeen* for non-resurfacing activities is 1.

For cashflow β, the focus of this research, a selective indexation is used. The cost component proportions for resurfacing activities are retrieved from an actual index calculation used in an undisclosed but recent DBFM project. Table 7 shows the cost component proportion for resurfacing activities (β). The proportions are retrieved from a comparable DBFM budget, precise source cannot be disclosed due to commercial sensitivity.



Table 7: cost component proportion for resurfacing activities

## Step 3: Probabilistic simulation of exploitation

For the simulation of the different paths caused by the uncertainty in the planning of resurfacing maintenance activities, a probabilistic exploitation must be generated. This is done by linking a stochastic function to the β-cashflow.

The stochastic function is retrieved from the TNO report (TNO, 2011)assessing the point in time of resurfacing of twinlay asphalt. In this report, experience in the field combined with expert judgment, result in a documentation of the  year of resurfacing for  3622 road sections.  The time between completion and resurfacing is called the maintenance interval. This data is then transformed into a probability density function (PDF), see Graph 38. This graph shows the probability of the size of the maintenance interval.
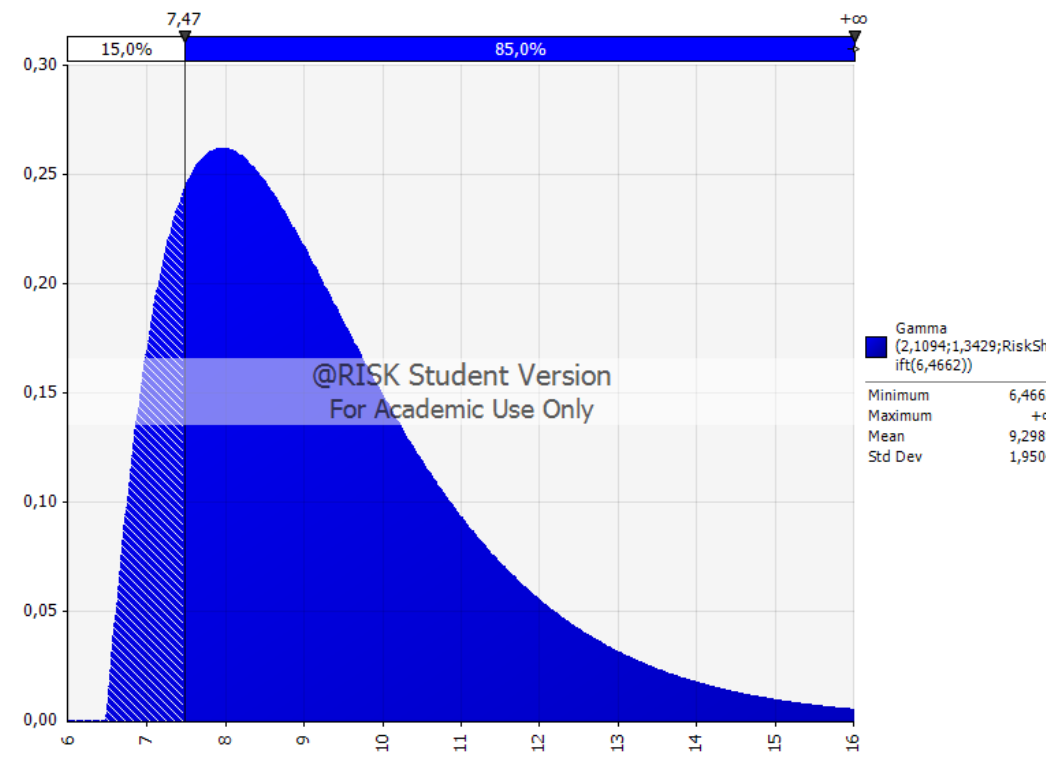
**Graph 38: PDF Maintenance interval resurfacing**

The usability of this PDF is strengthened by a different report from an asphalt innovation program from Rijkswaterstaat (IPG, 2008). The maintenance interval in this report shows the same shape of the PDF function, but it is translated to one year to the left (shorter maintenance interval). This is in line with the report's conclusion that there are improvements to be made on the lifetime, which would lead to a one year extension of maintenance interval. After the publication of this IPG report these improvements have been made and the new PDF obtained in 2011 is the result.

Because design practice in road construction uses an 85% confidence interval for the planning of the resurfacing activity, the deterministic cashflow described earlier has the resurfacing peak in year 7 (Moenielal, 2013). For the probabilistic exploitation, this timing ranges according to the horizontal axis of the PDF.
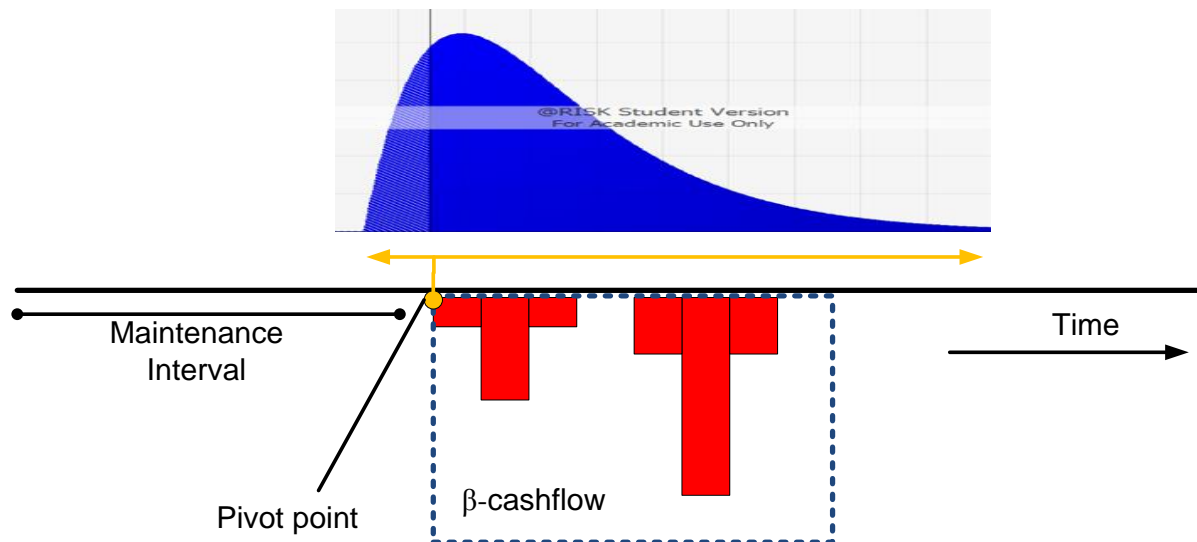
**Graph 39: simulation of different maintenance interval with PDF**

Graph 39 shows the mechanism used to simulate different maintenance intervals caused by the uncertainty of the degradation of the pavement. The uncertainty is fed into the model in the form of a probability density function. The β-cashflow is linked to this PDF at the foot of the first expense, called the pivot point. For each draw from the PDF, the pivot point is set at this point, shifting the entire cashflow alongside the timeline.

In strategy A, which has two resurfacing cycles and therefore two cashflow peaks, the model uses two separate pivot points with independent PDF's. The other strategies only have one peak, making this unnecessary.

In this example, the shape of the β-cashflow resembles the traditional resurfacing strategy, with a small peak for the resurfacing of the top layer followed by a total resurfacing a few years later. The interval between these peaks remains fixed. Furthermore, a new maintenance cycle starts after this resurfacing has been completed. In the same way, a second maintenance interval is simulated after the first resurfacing activities.

## Step 4: Calculation of inflation correction

The inflation correction is the amount of money the private party receives on top of the Availability Payment to compensate for price rise in a quarter. The inflation correction is calculated with the index formula from the DBFM agreement and has only one changing variable. This one changing variable is the mutation in price level, compared to the price level at the start of the project. The other inputs, the Availability Payment and weight factors are fixed at the start of the project. In this model, they are calculated in step 1 and 2. This is the formula used to calculate the inflation correction:

$$Inflation\ correction_t = (AP_t * Indexnumber_t) - AP_t$$

$$Indexnumber_t = 1 + \sum_{n=1}^{6} (a_{n,p} * m_{n,t})$$

With:

| | |
|---|---|
| Inflation correction$_t$ | = inflation correction in quarter $t$ |
| AP$_t$ | = Availability Payment in quarter $t$ |
| Indexnumber$_t$ | = inflation correction factor for quarter $t$ |
| a$_{n,p}$ | = weight factor for index $n$ in period $p$ |
| m$_{n,t}$ | = mutation of index $n$ in quarter $t$ , calculated as: |

$$m_{n,t} = \frac{i_{n,t}}{i_{n,t=2008}} - 1$$
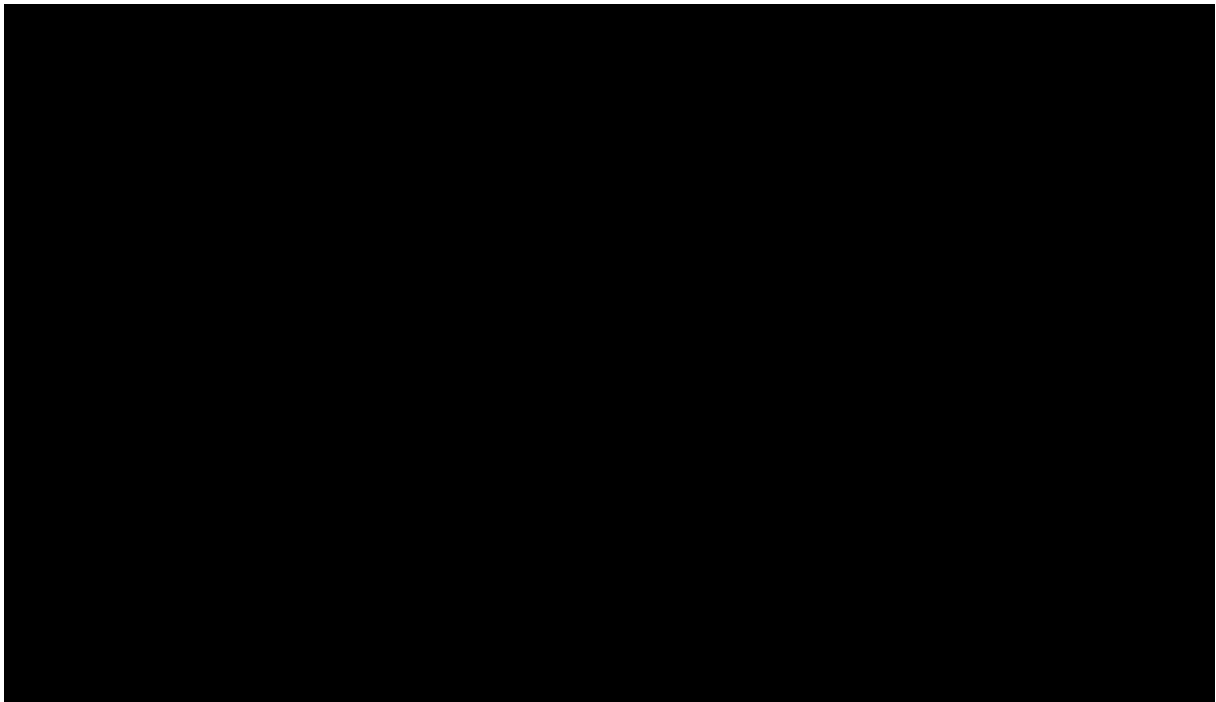
With:

| | |
|---|---|
| $I_{n,t}$ | = index figure for index $n$ in January in the year of quarter $t$ |
| $i_{n,t=2008}$ | =index figure at January 2008, starting point of the case study |

Note that the mutation input is set at the first of January for the following year, in this configuration, the formula misses the price rise over the course of the year. For some cost components like labour, this is reasonable because salaries are adjusted annually as well. But the price for gasoil or steel changes constantly. For the latter groups the formula is too rough to follow reality.

To calculate the mutation of an index figure in this model, price level development is simulated as a Monte Carlo input. The mechanism of this input is explained in Appendix A.

To be able to compare the different strategies, the time value of money has to be taken into account. This is done by calculating the present value of the inflation correction with the following formula:

$$PV\ inflation\ correction = \sum_{t=1}^{110} \frac{inflation\ correction_t}{(1+r)^t}$$

**Graph 40: cashflow diagram of Availability payments with inflation correction on top**

Graph 40 gives a possible outcome of the cashflow of a project with inflation correction. It is clearly visible that no inflation correction is applied in the first period and that each sequential period show an annual rise in inflation correction. After each period, the weight factors are adjusted and the rise starts at a new base level. In some consecutive years, the aggregated price level remains unchanged, the inflation correction is also the same for two years in such a case.

## Step 5: Inflation cost calculation

In this calculation, the model finds the amount of money the private party has to pay for maintenance activities due to price rise on top of the cashflow budgeted at the start of the project. As opposed to the index formula, the calculation uses the probabilistic budget as well as the price level development to calculate the inflation cost. Furthermore, the calculation of inflation cost in a quarter uses the index figure of that specific quarter, not the index figure of the first quarter of the year. The formula used is the following:

$$PV \; Inflation \; cost = PV \; Inflation \; cost_\alpha + PV \; Inflation \; cost_\beta$$

$$PV \; Inflation \; cost_\alpha = \sum_{t=1}^{110} \frac{\sum_{n=1}^{6}(Cost_{t,\alpha} * ccp_{n,\alpha,t} * m_{n,t})}{(1+r)^t}$$

$$PV \; Inflation \; cost_\beta = \sum_{t=1}^{110} \frac{\sum_{n=1}^{6} Cost_{t,\beta} * ccp_{n,\beta} * m_{n,t})}{(1+r)^t}$$
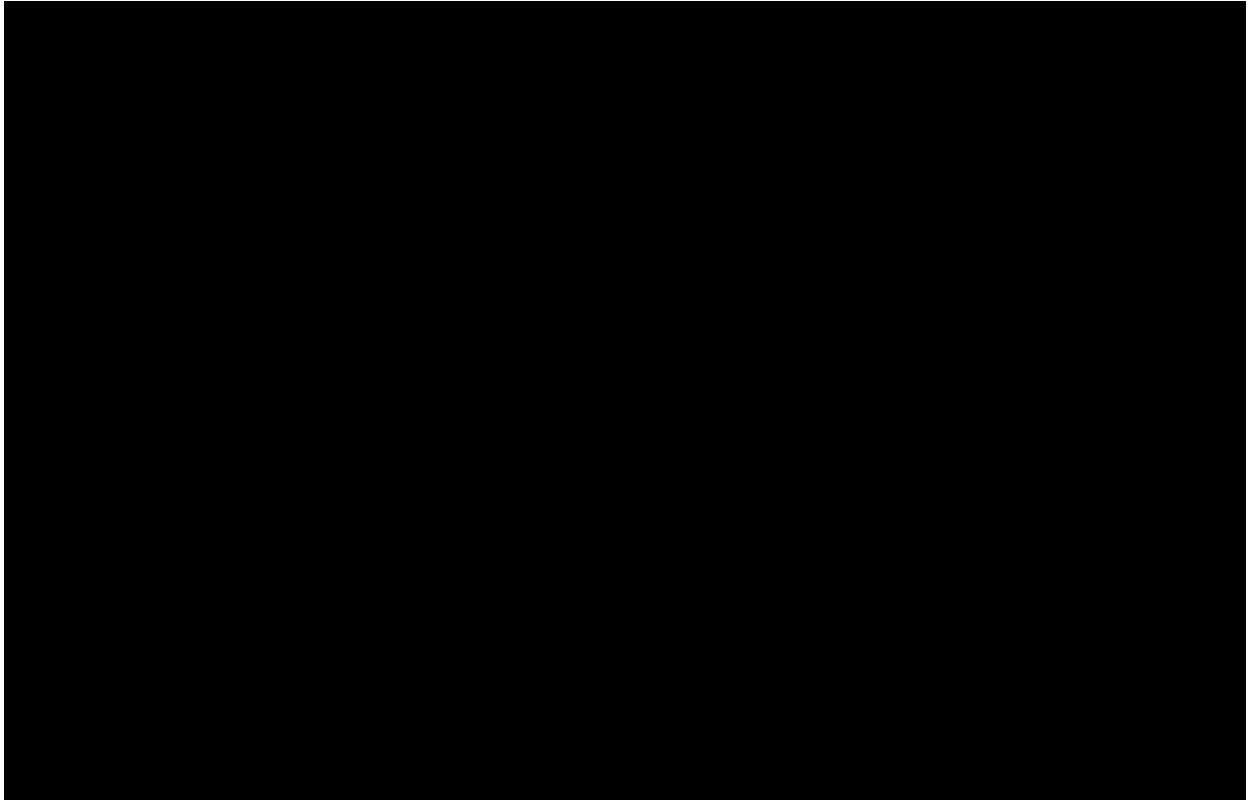
With:

PV = Present Value

$Cost_{t,\alpha}$ = cost of cashflow α in quarter $t$

$ccp_{n,\alpha,t}$ = cost component proportion of index $n$ for cashflow α in quarter $t$

$m_{n,t}$ = mutation of index $n$ at quarter $t$

$r$ = discount rate

By calculating the present value of the inflation cost, the time value of money is taken into account. This is necessary for an equal comparison between the different strategies.

**Graph 41: Cashflow diagram including escalated cost due to price rise**

The graph above shows the result of the calculation of the inflation cost together with the cashflow of the cost for the private party. The orange cashflow represents the inflation cost and only starts after the construction phase in accordance with the assumption that price level rise has been accounted for in the CAPEX budget. Furthermore, differences per quarter can be observed in the inflation cost because of the quarterly –instead of annually- calculation of the price level mutation. The graph also shows that the largest inflation cost peaks are incurred in the years with resurfacing activities.

## Step 6: Calculation of reference inflation correction

Rijkswaterstaat wants to include the expected cost for inflation correction when comparing the tenderbids from the different private parties. This is done by assuming annual inflation rates for different indexes and applying the index formula. The assumption of the annual inflation is called the reference value and is laid down in the subscription guide.

The only difference with the calculation described in Step 4 is the calculation of the index mutation $m$, which is in this case based on the index constructed with the reference value.

$$m_{n,t} = \frac{i_{n,t=2008} * \left(1 + k_{n,ref}\right)^t}{i_{n,t=2008}} - 1$$

With:

$$k_{n,ref} = reference\ value\ index\ n\ per\ quarter$$

These reference values have a strong influence on the tenderbid. The method of how Rijkswaterstaat establishes these estimates is kept secret. The price level developments constructed with the reference values differ from the mean of the price level developments used in the inflation simulation for this model. For some indexes like CPI and GWW algemeen the reference values are lower and for others they are higher.

Graph 42 shows the difference between the price level developments based on Rijkswaterstaat's reference values and the mean of their counterparts used in the inflation simulation. The difference between the two results in a difference between the present value of the project including indexation with the reference values and the present value of the exploitation of the project including indexation with the inflation simulation.
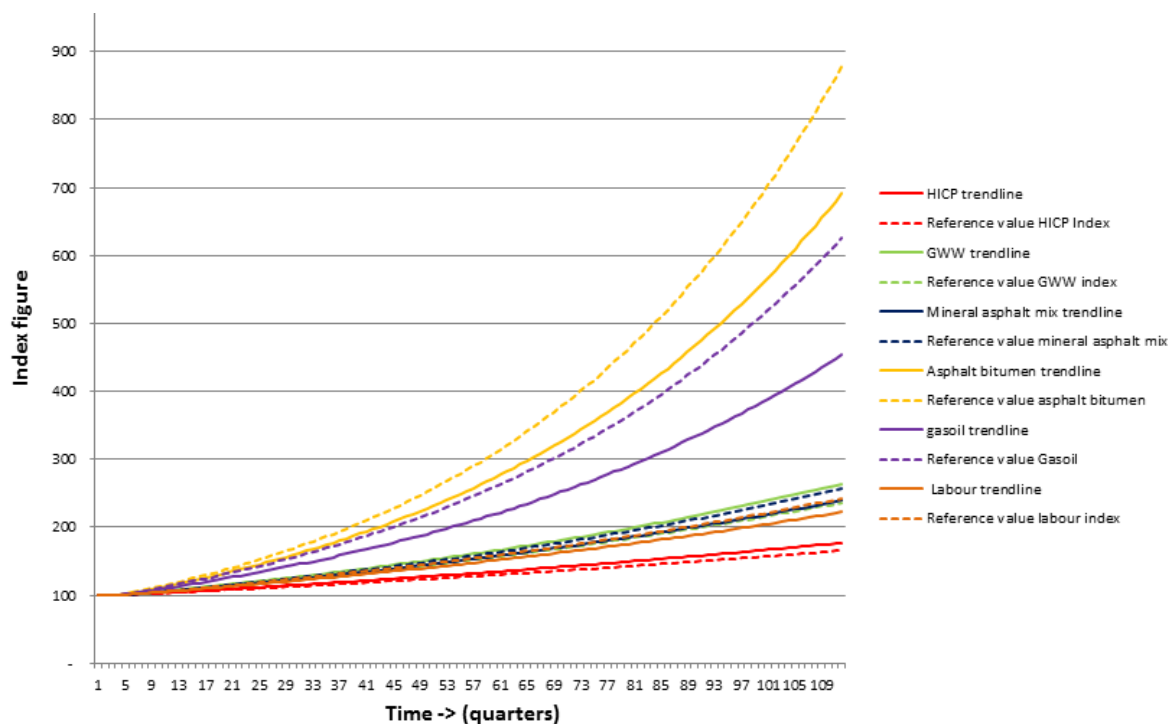


**Graph 42: Price level developments based on reference values versus inflation simulation**

## Outputs

The outputs of the calculation model are used to compare the different resurfacing strategies with each other. This research is interested in how well the index formula covers the inflation cost over the course of the project. To be able to do so, the Inflation Cost Cover Ratio (ICCR) has been created. The ICCR is calculated with the following formula:

$$ICCR = \frac{PV\ Inflation\ correction}{PV\ Inflation\ cost} * 100\%$$

The ICCR assumes a naïve position of the private party, in which the consortium assumes a perfectly working index formula. Interviews show this is unrealistic as private parties estimate how much inflation correction will be received and subsequently act on that strategically. The performance of a resurfacing strategy which takes the expected imperfection of the index formula into account is the $ICCR_D$. This parameter is the ICCR minus the ICCR of the base case. In the base case, no stochastic variables are used in either the resurfacing planning nor the price level developments. The resurfacing is fixed as planned and the price level developments are set by the $50^{th}$ percentile of the simulation. The result is one static output; the $ICCR_D$.

To be able to compare the project performance while taking into account the time value of money, the present values of the inflation correction and cost are used in the formula. The higher the ICCR, the better the cost for inflation are compensated and the better it is for the private party. Because the ICCR is an output with Monte Carlo inputs, the output is an stochastic function as well.

Another output of interest is the tenderbid including indexation with reference value. With this calculation the influence of each resurfacing strategy on the final offer can be compared.

# Validation

The model containing the ICCR calculation and inflation simulation is the testing facility of the strategies. Conclusions are drawn from the results of this facility and because of its importance, it must be validated.

## Logical tests

First of all, the model is created with care and according to the FAST standard. Nevertheless, errors can always remain. To validate the model, logical tests have been executed. A list of statements that should be true following from logical reasoning of the calculations are run in the model to see whether or not they hold.

| # | Statement | |
|---|-----------|---|
| 1 | If weight factors are all 0%, inflation correction is be €0 as well. | TRUE |
| 2 | If all indexed expenses all fall in the first quarters, ICCR is higher than if all expenses fall in fourth quarters | TRUE: median 1th q=294k vs median 4$^{th}$ q=-592k |
| 3 | If inflation is 0%, inflation correction and inflation cost are €0 as well | TRUE |
| 4 | If inflation is equal to reference value, PV tenderbid with expected indexation is equal to PV of actual payments to private party | TRUE |
| 5 | Inflation correction on gasoil should be higher than on labour (due to stronger price rise) | TRUE |
| 6 | With equal weight factors per period, the inflation correction should rise exponentially on average. | TRUE |
| 7 | With equal weight factors per period, the inflation correction shows the volatility of the combined price level indices | TRUE |
| 8 | Inflation correction is constant during the 4 quarters of one year | TRUE |
| 9 | If the discount rate is 0%, the PV of the inflation corrections is higher than when the discount rate is 6,25% | TRUE |
| 10 | If the discount rate is 0%, the PV of the inflation cost is higher than when the discount rate is 6,25% | TRUE |

## Infotron spreadsheet check

Secondly, the model is tested with software from F. Hermans who designed spreadsheet checking software as part of het PhD study at Delft University of Technology. The software checks spreadsheets on the following guidelines;

- No errors; no formula returns an error code
- No fixed numbers in formulas
- No long incomprehensible formulas
- Jealousy (importing cells from different sheet directly into a formula)
- One worksheet per linked source (importing from another file)

The conclusion of the software test was that the model was sound, only a few fixed numbers in formulas were detected by the software. These are all hardcoded trend lines necessary in the index construction. The report of the analysis can be found in *Appendix F: Infotron spreadsheet check.*

Thirdly, the model is thoroughly checked for errors by excel modellers at Iter Fidelis. Their conclusion is still to be reported.

## Level II calculation

There are several methods of calculation of the reliability of an element. In the structural domain, the Joint committee on structural safety proposed a level-classification of the calculation methods. This classification includes the following three levels (Vrijling, 1997):

- level III: The level III methods calculate the probability of failure, by considering the probability density functions of all variables. The reliability of an element is linked directly to the probability of failure.
- level II: This level comprises a number of methods for determining the probability of failure and thus the reliability. It entails linearising the reliability function in a carefully selected point. These methods approximate the probability distribution of each variable by a standard normal distribution.
- level I: At this level no failure probabilities are calculated. The level I calculation is a design method according to the standards, which consider an element sufficiently reliable if a certain margin is present between the representative values of the strength and the loads. This margin is created by taking so-called partial safety factors into account in the design.

This research uses a level III calculation; the Monte Carlo method. In simple calculations a level II calculation is able to approach the results of the level III calculation. This can be used as a validation of the results but in this case this check is unsuitable. The level II method is incompatible because:

- The reliability function has a very high number of variables (over 500), making calculations very time consuming
- The calculation involves non-normally distributed variables, decreasing accuracy trough necessary approximations
- The calculation involves non-linear distributed variables, decreasing accuracy through necessary approximations
- Price level variables are autocorrelated, Level II methods are unable to incorporate this
- Price level variables are correlated (dependent), Level II methods need transformations to incorporate this, resulting in inaccuracy

The result of such a calculation check would have an unknown inaccuracy and a very high calculation time. Therefore, this check is not applied.

# Appendix C: List of interviews

| Datum | Naam | Functie | Organisatie |
|---|---|---|---|
| 7-2-2013 | Carien Akkermans | *Development Manager* | BAM PPP Nederland |
| 12-2-2013 | Frank Bouwman | | Rijkswaterstaat DVS |
| 2-2013 | Stef de Jong | *Business Engineer* | Iter Fidelis |
| 2-2013 | Dennis van 't Ende | *Business Consultant* | Iter Fidelis |
| 1-3-2013 | Friso van der Meijden | *Financial Manager* | Ballast Nedam Concessions |
| 12-3-2013 | Friso van der Meijden Kees Vermeij | *Financial Manager hoofd Begrotingen* | Ballast Nedam Concessions Ballast Nedam Infra Speciale Projecten |
| 14-3-2013 | Jan van de Ven Maarten Kokshoorn | *bedrijfsleider* | Heijmans Civiel Services Heijmans PPS |
| 15-3-2013 | Rutger te Grotenhuis | *Financial Advisor* | Rebel Group |
| 21-3-2013 | Stijn Welage | *Investment Manager* | John Laing |
| 29-3-2013 | Martin Eggink | *Contractmanager* | A-lanes A15 |
| 11-4-2013 | Tom Spaargaren | *Business Consultant* | Iter Fidelis |
| 15-4-2013 | Geert van Eynde | *Financial Manager* | Vinci Concessions |
| 18-4-2013 | Mahesh Moenielal | *Asfalt specialist* | DIBEC |

# Appendix D: Model

Strategy comparison MC Model v1.6 (excel)