The financial consequences of an adaptable urban area concept from an investors perspective

Graduation thesis | Marit van Rheenen | Delft University of Technology | 1st of November 2010
Foreword

This report contains the final rapport (P5) of my graduation research at the laboratory of Real Estate Management. This laboratory is part of the Master of Real Estate and Housing, at the faculty of Architecture of the Delft University of Technology. The subject of this rapport are the financial consequences of an adaptable urban area concept from an investors viewpoint.

The rapport provides an insight into the final results, conclusions and recommendations of my graduation research. It contains the design of the research and a description of the model that was built to answer the main research question.

First supervisor of this research is Agnes Franzen, with a field of expertise in Urban Area Development. Second supervisor is Sjoerd Bijleveld, his field of expertise is Building Economics and Building Informatics. This graduation research is executed with the help of Dura Vermeer Business Development, where I had an internship. My corporate supervisor was director Chris Zevenbergen. Additional supervision concerning flood risk is offered by William Veerbeek from Unesco-IHE and Dura Vermeer Business Development.

I would like to take this opportunity to thank Agnes Franzen, Sjoerd Bijleveld, Chris Zevenbergen and William Veerbeek for their supervision. I would like to thank Berry Gersonius from Unesco-IHE and Cees Nuland, Joost Wilbrink and Johan van der Pol of Dura Vermeer for their time, input and feedback. Finally, I would like to thank Caroline Rovers (municipality of Rotterdam), and Emile Arens for their interest and support.

Marit van Rheenen, November 2010
Environmental awareness has recently gone mainstream, being sustainable is trendy. Within the abundance of (not always so productive) initiatives, projects and methods of implementation that have evolved ever since, the interpretation of what sustainability is often differs. In essence, a sustainable development is a development that meets the needs of the current generation without risking the provision of needs of future generations (Brundtland Commission, 1987). Sustainability is often mistaken for durability, as both these verbs are translated to ‘duurzaamheid’ in Dutch. Durability, lengthening the technical life-span of an object, is not the same as sustainability, the optimization of the technical life-span of an object to its functional life-span, to decrease demolition waste and the need for transformations.

Governmental institutions have been focussing on global implementation of sustainability for a little over two decades now. This has mainly been done with mitigation measures; measures aiming to limit the demand and use of energy, stimulate efficient energy use, and the use of non-fossile energy sources. More recently, the realization has come that mitigation measures are no longer sufficient, as the climate changes that have already been initiated are of such extend, that we will need to be able to adapt to those changes. Adaptive capacity does not only offer the capacity to cope which the climate changes that are unrevisable, but also offers to opportunity to cope with future uncertainties in the climate, economy and society, making is possible to constantly optimise our real estate supply to changing demands, both qualitative as quantitative.

To be able to integrate adaptability into an urban area, the different layers of an urban area will have to be taken into account (VROM, 2006). First of is the occupation layer, containing all real estate and its occupants. The occupational layer is the most dynamic layer, in which behavioural patterns change within 10 to 40 years. As this rate is shorter then the average technical life cycle of a real estate object, the need for physical flexibility in this layer is urgent. Industrial, flexible and demountable building techniques (IFD) can offer this physical flexibility. Beneath the occupational layer is the network layer. The network layer consists of transportation, water, energy and communication networks. The technical life-span of objects in this
layer is more cohesive with there functional life-span, 20 to 80 years. But in order to facilitate any changes in the occupational layer, networks need to be designed with an additional physical marge, making it possible to facilitate physical changes in the occupational layer over time, without having to physically change itself. Any sustainable measures taken in the occupational and network layer are meant to spare the third and final layer; the ground layer. The ground layer contains eco-systems, it is our ‘mother earth’, in which changes can take up to centuries to evolve. This system of an occupancy layer that contains physically flexible real estate and a over-sized occupancy layer capable of facilitating the occupancy layer without having to physically change itself in called ‘an adaptable urban area concept’.

An adaptable urban area concept offers the capacity to adapt to altering social conditions, whether it is the composition of our demography, or new trends in living and working. From an economic perspective this means that is will be easier to match supply to demand, optimizing returns, and minimizing for example vacancy. IFD techniques make it possible to resell demountable construction parts, making shrinkage and demolishment potentially profitable. Moreover, potential flood damage costs due to climate changes can be decreased, as flexible building concepts are more resilient. From an ecological perspective, it means that redevelopment of supply will be less polluting when the technical and functional life-span of objects will be optimized, as construction parts will be recyclable, and new technical developments (for example energy saving measures) can be implemented more easily.

Some challenges that the implementation of such an adaptable urban area concept still faces are the negative aesthetical stigma that flexible building concepts face, as they are often associated with container-like ascetics, while technical development makes it possible to give an flexible building any aesthetics. Moreover, legally a new form of spatial planning will need to be introduced, as the current Spatial Planning Act (Wet Ruimtelijke Ordening) in the Netherlands is mainly focussing on current developments and developments in the near future. And finally, because it is uncertain whether the higher initial investment costs in the network layer will be compensated sufficiently by potentially lower construction costs, profitable demountation, lower flood damage costs and the general capacity to optimise supply to demand, investors are still reluctant to take the plunge. The graduation research this rapport contains focuses on this last challenge: the lack of knowledge on the financial consequences of an adaptive urban area concept. The main research question of this graduation thesis therefore is:

What are the financial consequences of an adaptive urban area concept from an investors perspective?

The goal of the research is to develop a financial model that can simulate the financial consequences of an adaptable urban area concept, in order to gain insight into these consequences from an investors perspective.

The model developed to answer the research question is named ADURAM2100, which stands for Adaptive Urban Area Model, with a time frame from the year 2010 till 2100. This model is built using an existing model called RICARDO (Real Investment Calculator of Area Redevelopment Design Optimalisation). ADURAM2100 basically compares the functional program that is developed in an specific area, in this study the Merweharbor, to possible future functional demand in this area according to 4 scenarios of spatial development, at an interval rate of 5 years. If a difference between supply (existing functional composition of the area) and the scenarios’ demand develops, the model will transform the existing supply to match the current demand as much as possible within the rules and requirements set by the local government. At the next interval, the transformed supply will once again be compared to the scenarios’ demand at that interval, and so on.

The model simulates the financial consequences of the developed, transitions, maintenance (including potential flood damage costs) and benefits of the urban area for all four scenario, in which each time the area is developed for 50% as an adaptable urban area concept, and 50% as a traditional urban area concept. This makes is possible to compare the financial return of a traditional urban area to the financial return of an adaptable urban area.
The case study with ADURAM2100 at the Merweharbor in Rotterdam from a single investor's perspective shows that on average, an adaptable urban area concept is 8.9% less profitable than a traditional urban area concept. This is not a result of the higher initial investment costs in the network layer however, but is mainly caused by the shorter technical life-span of flexible construction parts which is not sufficiently compensated by the lower initial building costs. The ratio between the lower initial building costs and the higher large maintenance costs resulting from the frequent replacement needed due to the shorter life span is higher than that of traditional building concepts.

In the occupancy layer, the financial benefits of flexible constructions are slightly higher than those of traditional constructions. This results from higher rental incomes (a flexible function is constructed faster, and so rental income starts earlier) and profitable demountation. The profitability of demountation however results to be negligible as the demountation costs often approached the remaining value of the construction parts after depreciation.

In the network layer, as expected, the additional network costs in case of an adaptable urban area concept have a negative effect on the financial return, but this effect is not nearly as dominant as the maintenance costs, and is easily compensated by the lower expected flood damage costs.

Though the financial consequences of an adaptable urban area concept might be negative in comparison to a traditional urban area concept, further development and implementation of this concept offers potential now and in the future because potential social and ecological benefits, and the secondary positive financial consequences these benefits might have are not included.

Moreover, the sensitivity analyses show that there is potential to improve the profitability of an adaptable urban area concept by decreasing the initial building costs through industrialisation and large scale implementation of flexible building concepts, and increase the rental income by increasing the ratio of lettable floor area per square meter of gross floor area as a flexible floor plan can be adapted to its new occupants more easily than a traditional one.

Though the case study with ADURAM2100 at the Merweharbor in Rotterdam shows that on average an adaptable urban area concept is less profitable than a traditional urban area concept, it is not said that an adaptable urban area development is financial infeasible. Only when the all costs (those that where equal for the traditional and the adaptable concept where now excluded) will be included, can conclusions be drawn on the total financial feasibility of an adaptable urban area concept.

To be make the calculations on the financial consequences of an adaptable urban area more reliable, additional knowledge is needed on the costs of implementing an adaptable urban area concept, the expected annual flood damage for utility functions and large maintenance costs.

Besides the financial challenges that will need to be faced before an adaptable urban area development can be implemented, an legal armamentarium for flexible real estate and adaptable urban developments needs to be developed. And the negative social stigma that rests on flexible building concept will have to be improved.
Samenvatting

Sinds kort zijn wij er ons van bewust dat ons gedrag effect heeft op de ontwikkeling van het klimaat. In reactie daarop lijkt de term ‘duurzaamheid’ een modewoord te zijn geworden. In de overvloed aan (lang niet altijd productieve) initiatieven, projecten en methoden die dit met zich meebrengt wordt de betekenis van ‘duurzaamheid’ vaak verschillend geïnterpreteerd. In essentie is een duurzame ontwikkeling een ontwikkeling die de behoeften van de huidige generatie kan vervullen, zonder dat de vervulling van de behoeften van toekomstige generaties in gevaar te brengen. (Brundtland Commissie, 1987). Duurzaamheid wordt vaak verward met een lange technische levensduur, terwijl het bij duurzaamheid juist gaat om het op elkaar afstemmen van de functionele levensduur en de technische levensduur van een object, om zo vervullende transformaties of zelf sloop en afval te voorkomen.

De afgelopen twee decennia heeft de overheid zich in zijn beleid gericht op duurzaamheid, met name in de vorm van mitigatiemaatregelen. Mitigatiemaatregelen richten zich op het beperken van de behoefte aan energie, het zuinig en effectief gebruik van energie, en het gebruik van duurzame energiebronnen. Recentelijk is men echter tot het besef gekomen dat mitigatiemaatregelen niet langer toereikend zijn. De gevolgen van ons gedrag zijn onomkeerbaar, we zullen ons moeten aanpassen aan de veranderingen in het klimaat. Dit aanpassingsvermogen wordt in beleidstermen ‘adaptiviteit’ genoemd. Adaptiviteit maakt het niet alleen mogelijk om te gaan met de veranderingen die al in werking zijn gesteld, maar geeft ook de mogelijkheid zich te kunnen aanpassen waar toekomstige ontwikkelingen in het klimaat, de economie en de maatschappij nog onzeker zijn. Adaptiviteit maakt dat de bestaande vastgoed voorraad zich in de loop van zijn technische levensduur nog kan optimaliseren naar veranderende omstandigheden of wensen.

Om een concept als ‘adaptiviteit’ te kunnen integreren in een gebiedsontwikkeling, is het van belang naar de drie lager van een gebiedsontwikkeling te kijken (VROM, 2006). De bovenste laag van een gebiedsontwikkeling is de occupatielaag, hierin bevinden zich het vastgoed en de gebruiker. De occupatielaag is de meest dynamische laag met een omslagtijd van 10 tot 40 jaar waarin gedragspatronen veranderen. Omdat deze omslagtijd over het algemeen korter is dan de technische levensduur van vastgoedobjecten, is er in deze laag grote behoefte aan adaptief vermogen, oftewel fysieke flexibiliteit. Industriële, flexibele en demontabele (IFD) bouwtechnieken bieden deze fysieke flexibiliteit. Onder de occupatielaag bevindt zich de netwerklaag, bestaande uit transport-, water-, energie-, en communicatiesystemen. De technische levensduur van objecten in deze laag komt beter overeen met de functionele levensduur van die objecten mag worden verwacht aan de hand van de omslagtijd in deze laag, 20 tot 80 jaar. Hierdoor is er misschien minder behoefte aan fysieke flexibiliteit, maar om de dynamiek van de occupatielaag te kunnen faciliteren is het nodig netwerken over te dimensioneren. Zo kunnen ontwikkelingen in de occupatielaag ondersteund worden door de netwerklaag, zonder dat deze elke keer zelf fysiek aangepast hoeft te worden. Duurzame maatregelen betreffende adaptiviteit dan wel mitigatie hebben hetzelfde doel: de derde en laatste laag, de grondlaag, zo min mogelijk aan te tasten. In de grondlaag bevinden zich alle ecosystemen, en veranderingen in deze laag kunnen eeuwen duren. Het samengevoegde concept van een fysiek flexibele occupatielaag en een faciliterende en netwerklaag is een ‘adaptief gebiedsontwikkelingsconcept’.

Een adaptief gebiedsontwikkelingsconcept kan zich aanpassen aan veranderende omstandigheden in de maatschappij, of het de samenstelling van onze demografie betreft, of de trends die zich ontwikkelen in wonen en werken. Ook vanuit economische perspectief biedt een adaptief gebiedsontwikkelingsconcept voordelen, zo is het makkelijker om de vastgoed voorraad aan de vraag aan te passen, en zo kan bijvoorbeeld leegstand worden voorkomen. Bij krimp kunnen constructie onderdelen hergebruikt of doorverkocht worden, en in het geval van een overstroming heeft een flexibel bouwconcept meer van kracht dan een traditioneel bouwconcept. Ecologisch gezien zorgt dit concept voor minder afval, omdat de functionele levensduur en de technische levensduur van een gebouw beter op elkaar afgestemd worden, en wordt het gemakkelijker nieuwe en energiezuinige bouwtechnieken op te nemen in de bestaande voorraad.

Een adaptief gebiedsontwikkelingsconcept brengt ook uitdagingen met zich mee. Zo bestaat er een negatief esthetisch beeld van flexibele bouwconcepten, terwijl inmiddels technisch vrijwel elke gevel mogelijk is. Ook bestuurlijk vormt flexibel bouwen nog een uitdaging. De huidige Wet Ruimtelijk Ordening gaat uit
van huidige ontwikkelingen en ontwikkelingen in de nabije toekomst. Voor het omgaan met onzekerheid over bestemmingen op de lange termijn is geen instrumentarium aanwezig. En door de onervarenheid met flexibele bouwconcepten op gebiedsniveau bestaat er veel onzekerheid over de financiële consequenties van een dergelijk concept. Worden de hogere netwerkkosten voldoende gecompenseerd door de lagere bouwkosten, opbrengsten na demontage en lagere potentiële overstromingsschade?

Hoewel al deze uitdagingen om verder onderzoek vragen richt dit afstudeeronderzoek zich op de laatste: het tekort aan kennis over de financiële consequenties van een adaptief gebiedsontwikkelingsconcept. De hoofdonderzoeksvraag is dan ook:

Het doel van dit onderzoek is om een rekenmodel te ontwikkelen dat de financiële consequenties van een adaptief gebiedsontwikkelingsconcept kan simuleren, om zo meer inzicht te krijgen in de financiële consequenties van een adaptief gebiedsontwikkelingsconcept vanuit investeerdersperspectief.

Het model dat is ontwikkeld om antwoord te geven op deze onderzoeksvraag heet ADURAM2100, dit staat voor Adaptive Urban Area Model (Adaptief Gebiedsmodel) met een tijdsframe van 2010 tot het jaar 2100. Het model is voortgebouwd op het bestaande model RICARDO (Real Investment Calculator of Area Redevelopment Design Optimalisation). ADURAM2100 vergelijkt de bestaande vastgoed voorraad in een bepaald gebied (in deze studie de Merwehaven in Rotterdam) op vaste intervallen van 5 jaar met de mogelijke vraag op dat moment, aan de hand van 4 toekomstige vraagontwikkeling scenario’s. Als er op een interval blijkt dat er een verschil is ontstaan tussen de vastgoed voorraad in het gebied en de vraag volgens het scenario, transformeert het model de bestaande vastgoedvoorraad, zodat deze weer zo goed mogelijk aansluit aan de vraag op dat moment, binnen de eisen en randvoorwaarden die aan dat gebied worden gesteld door de overheid. Op iedere volgende interval zal de aangepaste voorraad opnieuw geconfronteerd worden met de vraag op dat moment volgens het scenario, en bestaat er telkens weer de mogelijkheid om tot transformatie over te gaan.

Het het financiële consequenties van een adaptief gebiedsontwikkelingsconcept te kunnen onderzoeken simuleert ADURAM2100 van elk gebied dat deze voor 50% traditioneel wordt ontwikkeld, en voor 50% adaptief. Hierin worden de initiële netwerkkosten, bouwkosten, onderhoudskosten, transformatiekosten, sloopkosten, potentiële kosten door overstromingsschade, sloop opbrengsten (indien demontabel en herbruikbaar) en huuropbrengsten meegenomen.

Uit de case studie van de Merwehaven in Rotterdam blijkt dat een adaptief gebiedsontwikkelingsconcept vanuit investeerdersperspectief gemiddeld 8,9% minder rendabel is dan een traditioneel gebiedsontwikkelingsconcept. Dit blijkt echter niet af te hangen van de schaalsprong van gebouw naar gebied en de daardoor verhoogde netwerkkosten, maar in grote mate te komen door de verhouding tussen bouw-, en onderhoudskosten van het flexibele vastgoed zelf. De kortere levensduur van de flexibele onderdelen wordt niet voldoende gecompenseerd door de lagere bouwkosten.

In de occupatielaag blijken de opbrengsten van een flexibel bouwconcept iets hoger te zijn dan die van een traditioneel bouwconcept. Dit resulteert omdat de huurinkomsten iets hoger zijn (doordat flexibele bouwconcepten sneller kunnen worden gebouwd starten de huurinkomsten eerder), en doorverkoop of hergebruik van gedemonteerd constructieonderdelen winst oplevert. Deze winst uit sloop blijkt echter minimaal te zijn omdat de demontagekosten zeer hoog waren in verhouding van die van een traditioneel gebouw, immers de onderdelen moeten voorzichtig gedemonteerd worden om hun waarde te behouden.

Zoals verwacht had heeft overdimensioneren van de netwerklaag een negatief effect op de opbrengsten van een flexibel bouwconcept, maar dit effect is lang niet zo sterk als de onderhoudskosten, en wordt gecompenseerd door de lagere overstromingsrisico's.
Hoewel een adaptief gebiedsontwikkelingsconcept minder rendabel blijkt dan een traditioneel gebiedsontwikkelingsconcept is het verder ontwikkelen en implementeren van dit concept aan te bevelen omdat in dit onderzoek enkel de primaire financiële consequenties zijn meegenomen in de berekeningen. Eventuele secundaire maatschappelijke en ecologische financiële consequenties kunnen een positieve invloed hebben op deze uitkomst. Bovendien betekend een lager rendement niet dat het concept in zijn totaliteit onrendabel is, door het weglaten van kosten die gelijk waren voor beide concepten zijn hier geen conclusies over te trekken.

Ook blijkt er uit verschillende gevoeligheidsanalyses van ADURAM2100 dat er potentie is tot het verhogen van het rendement van een dergelijk concept. Omdat flexibele bouwconcepten nu slecht nog mondziesmaat en incidenteel worden geïmplementeerd, terwijl de bouwtechniek zelf is gebaseerd op industrialisatie en modulaire implementatie, bestaat er de mogelijkheid om de bouwkosten verder te verlagen. Ook blijkt uit voorbeeldprojecten dat een flexibel bouwconcept zich makkelijker laat aanpassen aan de wensen van zijn gebruikers, hierdoor is een groter verhuurbaar vloeroppervlak te realiseren per vierkant meter bruto vloeroppervlak, en kunnen er dus meer huurinkomsten worden gegenereerd, welke nu nog niet mee zijn genomen in de berekeningen.

Om toekomstige berekeningen over de financiële consequenties van een adaptief gebiedsontwikkelingsconcept nog betrouwbaarder te maken is verdere kennis nodig betreffende; de kosten van het implementeren van flexibele bouwconcepten, de potentiële kosten door waterschade voor utiliteitsfuncties en grootonderhoudskosten voor zowel traditionele als flexibele bouwconcepten.

Naast de financiële uitdagingen die een adaptief gebiedsontwikkelingsconcept met zich meebrengt is het nodig aandacht te besteden aan de wet-, en regelgeving omtrent flexibiliteit en onzekerheid in de ruimtelijke ordening op de lange termijn. Ook zal er het negatieve esthetische stigma dat momenteel nog rust op flexibele bouwconcepten verbeterd moeten worden.
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The Urban Chameleon

Since the turn of the millennium we have been bombarded with the term ‘duurzaamheid’. In Dutch, this is the only word we know for both ‘sustainability’ and ‘durability’. It is therefore not surprising that we frequently mistake one for the other. In essence, a sustainable development is a development that meets the needs of the current generation without risking the provision of needs of future generations (Brundtland Commission, 1987). Durability, lengthening the technical life-span of an object, is not the same as sustainability, the optimization of the technical life-span of an object to its functional life-span in order to reduce polluting demolition and the production of waste.

A city can be perceived as a dynamic system that changes over time, and thus needs to be able to adapt to altering conditions. The be able to optimize the technical life-span of a real estate object to its’ functional-lifespan, while coping with future uncertainties in climate, economy and society, it needs to be physically flexible. The networks underlaying and connecting this real estate need to be able to facilitate these changes without constantly needing physically alteration themselves. Urban space should be a chameleon, being able to adapt to changing conditions and demands without having to be demolished and rebuilt again.

Marit van Rheenen, November 2010
1. Research design
In de field of real estate and housing, sustainability is slowly gaining momentum. The Trias Energetica (SenterNovem, 1996) is implemented on a building level though techniques like solar energy, green roofs and improved isolation.

The quick changes in our society, economy and environment however demand flexibility, resilience and adaptability, characteristics that initially do not belong to the field of real estate and housing. This, on its part, causes real estate to need environmentally polluting transformations (or even demolishing) before its technical life-span has come to an end.

When we would raise the level on which flexibility and adaptability is strategized from the building level, to the level of area development, changes in society, economy and environment can be adapted more easily. Though the average age of a home in the Netherlands is 120 years (Van Nunen, 2008), according to the layered approach (VROM, 2006), changes in the occupational layer take 20 to 40 years. Through the large-scale implementation of techniques such as IFD, an urban area could anticipate upon these changes without needing polluting transformations.

Innovative and flexible development concepts like industrial, flexible and demountable (IFD) building techniques entail preconditions for the area in which they are implemented. The area should be adaptive and facilitate the basis on which flexible real estate can be developed, and redeveloped over time. The higher initial investment costs and shorter exploitation span currently still cause a barrier for stakeholders to choose for these types of development concepts. Through gaining more insight into the costs and benefits of the large-scale implementation of flexible techniques, I strive to gain further insight into adaptive urban area concepts.

1.3 Relevance
It is widely known that we live in an era of constant and quick social, economical and environmental changes. It is the era of the 5 ‘i’s; individualism, informalism,
information, internationalism and intensifying. Although the dynamics of our society seem to change more rapidly as decades go by, and building techniques have evolved, the flexibility of our build environment seems to have decreased as the complexity of the urban environment has increased. The paradox between ‘vast’goed (fixed estate) and the dynamics of our society make adaptive urban area strategies relevant.

Attempting to decrease the climate changes caused by our behaviour, mitigation measures where taken. The Trias Energetica (VROM 1996) as a principle now forms the basis of many developments. However, in the mean time the climate changes became of such a level, that the urban space will have to be adapted to the effects of the changing climate, and mitigation measures are no longer sufficient (VROM, 2007). In government term, this is called adaptability or resilience. Some examples of topical subjects who would benefit from adaptive urban area concepts:

Flood risk
Flood risk is becoming more relevant as many the of the world’s urban areas have developed to become dens and widely expended metropolitan areas, sometimes extending into flood prone areas. Prognoses on future climate changes show variable expectations. Doom scenario’s and optimistic scenario’s take turns, making it hard to develop one clear policy to act upon. The increased uncertainty and urbanization of floodplains urges for extensive resilience of these areas, both trough mitigation and adaption, considering a wide range of flood events. Besides the fact that this has given risk management renewed attention, it also makes adaptability and resilience a ‘hot topic’.

Shrinkage
Netherland is subjected to shrinkage from several viewpoints. First of, due to the aging population in the Netherlands a decrease in the number of households is expected in the next three decades (De Jong and Van Duin, 2010). Though this shrinkage will not necessary influence the number of dwellings, the types of dwellings demanded will change. Why would we develop this supply to last 100 years when we know that the demand will shift in a few decades? Strategies based on adaptability make it possible to comply with the demands of our current population, without discarding the wishes of future inhabitants, and risking vacancy. Secondly, shrinkage is also related to the flood risk mentioned before. The uncertainties concerning the rising sea level, descending ground level and major fluctuation in the supply of river water make that the flood risk for certain plots of land are to high to be urbanized any longer.

Building techniques
New building techniques, aiming to make real estate as sustainable as possible, are constantly being developed. The average technical life-span of a dwelling however, is 120 years (Van Nunen, 2008). This makes it difficult for the general real estate stock to be updated to the latest technical and qualitative levels, for example sustainable innovations to improve the energy efficiency of a building. Flexible building techniques do not only make it possible to frequently adapt a building to the most recent standards of sustainability and living comforts, it also provides a opportunity to gain experience with new techniques.
1.4 Relation to the department of Real Estate & Housing
This graduation research is based upon several scientific domains of the Master of Real Estate and Housing. The large scale on which the subject is projected relates is to the domain of ‘Real Estate Management’ with a specialisation in ‘Urban Area Development’ (UAD). The fact that it focuses on the financial consequences of a concept relates it to the domain of ‘Building economics’. And the final aim to develop a financial model relates it to the domain of ‘Building Informatics’.

1.5 Problem statement
Future uncertainties concerning our environment, economy and society for whom urban areas are developed make that the long technical life-span of static developments often does not match with their functional life-span. Discrepancies between the functional and technical life-span of a building often result in polluting redevelopment or even demolishment. Therefore, sustainability should not be mistaken for durability. Urban areas as they are currently being developed are not adaptable enough to cope with future uncertainties. Adaptable urban area concepts are still hardly opted for as there are many uncertainties concerning the financial feasibility of these concepts.

1.6 Main research question

1.7 Detailed research questions
- What is sustainable urban area development?
- How can flexibility be adapted into an urban area concept?
- For which types of developments are flexible building concepts suitable?
- Which limitations does the integration of flexible real estate and adaptive urban area development entail?
- Which additional costs and benefits are related to adaptable urban area development?

1.8 Phasing
The table on the next page shows the phasing of the different research questions from November 2009 till October 2010. The bottom part of the table shows the methods that were used to answer the research questions. The table on the right page also shows the phasing of the graduation research, this time including the products per research question.

1.9 Final result
The final result of this research will be a model, designed to simulate the financial consequences of an adaptable urban area development on the long term versus a ‘traditional’ urban area development. Its aim is for investors to gain insight into the opportunities and financial returns of an adaptable urban area development concept, and stimulate them to implement flexible and adaptive solutions.

The interface of this tool will be built up on RICARDO (Real Investment Calculator of Area Redevelopment Design Optimization), with a design and an exploitative interface. Input will have to be given in the form of a plan of the site or area and a general drawing (vlekken) of the planned design and program. Within this drawing the adaptable and flexible features will have to be appointed. The flexible and adaptable functions will be able to transform over time according to some pre-conditions and restraints set by the local government, and within a bandwidth of demand created by several scenarios.

The output of the model will show the financial consequences of the urban plan according to the scenarios. As the financial return of a traditional urban area concept can be compared to the financial returns of a adaptable urban area concept.

On page 22 the conceptual model of the end result is shown. The complete model is described in chapter 6.
### The Urban Chameleon

**What is sustainable urban area development?**

**How can flexibility be adapted into an urban area concept?**

**For which types of developments are flexible building concepts suitable?**

**Which limitations does the integration of flexible real estate and adaptable urban area concept entail?**

**Which additional costs and benefits are related to an adaptable urban area concept?**

**What are the financial consequences of an adaptable urban area concept from investors perspective?**

#### Phasing

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**Literature study**

- Tool modelling
- Data collecting
- Case study

**Finalizing graduation report**
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The Urban Chameleon

Building costs
Network costs
Maintenance costs
Rental income
Transformation costs

Initial functional program 2010

Scenario A, 2015
Difference
Rules & requirements
Action?

Functional program 2015

Scenario A, 2020
Difference

Conceptual model
1.10 Objective
The objective of this research is to develop a financial model, which will simulate the financial consequences of an adaptable urban area concept.

1.11 Graduation company
Dura Vermeer Business Development is the company guiding this research besides the Delft University of Technology. This department of Dura Vermeer has recently done research on temporary developments and is cooperating with Unesco-IHE to research adaptive developments and flood risk in the city harbors of Rotterdam.

1.12 Readers guide
In this chapter the research design of the graduation thesis ‘The Urban Chameleon’ has been described. The next three chapters are based upon literature studies. Chapter 2 ‘Sustainability’ will focus on sustainability in general, while Chapter 3 ‘Sustainable urban area development’ will focus on sustainability in urban space. The concept of adaptable urban area development will be analysed on its feasibility from different viewpoints in Chapter 4. Chapter 5 summarizes which conclusions from the literature study will be taken into account in the model. In Chapter 6, the process and principle of the ADURAM2100 model described. Chapter 7 reveals the results of this model, interprets them and discusses further options. Chapter 8 contains the conclusions that can be drawn from the literature study and model, followed by further recommendations and an epilogue in chapter 9 and 10.
2. Sustainability
Due to the population growth and industrialisation after the Second World War, our current environmental problems arose. Partly due to the energy supplies deriving from fossil fuels, the growth of our economy seemed to be endless and prosperity vastly increased in the Western world.

The connection between human behaviour and the health of our planet was initially introduced to the wider public when the Club of Rome published a rapport titled ‘The Limits to growth, a global challenge’ (Meadows, 1972). This rapport originated awareness about our environment. When, in 1987, the World Commission on Environment and Development (United Nations) published the rapport ‘Our common future’, introducing sustainable development, a global awareness arose.

Prognoses about the climate changes the passed decades have shown variable expectations. Doom scenario’s and optimistic scenario’s take turns, making it hard to develop one clear policy to act upon. The discussion about the environment, whether is a periodical and natural phenomenon or a climate change caused by human society, continued for too long leaving us without a clear definition of the problem, and a plan of approach to tackle it.

This discussion however, did make sustainability a ‘hype’. During a hype, policy makers can easily communicate with the wider public, and count on a greater support, a so-called ‘window of opportunity’ (Kingdon, 1984). This hype also initiated a wide range of research focused on the cause of climate changes. William Rees and Matthijs Wackernagel for example, developed the ecological footprint. A way of defining the environmental burden of a citizen or country. An inhabitant of the Netherlands for example, uses an average of 4,7 hectares, which is 15 times as large as the land available to us within our own country (Hulsbergen, 2002).

But a media-hype also has its drawbacks. A media-hype defines itself by its explosive nature and short-lived popularity, the opposite of sustainability. The way in which citizens, companies, policy makers and managers experience the climate changes is strongly influenced by the way the media reports about it. Climate changes are now thoughtlessly related to topics of random nature. The danger is that after a period of intense media attention, the still relevant subject of sustainability is omitted, as the public is tired of it. The complexity, costs and social effort that are demanded to find a solution are perceived as too much of a burden. For these reasons it is not reasonable to think that sustainability will enjoy continues media attention, and remain a priority on the political agenda. This is also why it is of importance to undertake action now.

‘A sustainable development is a development that meets the needs of the current generation without risking the provision of needs of future generations’


Figure 2; Number of newspaper articles on sustainability per year
2.1 Mitigation
In the past decennia, climate changes have mainly been discussed from the idea of reducing the causes. This focused on the reduction of polluting emissions. Reduction strategies are formally known as ‘mitigation’. In the Netherlands, mitigation on a large scale entails the prevention of flooding and resulting damage costs, or the capitalization of damage costs. Though this has no direct connection to reduction of polluting emissions, it can be called mitigation as it prevents a cause from having consequences. On a smaller scale, mitigation is now individually implemented on a building level through the Trias Energetica (VROM, 1996). This energy assessment method in the Netherlands focuses mainly on the climate control of building. The “Trias Energetica” refers to three categories of measurements:

1. Limit energy demand
2. Use renewable energy
3. If necessary, use fossil fuels as efficiently and cleanly as possible

Limit the Demand for Energy
Reducing the consumption of energy itself is the hart of the problem. Though the habits of the users are hard to change, the energy demand of the building itself can be altered by taking measurements, which make the building’s energy-use less. Measures can for example be the use of insulation and efficient ventilators, or the use of passive solar energy the heat a home so it doesn’t need additional ‘artificial’ heating.

Use Sustainable Energy
The use of natural resources is possible at any level and any system. Solar collectors can provide solar energy, and a seasonal surplus can be stored to be used all year round. Other sustainable energy sources are wind power, hydropower, geothermal power and biomass. A more recent development in sustainable energy is the use of geothermal energy. The principle of geothermal energy can not only provide the necessary heat, but by using a heat pump it is also possible in some parts of the world to cool offices and houses. In the Netherlands heat pumps are used to heat up in the winter and to cool down in the summer.

Use conventional energy with maximum efficiency and compensate
If steps one and two are inadequate to provide the necessary energy, the remaining energy need will be met by applying fossil fuels. This has to be done as efficiently as possible by applying sustainable techniques. The extent to which the use of fossil fuels results into the emission of Carbon Dioxide needs to be minimized and compensated, for example by responsible planting of trees elsewhere. The use of fossil fuels can be further minimized by the use of information technology controlling ventilation, lighting en heating.

2.2 Adaption
In the mean time, it has come to our attention that the climate changes already initiated are of such impact that mitigation is no longer sufficient. The urban plan will have to alter to the consequences of these changes. These strategies are formally known as ‘adaption’. Adaption stands for the capacity cope with surrounding changes. Being adaptable entails being able to adapt to these changes in current condition, quickly physically change to comply to these conditions, or the capacity to be resilient when surrounding changes are temporary. Adaption doesn’t make mitigation redundant. On the contrary, in order to reduce and cope with future developments in our climate, adaption and mitigation both need to be implemented (VROM, 2007).

Dutch governmental institutions need to change policies from a single prevention perspective with climate changes as the main threat, to adaptive policies, using adaptability as a strategy to cooperate with climate changes when planning spatial developments. And besides climate changes, adaptability also offers the opportunity to adapt to changes in society, economics, technique and the environment without needing polluting transformations or demolishment.

The Dutch government is not the only sector that needs to change its ways, this mental transformation needs to be adapted by private organisations and society too. Pressure groups as well as the business community still have mitigation as their first and main association when exercising sustainable management. This is often characterized by short-term investment perspectives (VROM, 2007, pag. 33),
while long-term adaptable strategies can reduce the risk of over-investments, add value as they add future possibilities and increase the financial resilience and continuity in case of incompatibility with the market or a natural hazard.

A field of study and practice in which adaptability is on the agenda, if the field of flood risk, a direct result of climate changes. Until recently, flood risk management and flood protection mainly focused on mitigation measures like flood defence systems. But as climate changes increase the uncertainty levels in the statistical distribution of flood probabilities, more attention is now paid to the reduction of the consequences of flooding.

Another word used for adaptability used in this field of research is resilience. Resilience stands for the capacity of an object or subject to regain its original shape and state after being physically or mentally effected (Van Dale, 2010) by for example, in this case a flood. Both these terms aim to minimize the damage a flood can cause, and the time it will take for an urban area to ‘get back to normal’.

The flood hazard in New Orleans due to hurricane Katrina has shown that the recovery process needed after a flood requires substantial attention. Similar to mitigation, adaptability and resilience need pre-disaster management, so everyday activities can be resumed as quickly as possible (Jonkman, Bockarjova, Kok and Bernardini, 2008, page 88). Mitigation, adaptability and resilience measures should never be considered as separated management choices. On the contrary, in order to reduce and cope with future developments in our climate, adaptation and mitigation both need to be implemented simultaneously and continuously (VROM, 2007).

The insight into these flood levels can also drive innovative building techniques like IFD, to produce flood-proof building typologies and constructions (Veerbeek and Zevenbergen, 2009, page 52). As our knowledge of weaknesses in the current applied building components grows, IFD offers the possibility to easily replace the affected parts of a building quickly. More so, one could opt to assemble the building with flood proof construction parts on the levels where flooding is most likely.
3. Sustainable urban area development
Social, economical and environmental changes are interrelated and all have effects on topics like water, nature, health, agriculture, energy supplies, transport systems, recreation, leisure and tourism. These continues changes also effect urban area developments and its real estate. The many layers that are integrated in urban area development make it a complex to become sustainable. John Elkington formulated this integration as ‘people, planet, profit’, referring to the fact that changes in either our society, economy or environment have effects on all three.

In the design and construction industry, sustainability is mainly implemented on a building level or neighbourhood. In the few cases in which sustainability is implemented on a larger scale, these often are expansion areas (uitleglocaties). Solutions like heat pumps, use of wind-, and solar energy, green roofs, recycling waist and use of rainwater are often implemented on a individual building level. Sustainable urban area development demands a larger scale implementation and is still in its infancy. Sustainable urban area development is not just a matter of energy, water or green, but a sustainable development as a covering concept: future generations shouldn’t have to deal with the negative consequences of our actions. Sustainable urban area development contains intensifying, renovations, diversity, adaptability and flexibility.

Due to the low level of flexibility of real estate and the high rate of environmental changes, offices, shops, schools, dwellings and hospitals lose their functionality long before their technical life-span has come to an end. Sometimes they are revitalized trough renovation project, but often they will be demolished. The number of demolished dwellings in the Netherlands has gone up recently, mainly due to the large stock or post-war buildings. The transformation of many of these buildings to current standards is unfeasible. Mainly due to functional reasons more then half a million dwellings will be demolishes in the next five years. Over 60.000 dwellings have already been demolished and replaced in the passed five years (Post, 2006).

3.1 Layered approach
Sustainable urban area development will now be further analysed according to the layered approach of the ministry of Housing, Spatial Planning and the Environment (VROM, 2006).
3.1.1 Occupational layer

The occupational layer characterized by a high rate of changes. The occupational layer focuses on urban patterns, like neighbourhoods and industrial areas, formed by real estate. The occupational layer is formed by real estate and its users. Though the picture on the left side of this page also shows us green zones, in this research, these will be appointed to the ground layer. Characterized by the fast pace of life, many of the changes occur within one generation, taking 10 up to 40 years. The urban pattern shows how we use our space to live in, work in, produce food and recreate, they are a mirror of human behaviour (VROM, 2010).

Working part-time, at home or job-hopping are terms that did not exist a few decades ago, and illustrate the end of the separation of functions. Users of building no longer let their activities be limited by the possibilities that the buildings offers them. Important drivers of these changing demands are the aging population, individualism and internationalism. Households are shrinking and citizens are becoming articulated. Studying is no longer something you do in your youth; it is something you do for an entire lifetime. Sports are not for the weekends, to be practiced in your own neighbourhood, but also for during the week, and on a golf course far from home. Work is combined with family care and a study. We think, act and communicate on a global level.

Traditional building therefore, no longer meet the needs of our society. Dwellings need to change as soon as a family is expended. Schools become dwellings when a neighbourhood ages. And the diversity in needs will further increase over the next few decades as individualism increases.

When sustainability is discussed on the level of the occupational layer, subjects are often related to the quality of life of the users. The quality of air, noise pollution and safety are often experienced as a burden in spatial planning. This is because plans are often checked on environmental aspects at the end of a planning process. When sustainability is integrated in spatial planning of the occupancy layer in an earlier stage, new opportunities arise. Sustainability in this layer is often implemented trough real estate. To be able to cope with the fast pace of changes in a sustainable way, real estate should be flexible. Being flexible creates the opportunity to constantly optimise the supply of real estate to changing demands.
So the need for flexibility in this layer is very high, as changes take place in a fast pace. For example the fact that now elderly live independent for a longer time and young people wait longer to start living together with their partner. Within one generation, this results in a notable increase in one-person households (Turbantia, 2009), which on its term have an effect on the economy. In Japan, the economy and society is already greatly affected by changes in its occupancy layer. Last year, 35% of the Japanese population has retired, but in 2050 this will be 74% (Chaudron, 2009).

Building in the occupational layer is still being developed with little flexibility. Flexible building techniques are available and constantly improved. Uncertainties concerning the financial consequences of such techniques seem to form a barrier. Flexible developments in this layer make the urban area more adaptable to changes, and for example, they make shrinkage less harmful. For all of these solutions it is of importance that they are synchronized with the connected layers, whether they are directly linked or not. When planning the occupational layer, attention needs to be paid to its connections to the network layer and the ground layer, and the restrictions that these layers entail.

Besides flexibility, some other dimensions of sustainability offer opportunities in the occupational layer:

- Concentrate spatial use around well accessible junctions and centres, powerful and well tuned junctions can form the basis of further development of the spatial and economic main structure. This also emphasizes the close relation between the occupational layer and the network layer.
- Strengthen the spatial diversity, in order to create a string and recognizable spatial and economical structure, a high spatial quality is of great importance. Living environments for example can be combined with cultural functions and water and green. These functions can strengthen each other.
- Organize green and blue areas, blue being water. Preferably these areas are connected and in prominent placed. But they can also be used to fill places unsuitable for other functions.
- Intensify spatial use, it can be used as a mean to create additional spatial quality. Advantages can be e reduction in energy use and an increased support basis for facilities like public transport. Underground infrastructure, stacked building and chained building also belong to this strategy.
- Combine functions, this way the liveliness and dynamics of a location can increase. This, on its term, can contribute to an improved quality of perception and an increased feeling of social safety. The presence of several functions in the same location decreases the needed travelling time and so also decreases the use of motorized transport.
3.1.2 Network layer

The network layer is characterized by high initial costs and a long initiative and preparation phase. Important changes in this layer take 20 up to 80 years. This layer contains networks for transport, energy, water, green and communication. These networks form the most important preconditions for our urban and economical dynamics. In spatial planning it is of great importance to define the characteristics and functions of these networks in order to understand the preconditions they lay upon other layers (VROM, 2010).

Sustainability in this layer is implemented on a larger scale then in the occupation layer, it contains a city or a region. Sustainable measures can involve public transport systems or the provision of environmentally friendly energy supplies. Spatial planning on the level of the network layer creates conditions that affect all layers. When an urban network is designed, including infrastructure and the separation between private and public space, it will show continuity and perseverance over a long period of time.

The necessity for flexibility in this layer is less urgent then in the occupation layer, as changes are more predictable. However, as this flexibility is needed in the occupational layer, the network layer needs to be able the adapt to possible changes. A smart, strong and adaptable network layer is essential to sustainable urban area development. Sustainable urban area development should focus upon the design of the network layer and its capability to adapt to changes in time (Heelig, Meyer, and Westrik, 2002). The dimensional margin with which the network layer is developed should facilitate any future development without needing frequent and polluting redevelopment of the network layer itself. Initial oversized development is often needed, making the network layer robust on the long term. Besides facilitating the occupational layer, a description of some other dimensions of sustainability offer opportunities in the network layer is given on the next page.
Transport
Mobility is of importance for every human being. But the way in which we move can be of great impact upon our living environment, climate and the landscape. Motorized traffic in urban area causes harmful pollution (for its inhabitants as well as for nature), noise, disintegration of the public space and danger. Parked cars take possession of scares public space. Great improvements in special quality can be made by decreasing motorized traffic.
- Slow traffic as a starting point, people tend to walk when the destination is less than 1 kilometre away, and bicycle when their destination is less than 6 kilometres away. To stimulate unmotorized travelling plan fast, direct and safe connection.
- High quality public transport, fast and safe connections by train, tram or bus can further reduce the use of motorized traffic.
- Mineralize infrastructure, concentrate and combine infrastructure. The higher the urban density, the more intense the usage, the higher the quality of the infrastructure. And public transport takes up less space then cars.

Energy
The energy network does not only provide electricity, but also gas and internet. International agreements about the reduction of greenhouse gasses can be implemented on a local level through smart energy goals. Possible strategies to improve the sustainability of the energy network are:
- Use alternative energy sources, like cold/heat storage, earth warmth from ground layers, passive solar energy, PV panels and windmills.
- Realize high densities, this decreases the loss of heat and energy in pipes and wires, and increases the exploitational perspective.
- Use warmth networks, new techniques and methods (industrial, electricity production, waist burn) make these financially and environmentally feasible.

Green and water
Inhabitants of green and blue neighbourhoods experience their neighbourhood as very positive. More but also a higher quality of green also improves the quality of our living environment. Combining green and water gives an extra quality impulse to urban areas, further improving the quality of live. An effective water system is of the essence for a healthy water flow, but also for the living environment. Clear, clean water forms a basis for a healthy ecology, but also offers a recreation value. Water systems should be designed to cope with additional water storage. The additional value created by green and blue networks can be optimized by:
- Combining disintegrated green and water, by connection the different green and blue networks in an area, the quality of the water and the green, as well as the recreational value can be improved. Baring in mind the climate changes and the rise of sea levels, it is of importance for water management to develop long-term strategies.
- Strengthen ecological, recreational and perception value, when provided with the opportunity to recreate close to home, motorized travelling in order to recreate will decrease. Additional value can be added to the real estate nearby.
- Combine green and water, development changes of nature are strongly related to a healthy water system.
3.1.3 Ground layer
The ground layer is the layer with the longest history, the ground layer facilitates all life on earth and contains all eco-systems. Changes can take over a century to become noticeable. The ground layer can buffer the negative effects and spatial interventions, so the consequences will be felt long after the damage is done. Think about typhoons, high temperatures, rising sea levels, forest fires, the end of our oil reserves and shortages of drinking water (VROM, 2010).

Sufficient knowledge of the ground layer is of importance to be able to practice sustainable urban area development. The ground layer determines the living environment of humans, animals and nature on the long term. In order to be able to support a healthy living environment the ground layer contains many systems which should be treated with the upmost care. Examples of sustainability in this layer are related to geothermal solutions, and biotical waste systems as this layer contains our biotical, abiotical and (ground)water systems. Spatial planning needs to be designed to disturb this layer as little as possible.

Within this layer, there are no flexible or adaptive possibilities. Flexibility or adaptability is not demanded in this layer, on the contrary, adaptability and flexibility in other layers should make daily life possible while effecting the ground as little as possible.

3.2 Integration of flexibility and adaptability
Sustainable urban area development should always strive to have as little effect on the ground layer as possible. To be able to achieve sustainability in a dynamic and complex world that changes every second the occupational layer and the network layer need to cooperate, being flexible, and adaptable. Long term strategizing is essential in order to be able to create adaptability and flexibility.

The ground layer is the basis of our being, urban area developments should be designed to effect the ground layer as little as possible.
The layered approach shows that the occupational layer can benefit from flexible real estate. Flexible real estate offers the possibility of having a shorter functional lifespan, without having a polluting and short technical lifespan. The functional time span is the time span in which a building or the build environment complies with the demands and wishes of the user. The technical lifespan is the time span in which a building or the build environment technically and physically can function. New techniques like demountable preassemblies building parts make this possible.

The translation from an abstract concept like ‘adaptability’ to implementable measures is hampered by several factors. A fundamental factor is the recent understanding that our climate system as well as our urban system are non-stationary systems. Adaptability is a process of constantly changing environmental conditions and stress factors. The inherent uncertainties in our changing climate as well as the effects of interventions on the urban space make a high level of adaptability desirable (Rijke, Veerbeek and Zevenbergen, 2009).

When flexible real estate is implemented on a larger scale, new opportunities arise. Besides the opportunity to anticipate upon unexpected changes in the technique, economy, demography or qualitative demand, it also creates tonus after external influences have shifted and can function as a catalyst in the phasing of an urban area development. To be able to facilitate flexible real estate, a network of adaptable infrastructure, energy, green and water is needed. Adaptability in the network layer mainly focuses on capacity and quality. A location build upon with flexible real estate should be provided with a network layer able to adapt to any of the functions the flexible real estate is demanded to become when necessary. This system of an occupancy layer that contains physically flexible real estate and a over-sized occupancy layer capable of facilitating the occupancy layer without having to physically change itself in called ‘an adaptable urban area concept’.

Adaptability of an urban location increases the capability of a system to function within current environmental conditions and reduces the potential consequences of climate changes upon our economy and society, because its sensitivity has been reduced. Adaptable systems and networks make it easier for a location to develop itself. Concentrating the urban functions around well accessible junctions makes sure that the economical profile of a centre is well tuned to its accessibility. Concentrated, efficient and well-connected junctions form the basis of further development of the spatial and economical main structure. Besides the fact that an adaptable network layer facilitates a flexible occupational layer in transition, on the contrary the adaptable network layer can also be an impulse for the urban system.

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**A sustainable urban area development is a development in which all involved actors integrate planning and spatial investments for an area, to result in the execution and lifecycle management of a spatial plan based on mitigation, that is adaptable so it can meet the needs of the current generation without risking the provision of needs of future generations.**
4. Feasibility
The feasibility of an adaptable urban area concept will be discussed in this chapter. Different aspects of feasibility are; social, ecological, functional, technical, legal and financial.

4.1 Social feasibility
The biggest drawback of flexible real estate is the great social, cultural and economic difficulties future users can have with the principle that a building is temporary. ‘Temporary’ is often associated with buildings of a low aesthetical value (or even containers), and users not caring for their environment as it is temporary anyway.

It is true that these stereotypes exist. The large-scale implementation of flexible real estate will need a social transformation. As techniques improve the aesthetics of this concept, governmental planning will have to pay attention to the development of a high social and physical living environment. For people to be willing to live in a certain area, they need to have some affiliation to the area. Making an area 100% flexible will make this impossible, as the character of the area will completely change every few decades. The presence of daily facilities can help improve the relation between occupant and location and stimulate social binding (VROM, 2009). For one thing, the analysis of sustainable urban area development according to the layered approach underlines the necessity of a strong green, blue, energy and infrastructural network.

As occupants need to be able to affiliate with their environment, the temporary technical life-span of the buildings should not interfere with the functional life-span and social functioning of the buildings. Users should have some certainty on the future of their environment. Contracts between owner and occupant should therefore have a minimal duration of a fixed period, depending on the function of the building. In the mean time, society starts to appreciate flexibility as it is able to transform a house or office to the demands of it occupants both initially as well as occupants shift. These changing demands not only entail the interior layout but also entail higher demand in energy performances and technical which evolve during the life-span of the building. This simultaneously satisfies the governmental policy to increase the choices of citizens.

On the next page, some reference projects constructed through IFD techniques are shown, to underline the fact that flexible building do not have to look like containers.

4.2 Ecological feasibility
When a building is programmed for a technical life-span of twenty years, the environmental pollution it causes originates for 60% to 70% from the materials used for this building. A ‘traditional’ building is programmed for a longer period of time, so one can reason that the materialization will be less of a burden to our environment. The environmental awareness created in between 1990 and 2000 however, was counteracted by the large amount of polluting building transformation that decade (SenterNovem, 2007). So the initial materialization as well as the necessity to transform are of great importance.

Building materials should not just end up at dumping grounds. The materialization of a building should be adjusted to its expected life span. To be able to build real estate with a short functional life-span, innovative industrial, flexible and demountable building techniques are needed. IFD techniques offer the opportunity to add several functional life spans to a construction part, making it demountable and separating the load bearing structure from its façade, roof, installations and interior (Duijvestein, 1999). Over 80% of the building part used in IFD technique are reusable after demountation (www.ifd.nl, February 2010). Moreover, the capacity to demount and replace a construction part offers the opportunity to integrate new (energy-saving) building techniques into the existing supply more easily.

4.3 Functional feasibility
It is imaginable that when you want to buy your own home, a flexible building transitioning every few years is not desirable. As flexible real estate is often of a temporary or dynamic character, it is not suitable for the owner-occupant market. Functions in the rental sector with a longer technical life span then functional life-span are very suitable however. A general description of these functions is given below (Post, 2006).
Figure 9: Examples of IFD projects
Offices and industrial building
Companies undergo changes like the seasons of nature due to reorganisation, mergers, privatizing or takeovers. As demand and supply change, new protocols, routines and collaborations are being developed. The developments take place in such a pace, that the program of requirements obsolete before the building has been finished. Companies nowadays want to present themselves as being sustainable and building sustainable. But as the demand for sustainable offices grows, the supply becomes inadequate. So even though the Dutch office market is currently characterized by a surplus in supply, and the interest is there, there are too little sustainable office buildings.

Dwellings
Dwellings are one of the most difficult functions to build for a shorter functional life span. De economical, social and cultural objections are a complex burden as people tend to identify with temporary constructions. But many of the post war dwellings in the Netherlands are positioned in lower areas, making them vulnerable to floods and excellent candidates for flexible and demountable housing techniques. There are dwellings though that has more temporary and dynamic characteristics, which make them very suitable for flexible developments; elderly dwellings, communes, student accommodation, asylum centres and recreational dwellings. All mainly in the rental sector.

Government
Penitentiary institutions, governmental buildings, project organisations, police departments, fire brigade, information centres, ambulance stations, research centres and education are functions suitable for flexible real estate. Especially education, from primary school to university is a dynamic function. Education is no longer just focused on obtaining knowledge, but also on the development of competitions. It is for youth as well as adults, and often cooperates with the corporate world and welfare. Social processes of individualization and digitalization change the way in which governmental buildings function.

Culture
Cultural function often need to be able to accommodate a large variety of functions, or are only of a temporary nature. Cultural functions suitable for flexible real estate are: community centre, visitors centre, sport facilities, recreational functions, leisure functions, retail functions, hotel, hostel of museums.

Events
Events are mostly of a temporary nature, and therefore very suitable for flexible building concepts. Event buildings are buildings like congress halls, sport stadia or the Olympic Games.

Care
As medical science constantly develops, every generation has a new and modernized care service system. The continues factors are the buildings needed to provide care. These buildings can accommodate the care, the caregivers as well as the caretakers. Experience teaches us that ‘traditional’ buildings are often in conflict with the constantly changing care vision. The consequence is that buildings are demolished before their technical life span is finished. Flexible real estate concepts are already being implemented in this sector, and have proven to be successful. Besides the obvious hospital, an example of a care function suitable for flexible real estate is a day care centre.

Water
Water appears not to be a suitable functions for flexible real estate, however, it does benefit from temporary buildings. Due to climate changes, many urban areas are at risk of flooding (VROM, 2006). When building upon a certain area on a temporary basis, the area will remain available for water storage on the long term.

4.4 Technical feasibility
Industrial, flexible and demountable building techniques (the IFD method) stimulate the utilization of industrially developed and produced building components in new buildings and constructions as well as ones to be renovated. IFD-methods directly comply with objectives to minimize the use of fossil fuels and stimulate recycling and reuse. Demountability and flexibility make it possible to lengthen the technical life span of a construction, opting for multiple users, multiple functions and even multiple locations. Standardization stimulates efficient use of materials both during production as well as recycling. In this way, IFD methods combine environmental goals with economical goals.
Industrialisation increases standardization on the building site. Variance in the standard sizes of components provides for variance in the final product.

Flexibility provides the possibility the change a building as the demands of the user change. The longer the expected functional life-span, the more flexibility is demanded.

Demountable building techniques make it possible to recycle and re-use the majority of the construction parts. Especially with demountable building techniques, additional attention needs to be paid to the environmental aspects of the chosen materials and production methods.

The different parts of buildings each have their own characteristics and their own technical life-span. The interior has a life-span of 10 years, the installations a life-span of 15 years, the façade and roof a life-span of 25 years, and the load bearing structure a life-span of 100 years. This means some parts can be re-used more than others. The choice for a flexible building concept therefore is not just a initial design choice, but entails active and continues maintenance, as the different parts have their own replacement cycle. When flexibility is strategized in an urban area, this can be adapted into the zoning plan. Flexibility makes it possible for governmental policies and discussion to be optimized to changing demands or new insight later on in the life cycle of an urban area, making the initial policy or discussion sell rigid.

4.5 Legal feasibility

The traditional planning process of initiative, design, implementation and maintenance in essence is suitable for a cyclic adaptable development concept. Attention needs to be paid to the evaluation of the urban environment, this should not end after the realisation of a development, just to be maintained without monitoring the changes (Post, 2006).

The long-term strategies needed to create urban adaptability pose a problem for the government. Predicting the future of social, economical and environmental changes for decennia to come is virtually impossible. In contrast to the needed long-term strategies, governmental officials are judges upon their short-term performances, because within four years they will have to be re-elected, so they tend to focus on this four-year period too. A problem arises when the vision of the officials is shorter than the life span of the actions they plan. Urban areas planned right now are evaluated till 2050 max, while they will probably still be there after 2100. A well considered strategy contains an adaptable land use plan, which can be applied on the long term. The shorter depreciation period of its real estate makes the land use plan flexible. The current spatial planning laws in the Netherlands however, complicate flexibility (VROM, 2007).

The main focus of the Spatial Planning Act (Wet Ruimtelijke Ordening) is current developments, and developments in the near future. There are no specific tools to plan for the long term, an armamentarium for flexible real estate and adaptable urban developments is lacking. The two regulations that do discuss temporary planning are:

- Temporary utilization is possible for a period of five years. This allows a municipality to use a plot of land for a function other than the one defined in the zoning plan. The governments need to make is plausible that the function is actually temporary. (Oosterberg, Zevenbergen, Rikko, 2008)
- Temporary destined is possible if the zoning plan states that the first function will be followed by a second function. The first and second function need to be defined when making the zoning plan however, leaving little room for flexibility in the long run.

The VROM-Raad has recognized however, that uncertainties about future developments should not lead to additional research of future developments, but to a process organization in which demand and supply of functions are continuously synchronized. This can be established when long term involvement and responsibility of investors and actors is secured. Some actors have this long term horizon by nature, like corporations or project developing investors (VROM-Raad, 2009).

4.6 Financial feasibility

In the circuit from farming land to urban neighbourhood many prosper. This circuit is interrupted by flexible real estate. A temporary function does not have a continuously more or less stable value like a ‘traditional’ building with the same qualities. Land destined for water storage is less valuable then land to be build upon. The
interim transformations of a flexible location are costly and someone needs to pay those costs (SenterNovem, 2007).

Building techniques like IFD entail higher initial investment costs in the network layer as the network has to be over-dimensioned to be able to comply to any future real estate developments. Furthermore, the exploitational period per function is uncertain. Benefits can be the shorter time frame from initiative to realization, lower building site costs and the reuse value of the construction parts. Long term planning with adaptability and flexibility can be used to decrease over investments. When damage (a mismatch with the market or for example floods) occurs, the system is more resilient. Or when the quantitative demand for real estate stabilizes or shrinks, the future value of existing traditional real estate becomes uncertain, while flexible real estate can continuously and more easily be altered to changing qualitative demand or when needed, be demounted. On the other hand, adaptation measures like water storage only generate benefits when the flood actually occurs. The major uncertainties for which the flexibility is integrated can cause overinvestment as well as prevent them. So in order to make adaptable urban area concepts financially feasible, new and innovative land development will have to be developed, including not only the direct and primary costs and benefits, but also entailing secondary social and ecological costs and benefits. Many land developments and exploitational plans now, are designed for the Vinex-period. A period in which the final outcome of the plan was very clear and flexibility was not an issue. Adaptable urban area concepts need flexible land developments. Anticipating land developments or area exploitations (gebiedsexploitaties) for example would prove helpful to adaptable urban area concepts. In anticipating land developments strict agreements can be made, while on the other hand the future developments are still flexible. An area-exploitation helps involved actors to include additional value creation, which flexibility can result in (Harkes, 2004).

Traditional urban area developments are often seen as current developments that need to be financially feasible almost instantly. Well designed and sustainable urban area development can generate added value over time. Added value can be an increase in property prices as an area becomes appreciated and popular due to its pleasant living environment. Added value can also be the capacity to cope with changes in its context, without having to compromise the living environment. The crisis for example has proven that property prices can not be assumed to be continuously increasing. As the future quantitative demand might stagnate or even shrink, traditional properties can lose their value, while flexible properties can be altered to new requirements, or even demounted and resold. Sustainable investments are often not directly visible in the returns. As shrinkage sets in, property prices might drop due to a surplus in supply. Flexible real estate would make it easier to correct this mismatch between supply and demand. Problem is that investors often don’t have the time or money to wait on their return, especially not in a crisis. Therefore it is necessary to research potential future value, and integrate this into exploitational plans.

The financial consequences of an adaptable urban area concept from an investors perspective
5. Input model
Concluding from the literature study, the following findings will be taken into account for the final model.

‘This system of an occupancy layer that contains physically flexible real estate and a over-sized occupancy layer capable of facilitating the occupancy layer without having to physically change itself in called ‘an adaptable urban area concept’ (page 35)

As input for the model, this means that investments in the network layer will be more expensive when simulating a flexible building concept, then when simulating a traditional building concept. As the use of a location can change over time, the network layer has to be installed to fit the most intensive function possible at all times, under ground as well as above ground.

‘For people to be willing to live in a certain area, they need to have some affiliation to the area. Making an area 100% flexible will make this impossible, as the character of the area will completely change every few decades.’ (page 37)

As the model will uptimes and decide which balance between functional and flexible real estate is the most interesting for the investor, boundaries can be set the minimal amount of traditional build programme.

‘As techniques improve the aesthetics of this concept, governmental planning will have to pay attention to the development of a high social and physical living environment. .... The presence of daily facilities can help and regular activities can help improve the relation between occupant and location and stimulate social binding.’ (page 37)

In the interface of the model, the user will have the option to set limits to the different combinations and ratios in functional mixes. This way, the facility level can be controlled.

As flexible real estate is of a temporary character, it is not suitable for all functions.’ (page 37)

The function implemented in the model and suitable for flexible real estate are: offices, industrial buildings, student-, senior-, recreational-, and starter dwellings, asylum centres, communes, penitentiary-, and governmental institutions, project organisation, police, fire brigade, ambulance, information’s centres, research-, and educational institutions, recreational-, leisure-, and retail functions, hostels or hotels, sport accommodation, events, community centres, medical-, permanent institutional-, and child care in the rental sector.

‘Contracts between owner and occupant should have a minimal duration of a fixed period, depending on the function of the building’. (page 37)

The technical life cycle of certain functions will be set to have a minimal time period. As transformation in the programme become relevant, the age of the building to be transformed or de-assembled will be checked first.

‘The different parts of buildings each have their own characteristics and their own technical life-span. The interior has a life-span of 10 years, the installations a life-span of 15 years, the façade and roof a life-span of 25 years, and the load boring structure a life-span of 100 years!’ (page 40)

Building maintenance in flexible buildings will have a different frequency then in traditional buildings. As the different parts of the building have different technical life spans, they will each have their own maintenance schedule. And as flexible buildings will be de-assembled, the value of the building will be assessed per part. In traditional buildings a frequent pattern of maintenance for the whole building is established, and as disassembles is not an options, rest value is none.
6. ADURAM2100
ADURAM2100 stands for Adaptive Urban Area Model with a time frame of the year 2010 till 2100. The goal of the model is to offer its users insight into the financial consequences of implementing an adaptable urban area concept. The model will calculate the financial feasibility of a plan on the long term, with the financial differences between ‘traditional’ build functions and ‘flexible’ build functions as the main focus point. The financial feasibility will be calculated through the perspective of an investor for the entire development. The scenarios represent the demands of the final occupant, and by means of boundaries and requirements the government is represented. The financial consequences integrated in the model are primary and direct costs and benefits resulting from construction and maintenance of the real estate itself.

The time frame of 90 years is chosen to be able to capture sufficient change in the occupational layer (paragraph 3.1.1). Moreover, this long time frame makes it possible to test what the financial differences are between the limited functional life cycle of a traditional building (max. 50 years for a residential functions), and the continuous functional life cycle of a flexible building (with a max. of 100 years due to the load baring structure). The longer time frame also relates to the expected annual damage resulting from flood risk scenarios, that strongly increases after 2050 (paragraph 6.3.4). The influence of this discussion to set a time frame of 90 years on ADURAM2100 will be tested later on in chapter 7.

6.1 Perspectives
As the research question of this graduation thesis makes clear; the goal of this research is the approach the consequences of adaptive urban area concept from an investors’ perspective. In reality though, this doesn’t mean that the voice of other actors should not be heard. For this reason, an analysis follows of the investor itself, and the government (generally representing the interest of the end user).

6.1.1 The investor
An investor invests in an object or activity with the believe that this object or activity will provide a positive return on investment. In case of urban area development this investment is mostly financial. The financial return on investment is the return realized over a studied time frame, equal to the profit within this time frame in ratio to the invested capital. Investment management in real estate can be divided into portfolio management, asset management and property management (Van Driel, 1998). To be able to explain the perspective of an investor and the steering options of the investor as build upon in the model, a short explanation of these terms are described next.

Portfolio management
Portfolio management focuses on the composition of the portfolio, and the division in means of investment it contains. In general investment, these means can be stock shares, loan stock debentures, public loans, fluid assets or real estate. Portfolio management focuses on the ratio between these different investments means within the portfolio. When an investor has invested solely in real estate, portfolio management focuses on the division in real estate. What types, functions, locations, or contract forms will generate the higher return on investment of the portfolio in total while maintaining the lowest risk?

In ADURAM2100, the area of research will represent the portfolio, so the location is fixed (see paragraph 6.2 for more information on the location). The composition of the portfolio will be variable considering functions, within the qualitative and quantitative boundaries and requirements set by the government. The results will show what the return on a portfolio of flexible real estate is in comparison to a portfolio with traditional real estate.

Asset management
Asset management assesses the financial performance of individual projects or several complexes. According to the results of these assessments actions can be taken per complex or project. Actions can be:
- Consolidate: maintain the project or complex and continue regular maintenance.
- Improve: maintain the project or complex but undertake additional physical transformation or maintenance.
- Reject: sell or demolish the project or complex.
- Acquisition: the development or purchase of additional projects or complexes.
In ADURAM2100, consolidation, improvement, rejection and acquisition are all possibilities. Consolidation implies management costs like regular management, the expected annual damage due to flooding and benefits through rental income. Improvement is preprogrammed in the form of large maintenance cycles, which will be described in paragraph 6.3.4. Rejection is limited to demolishment, as the model is based upon the principle of only one investor for the entire area. For the same reason, acquisitioning is limited to new build.

**Property management**

Property management focuses on the daily maintenance of projects or complexes. Besides the technical maintenance of the real estate, this entails the contact and service for occupants and potential clients, rent collection and marketing. In ADURAM2100, the costs and benefits of property management are fixed per type and function.

### 6.1.2 The government

To guard the social relevance of this research, it is of importance not only to focus on the financial feasibility, but also the social feasibility. Social feasibility focuses on the realization of public and common goals separate from profitability. Future and current occupants demand a pleasant and efficient living and working environment and sufficient and diverse supply in functions within an acceptable price range.

To guard and regulate these demands, the government can set certain rules and requirements for an area and its supply. Furthermore, it can guard the composition of stock supply on a larger scale, like portfolio management.

In ADURAM2100, the quantitative demand in supply of the (future) occupants is expressed in the four scenarios, which will be discussed in paragraph 6.3.3. The governmental qualitative demand can express itself through the zoning plan, in physical requirement, like the acceptable range in density, the preferred ground space index (GSI), the maximum or minimal building height, the functional mix needed to create a certain living environment, or more legal objectives, like a minimal or the acceptability of certain functions in specific locations.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Focus</th>
<th>Input model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investor</td>
<td>Financial feasibility</td>
<td>Asset and property management decisions.</td>
</tr>
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<td>Government</td>
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<td>Quantitative demand of future occupants through scenarios.</td>
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<tr>
<td></td>
<td>Legal feasibility</td>
<td>Qualitative demand of future occupants through zoning plan.</td>
</tr>
</tbody>
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Table 1; Diversion of perspectives

### 6.2 Location

Basically, the demands and requirements as mentioned in the previous paragraph can be as wide as any of the demands and requirements that can be found in a regular zoning plan in the Netherlands. To be able to conduct a surveyable study of the financial consequences of adaptive urban area development, a case study will be performed, projection ADURAM2100 on a location within the city harbors of Rotterdam. The city harbors of Rotterdam are selected because the municipality of Rotterdam has recently indicated that they are planning to redevelop these areas, as some of the harbor industry is moving to Maasvlakte 2 (Project group City harbors of Rotterdam, May 2008). Adaptability in these areas is relevant as the municipality itself has indicated to opt for flexible and sustainable solutions during and after the logistically complex and long term developments that are about to take place. Moreover, many of the locations that will open up as harbor industry will move out of the city centre are threatened by flooding.

### 6.2.1 Selection criteria

A selection of locations is made and tested upon according to the following criteria:

- To enable dynamic of future developments, the area has to be between 25 and 125 hectares
- Current use enables future flexibility, the presence of monuments, listed buildings or other protected areas will aggravate this.
- Future developments must entail dynamic developments that can be candidates for flexible constructions. Resulting from variety in demand of the scenarios (see paragraph 6.3.3) this means at least residential and office functions need to be demanded.
The financial consequences of an adaptable urban area concept from an investors perspective

There should be sufficient documentation available.
The financial consequences of flexibility in the occupancy layer are influenced by the additional investments needed to make the network layer adaptive. To be able to research this relation, no network layer of high and adaptive quality is allowed to currently be present.

With these selection criteria in mind, I studied the different areas to be redeveloped in the city harbors of Rotterdam, and asked fellow colleagues at Dura Vermeer Business Development which were informed on the subject of my graduation study, whether they had suggestions unto which locations would be interesting for me to study. The six locations within the city harbors of Rotterdam highlighted in figure 14 where subjected to a quick scan. These locations are Heijplaat (2), Katendrecht (3), Noordereiland (4), Verolme terrain (5), Merweharbor (1), and the Nederlek area (6). A short description of the city harbors of Rotterdam and the quick scan of the six locations can be found in appendix 1.

Resulting from this quick scan, the Merweharbor is chosen to be the location to project ADURAM2100 on. The Merweharbor area as shown in figure 15 consists of the Merweharbor and Vierharbors, sometimes named Nieuw Mathenesse. This area now still mainly focuses on fruit, energy and environmental industry. Within the coming years, most of the fruit industry will move to the Waalhaven and the Eemhaven, at the southern bank of the Maas, opening up space for new activities.

In the future an innovative work-live environment will be realized, focusing on sustainable energy and water management, with strong connections to its surrounding neighbourhoods. With the RDM campus at the other site of the Maas, the Merwehaven is the perfect location for a Climate Campus where scientific research on and implementation of delta technology valorizes. The close proximity of other institutions like the TU Delft and the Erasmus University make this location an ideal spot for international cooperation and entrepreneurs.

Remarkable living concepts like floating communities will attract well educated residences, a target group Rotterdam is aiming for in order to renew its economy. A first initiative that is currently being developed is the Dakpark, where creative entrepreneurs in retail, leisure and other commercial facilities are settling. It is the goal for the Merweharbor to offer facilities for its surroundings, as well as that the surrounding areas offer facilities for the Merweharbor.

Tough the Merweharbor is well accessible by car, train, metro and tram, the infrastructure is mainly focused on industrial transport, so additional efforts will have to be made in order to make in pedestrian and bicycle friendly (City harbors of Rotterdam, 2009). The development of the Merweharbor area is split in several phases. A further description of these phases, and a programmatic quantification of the future developments in the Merweharbor will be discussed in paragraph 6.3.2.
6.3 The model
ADURAM2100 is built upon RICARDO (Real Investment Calculator of Area Redevelopment Design Optimization), a model to study the financial feasibility of land development plans. The biggest difference between RICARDO and ADURAM2100 is the fact that RICARDO is focused on current developments and the phasing of these planned developments, while ADURAM2100 focuses on the behaviour of these developments till the year 2100, and integrates management and maintenance. In this paragraph, the functioning ADURAM2100 will be explained.

6.3.1 The principle
A conceptual scheme of the modelling principles can be found on page 22.

Initially, ADURAM2100 was to be developed as a model that could be linearly optimized financially, with the ratio of flexibility in the program as variable. After building and testing this model, it turned out these calculations were unreliable, as the model was not linear. This mainly resulted from the nonlinearity relation between depreciation and maintenance. To be able to research the financial consequences of an adaptive urban area concept without having to linearly optimise, the calculations were split in two, of which one part calculated the return on investment when 50% of the program is realized through traditional building techniques, and the other part calculated the return on investment when 50% of the program is realized through flexible building techniques. So of every square meter that is developed, half of it is realized traditionally, and half of it is realized flexible. This way two equally developed parts derived, making it possible to study the difference on financial returns between traditional and flexible developments.

Working with ADURAM2100 works the same as working with RICARDO. Modelling starts with the implementation of a land development plan through the drawing interface (tab sheet ‘Plangebied’), making it possible to either enter specific functions by the use of stamps, or contouring specific areas and assigning functions to these areas. Though the functions present in ADURAM2100 are pre-programmed (tab sheet ‘Bibliotheek vlekken’) to have certain physical characteristics, costs and benefits, each of these characteristics can be altered in a simple menu in the drawing interface. To be able to calculate the long term development of an area in ADURAM2100, additional information on maintenance costs, demolition costs, duration of construction, ground prices and the costs of structural infrastructure should be adapted into the pre-programmed characteristics (this information can now be found in tab ‘Functions’, or appendix 7). When drawing a contoured area, in the characteristics menu makes it possible to opt for multiple functions within one area. As future developments in the ADURAM2100 model will be delimited by the zoning plan, additional to the present possibilities in this menu, it will have to become possible to enter the demands and requirements related to the zoning plan in this menu. A conceptual interphase of ADURAM2100, based on RICARDO, can be found on page 50. Additional to entering the initial programme, it is also possible to phase the development (Tab ‘Kosten & Opbrengsten’). In ADURAM2100, the phasing runs from 2010 till 2100, to be able to phase long term developments, like for example the ones in the Merweharbor area.

In tab sheets that are normally hidden from the user, all the quantitative input from the land development drawings is collected (Tabs ‘Database stempels’ and ‘Database vlekken’). A solver plug-in for Excel calculates how many stamps can be realized within one contoured area.

Now, the initially entered functional program can be compared to the future demanded program according to four scenarios. This happens at fixed intervals and only for the rental part of the initially entered program, as other properties will be sold to other parties and extracted from the portfolio of the investor. The fixed intervals in this case are set at 5 years, this interval is chosen because;

- It sets the minimum contract duration, limiting the negative financial effects of short term contracts.
- It renders the definitions of turning points redundant. Turning points entail the moment on which the difference between demand and supply is big enough to undertake action. After researching turning point related to rental fluctuations and additional project costs it turned out to be a subject on which too little knowledge was available.
- All of the data concerning future development and management is based on 5 year intervals.
- An interval of 5 years somewhat mimics the governmental interval of elections (every 4 years), after which a renewed vision on spatial development is sometimes implemented.
At every interval the existing supply is confronted with the demand at that moment, and given the option to either build or demolish parts of the supply. Zoning plan requirements are integrated as contains and show an error when the supply realized does not meet the requirement of the zoning plan. To be able to really focus on the financial consequences of an adaptive urban area development, the model is simplified and variables that have and equal influence on both flexible as well as traditional real estate are left out as much as possible.

In the output of the model a time path can be seen of the development of the program over time. The return per interval, per functions and in total is visible both for the flexible part of the program as well as the traditional part (tab sheet “Optimize”).

By altering the characteristics of the functions initially entered in the drawing interface, the growth of shrinkage ratio of the quantitative demand scenarios, or the flood scenarios, one can research the financial consequences of adaptive urban area development. Tab sheet ‘Output’ shows how the output changes as the characteristics, scenarios and other variables are tested on their sensibility, and the influence they have on the total return.

6.3.2 Input
The input for the case study of the Merweharbor in Rotterdam is based upon the execution program of the municipality of Rotterdam (Project group City harbors of Rotterdam, October 2008) and several conversations with Caroline Rovers, who works for the municipality of Rotterdam, and is currently configuring the zoning plan for the Merweharbor area.

Until 2025, four projects are chosen to initiate the redevelopment of New Maathenesse. These projects are chosen for their public function, positive image and innovative goals. The Vierhavenstraat is currently being developed to become the multi layered Parklane (section 22 in figure 12), offering leisure functions on top, and office and retail space beneath. In the Keilehaven (section 13-15 in figure 12) innovative office space, retail, culture, and food and catering functions will complement the developments at the Dakpark. Monumental industrial building will be given a new function when possible.

Following the Rotterdam Climate Initiative, the development of the Rotterdam Climate Campus has started in 2008. This is currently situated in existing buildings as much as possible, but will become one of the iconic buildings of the area in the future. The fourth project is the Marconifreezone, offering temporary and long term housing for public facilities related to green, technique, leisure and art (section 3 in figure 12), this section will be transformed in a merely residential area after 2025.

After 2025, a floating community is realized in the Merwehaven. Matching facilities are realized, like a small recreational harbor, a water sport club and a café, and under water parking facilities will be realized. This floating community is not taken into account in ADURAM2100. More residential functions are added to the Marconistrip as it densifies. The rate of transitions mainly depends in the immigrations of the fruit industry. In the area a mix of single dwellings, more urban apartments, floating dwellings and offices is complemented by vegetable gardens, sports facilities, offices, shops and a theatre (City harbors of Rotterdam, January 2009).
Conceptual interface RICARDO + ADURAM2100

Multi-functioneel gebied

afmeting van geselecteerde “vlek”: [Fields]

- type object:
  - [Checkboxes] 1 * eengezinswoning middelduur
  - [Checkboxes] 2 * eengezinswoning sociaal
  - [Checkboxes] 3 herenhuis
  - [Checkboxes] 4 * twee onder één kap duur
  - [Checkboxes] 5 * vrijstaand duur
  - [Checkboxes] 6 gesloten bouwblok traditioneel
  - [Checkboxes] 7 * vrije kavel
  - [Checkboxes] 8 Bebo-woning breed
  - [Checkboxes] 9 Bebo-woning smal sociaal
  - [Checkboxes] 10 * appartementsgebouw middelduur
  - [Checkboxes] 11 * appartementsgebouw sociaal
  - [Checkboxes] 12 urban villa
  - [Checkboxes] 13 * appartementsgebouw duur
  - [Checkboxes] 14 U-blok
  - [Checkboxes] 15 toren 50 m

- [Fields] % selling market min max
- [Fields] Number of floors min max
- [Fields] % of total supply min max
- [Fields] OSR min max
In the redevelopment strategy of the municipality, the existing office area at the Marconisquare (section 10 in figure 12) and the area surrounding the Eon power station are not integrated (section 9 in figure 12). This strategy however only entails developments until the year 2025. As the model stretches till the year 2100, the assumption is made that eventually the office area at the Marconisquare will be redeveloped after 2025 and the high quality in urban living and working that will be realized will make it necessary for the Eon power station to move out of the area too, opening up another area to redevelop. In general, the developments taking place in the area will continuously strive for an urban environment with living and working as primary functions.

A description of the ground surface occupation of this urban environment by the Planbureau voor de Leefomgeving will give a continues guideline to the developments over time (figure 13) (Ritsema van Eck, Amsterdam Van der Schuit, 2009, page 61). Within the residential section, 40% of the homes will be rentals, and 60% will be sold to private individuals.

Basic requirement of the future zoning plan mainly entailed a maximum building height and FSI (floor space index). A quantitative summary of the program entered into ADURAM2100 and the requirements set by the municipality can be found in appendix 2. A more extensive description of the functions used in ADURAM2100 can be found in appendix 3 (Companen, 2007).

6.3.3 Scenario’s

As the future of the test location is not certain, the model will calculate the financial feasibility according to four different scenarios of future quantitative spatial development. To determine which variables will be of importance in the future for the development of the area, the different ‘aspects of urban area development’ are analysed first. In ‘De engel uit graniet’, Friso de Zeeuw makes a division between the following aspects of urban area development (De Zeeuw, Franzen, 2009):

1. Concept and design
2. Program and phasing
3. Costs, revenues and risks
4. Steering, cooperation and management of interest

Concept and design are represented in ADURAM2100 by the initial program as entered into the drawing interface. The second and third element, program, phasing, costs, revenues and risks will differ per scenario. All of the aspects mentioned in number 1 – 3 can be categorized as micro aspects, directly related to the location itself. The aspects at point 4 can be categorized as macro aspects, as they influence the other aspects from out sight the location, they are the context in which the location is developed and can be social, economic, legal or political. These are mainly the aspects that will shape the scenarios.
To determine the external macro variables influencing the local micro variables, four scenarios of the CBS (2005) are used. These scenarios are feasible and consistent views of the future. They do not aim to predict the future, but rather to sketch alternative futures. These scenarios of the macro contextual influences form the background against which later, strategic decisions can be explored.

The first challenge is whether countries will succeed in international cooperation, which is necessary in order to deal adequately with cross-border issues. In particular, this uncertainty relates to the difficulties in reforming current international organisations such as the European Union and the World Trade Organisation (WTO), and institutionalising new forms of cooperation to deal with global problems. International cooperation thus refers to cooperation both in the European Union and between the European Union and other regions.

The second key uncertainty refers to institutional reforms in the public sector in European economies. It involves developments that put the public sector under pressure such as ageing, the division between low-skilled and high-skilled labour, policy competition, and individualization. National governments are clearly unable to continue on the old footing. It is uncertain, however, how they will respond to these challenges.

These two key uncertainties are illustrated in figure 15. The upper left quadrant represents a world labelled Strong Europe (SE), featuring ample international cooperation and important public institutions. The bottom left reflects the scenario Regional Communities (RC), combining ample public responsibilities with little international cooperation. The lower right quadrant represents Transatlantic Market (TM), a world with affinity for national sovereignty and ample room for private initiatives. Finally, Global Economy (GE) is given in the upper right quadrant, combining flourishing international cooperation and a move towards more private responsibilities. A more extensive description of these scenarios can be found in appendix 4.

The four scenarios described are expressed in statistical indicators related to the contextual influences on a macro level. These indicators are translated from Europe to the Netherlands, and can be stretched from 2040 till 2100 (CBS, 2008). The transition from external indicators to spatial use has been made (CPB, MNB, RPB, 2006) and was enlengthend to 2100 with the help of the Spatial Information Laboratory at the VU Universiteit Amsterdam (Van der Hoeven, Jacobs and Koomen, Sept. 2008), and then translated to the spatial demand in the Randstad (VROM, 2008). The quantitative spatial demand for the Randstad is directly projected on the development plan of the municipality of Rotterdam for the Merweharbor. The four scenarios for the Randstad that are projected on to the Merweharbor can be found in figures 16 – 18.

Figure 15; Two main uncertainties in scenarios

Figure 16; Quantitative demand residences in the Randstad (hectares x 1000 over 90 year period)
In all of the scenarios, the growth of the population is dominant to other developments. Future growth mainly results from immigration, and is strongly related to the quantitative demand for residential functions. Without a strong economy, immigration is less and the Dutch population stagnates or even shrinks. The qualitative demand for residences is strongly determined by individualization, simultaneously increasing the number of dwellings demanded, without directly increasing the total quantitative demand. Where future residential developments will be located depends on politics and policy. Work related functions are subordinate to residential functions, but the location of office development depends on the willingness to commute. Trend concepts like working from home are not mentioned in these scenarios (CPB, MNB, RPB, 2006).

6.3.4 Variables of the occupancy layer
In this paragraph the variables that influence the financial consequences of the occupancy layer will be discussed according to the actions the investor could take when managing real estate as an asset; consolidate, improve, reject or acquisition. Consolidation and improvement are combined as they both entail technical maintenance costs, and the improvements are preprogrammed in the form of large maintenance cycles. All costs are checked to be excluding taxes, lose furniture and additional operating costs.

**Consolidation and improvement**
The consolidation and improvement of asset management entails three financial consequences; technical maintenance costs, the expected annual damage through floodings, and the of course the benefits through rental revenues.

**Technical maintenance costs**
Literature,- and case studies have not shown that there is a difference in regular maintenance costs between flexible and traditional constructions. For this reason, regular technical maintenance costs are assumed to be 1.5% of the initial investment yearly (Soeters, Koppels, and Binnenkamp, Sept. 2008, page 58). Large maintenance however, shows a big difference between flexible and traditional constructions. In traditional buildings, different construction elements are somewhat melted together, making it difficult to separate the functional life cycle of the building from the technical life cycle of the building. For this reason, large maintenance costs of traditional building are assumed as a percentage of the initial investment on the entire building. Moreover, when the technical,- or functional performance of a building no longer correspond, integrated elements of the building will need large maintenance, often effecting the entire building. For this reason, the technical life-span of traditional buildings is linked to their functional life-span, making a division between residential functions, industrial functions other utility like offices of commercial functions.
As knowledge on large maintenance cycles has proven to be inconclusive on a general perception in maintenance planning, for this research a maintenance cycle based on the principles of Vroman is assumed (Vroman, 1982). Though in reality depreciation and maintenance cycles are more likely to be exponential (Straub, 2001), Vroman simplifies them and interprets them linear. Based on the depreciation of the buildings, linearly linked to their technical life span, large maintenance is implemented in intervals of 10 years. The remaining value of the building according to depreciation is assumed to be directly linked to the acceptation level, and cannot drop below 50%. This assumption also derives from the fact that replacement is often more profitable then repair when a construction has past half its technical life span (Vroman, 1982). Based on this assumption, the maintenance cycles as shown in figure 20 have been used in ADURAM2100 in case of traditional construction.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 10</td>
<td>5%</td>
<td>25%</td>
<td>5%</td>
</tr>
<tr>
<td>Year 20</td>
<td>20%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Year 30</td>
<td>25%</td>
<td>20%</td>
<td>15%</td>
</tr>
<tr>
<td>Year 40</td>
<td></td>
<td>20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Table 2; Large maintenance intervals as percentage of the initial investment on traditional construction
In case of flexible constructed buildings, the life span of the building is not linked to the functional use of the building, as this can easily be altered over time. The large maintenance cycles therefore are directly inked to the technical life span of the different building parts that can be demounted or altered; the interior, the installations, the roof & façade, and the load baring structure. The composition of a building from these different constructions parts will differ per functions, in the model, a distinction is made between the composition of low rise buildings (less then 3 floors, figure 22) and high rise buildings (more then 3 floors, figure 21). The large maintenance cycle results directly from the depreciation of the different construction parts, they are replaced as their life span ends.

<table>
<thead>
<tr>
<th>Flexible</th>
<th>Lifespan</th>
<th>High rise</th>
<th>Low rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load baring structure</td>
<td>100 years (Van den Dobbelsteen, 2004)</td>
<td>15% (Van de Bogaard and Van Eldik, 1995)</td>
<td>19% (PRC, 2009)</td>
</tr>
<tr>
<td>Roof and facade</td>
<td>25 years</td>
<td>34%</td>
<td>40%</td>
</tr>
<tr>
<td>Installation</td>
<td>15 years</td>
<td>9%</td>
<td>18%</td>
</tr>
<tr>
<td>Interior</td>
<td>10 years</td>
<td>42%</td>
<td>23%</td>
</tr>
</tbody>
</table>

Table 3: Lifespan and ratio of construction parts for flexible construction

In ADURAM2100, this results in the following formulas;

Total maintenance costs per interval
\[1.5\% \times \text{initial building costs per m}^2 \times \text{surface area} \times 5 \text{ year} + \text{sum large maintenance past 5 years}\]

Large maintenance
\[\text{initial building costs per m}^2 \times \text{surface area} \times (\text{percentage of the initial investment needed at that interval according to the maintenance cycle})\]

In case of newly build structures, maintenance costs over 5 years are decreased by the initial construction time of the function. The initial maintenance cycles can be found in tab sheet ‘Depreciation’. The implementation of these cycles linked to the actual supply can be found in tab sheets called ‘Progress’.

![Figure 21: Depreciation and maintenance of flexible construction higher then 3 layers per interval](image1)

![Figure 22: Depreciation and maintenance of flexible construction till 3 layers per interval](image2)
Expected annual damage

The expected annual damage (EAD) is calculated according to inundation data provided by the UNESCO-IHE Institute for Water Education. More information on the origin of expected annual damage can be found in appendix 5 and 6. Though the three main characteristics of flooding causing damage to real estate are the amount of debris in the water, the velocity of the water and the flood depth, for this study the flood-damage-curves are limited to the flood depth. And as over time, it is not clear where new developments in the functional program will land within the Merweharbor, the average flood depth of the entire area has been calculated per scenario, these assumptions can be found in appendix 6.

Moreover, the expected annual damage only effects the functions that are ground bound, as the flood levels in all scenario’s are relatively low (0 – 0,8 meters). Once again, over time, it is not clear where new developments in the functional program will land within the Merweharbor. As described in figure 13 in paragraph 6.3.2, the envisioned living environment that will be developed in this area entails a certain division on ground bound functions. This division will be the basis on which the EAD will be calculated. As the quantitative program grows, this won’t have any effect of the EAD, as this mainly entails an increase in building levels. As the quantitative program shrinks below the initial program build however, this means that less ground surface will be build on, and so the EAD decreases accordingly.

Besides shrinkage or growth compared to the initially realized program (as from 2025 on), the expected annual damage is affected by the percentage of the program that is realized flexible and the part of the program that is realized traditional. This is, because a flexible building can be restored faster, it is more resilient, and so, rental income losses are less. For this model it is assumed that the lower flood depth lever will lead to restoration works, and not to mayor reconstructions. In reality, this is of course strongly related to the velocity of the water, and the debris in it. Renovation is set to take no more then 6 months (0,5 year) (Barton, 1969). And as flexible building have a construction time of 40% less (Meulendijk, 2010), this results in a restoration time of 3,6 months (0,3 year). This is integrated in the EAD as potential income that is subtracted from the benefits.

Finally, the expected annual damage per function is calculated with the help of some reference building provided by the UNESCO-IHE Institute for Water Education (Gersonius, Zevenbergen, Puyan and Billah, 2009). As these references only entail residential functions, the damage costs have been indexed in ratio to their building costs. The terraced building (H2) formed the reference for the single-family dwellings. The ground floor flat (H4) formed the reference for all the other functions, with the apartment building in the model as direct translation.

The expected annual damage per function per year can be found tab sheet ‘EAD’. The total expected annual damage according to the initial program can also be found in the tab sheet ‘EAD’. The eventual annual damage according to the scenario’s, development and the ratio of flexible or traditional construction can be found in the tab sheet ‘Optimize’, on the 16th row.

In ADURAM2100, this results in the following formulas;

\[
\text{Expected annual damage per function} = \left( \text{Expected damage for function} + (\text{restoration time} \times \text{income per year}) \right) \times \left( \frac{\text{ratio of building costs compared to reference building}}{\text{frequency of scenario}} \right)
\]

\[
\text{Initial expected annual damage for the entire area} = \sum \left( \text{EAD per function per scenario per interval} \times \text{ground surface area per function} \right)
\]

\[
\text{Expected annual damage per interval for the entire area} = \begin{cases} 
\text{IF} & \left( \frac{\text{total bvo at interval} \geq \text{initial bvo}}{\text{total bvo at interval}} \times \text{percentage not flexible} \right) \times \text{total initial EAD if not flexible} \times \text{percentage flexible} + \text{total initial EAD if flexible} \\
\text{THEN} & \left( \frac{\text{total bvo at interval}}{\text{initial total bvo}} \times \text{percentage not flexible} \right) \times \text{total initial EAD if not flexible} \times \text{percentage flexible} + \text{total initial EAD if flexible} \\
\text{IF NOT THEN} & \left( \frac{\text{total bvo at interval}}{\text{initial total bvo}} \right) \times \text{percentage not flexible} \times \text{total initial EAD if not flexible} \times \text{percentage flexible} + \text{total initial EAD if flexible} 
\end{cases}
\]
Benefits
Benefits are generally just the rental incomes generated from the developed real estate. The negative social and aesthetical assumptions that currently might still affect the rental prices an investor can ask for potential flexible property are not integrated into the model, as examples of projects show that current technical developments counteract this stigma (see figure 9). Senternovem, an agency that is part of the Ministry of Finance and focuses on subject concerning innovation and sustainability, even states that is possible to increase the efficiency of ground surface area versus the rental surface area up to 30% (duurzaambouwen.senternovem.nl, consulted at 10th of July 2010.). An affect that is integrated into ADURAM2100, is the possibility of vacancy, when a surplus of supply is developed. Every square meter realized over the demand according to the scenario’s, does not generate any rental incomes. The rental income is based on the supply in program based on the passed 5 years before the interval.

In ADURAM2100, this results in the following formulas;

Rental income

\[
\text{IF } \left( \left( \text{new build supply in past 5 years} + \text{consolidated supply in past five years} \right) \leq \text{demand according to scenario at interval} \right) \text{ THEN } \\
\left( \left( \text{new build supply in past 5 years} + \text{consolidated supply in past five years} \right) \times \text{income related to function} \right) \\
\text{IF NOT THEN } \left( \frac{\text{demand}}{\text{supply}} \times \left( \text{new build supply in past 5 years} + \text{consolidated supply in past five years} \right) \times \text{income related to function} \right)
\]

In case of newly build structures, rental incomes over 5 years are decreased by the building time of the function. The rental fees can be found in tab sheet ‘Functions’. The rental benefits generated can be found in tab sheet ‘Optimize’ at the rows called ‘benefits’. The rental prices used for the model can be found in appendix 7.

Rejection
As mentioned in paragraph 6.1.1, rejection stand for demolishment, as there the model is built with the perspective of one investor in mind for the entire area. The demolishment costs are influences by 3 factors; the age of the building, the depreciation value of the building, and the demolishment costs. The first two factors directly influence each other.

When rejection is opted for in the optimization on the financial benefits, ADURAM2100 is programmed to demolish not necessary the oldest building first, but the building with the lowest remaining value. The value that remains goes to waist when the building is build traditional, as this is most likely caused by a surplus in supply. When the building is constructed flexible however, the different construction parts can be demounted and re-used. Practice has proven that about 80% (www.ifd.nl, consulted at 4th of July 2010) of all the construction parts can be re-used. Naturally, this also leads to high demolishment costs. Where the demolishment costs of traditionally constructed property differs from 14 to 20 euro’s per square meter of surface area (www.bouwkompas.nl, consulted at 1st of July 2010), the costs of demounting a flexible space can vary from 100 to 200 euro’s per square meter (Post and Klomp, 1999). The demolishment prices used per function can be found in appendix 7. If the use of IFD techniques will become more mainstream, the re-usability of constructions parts will become easier, as there will be a bigger market for it. A downside could be, that in case of national shrinkage of the demanded quantitative program, a surplus of construction part could a reselling these parts could become difficult.

In ADURAM2100, this results in the following formulas;

Demolishment costs for traditional building;
\[
[\text{Surface area of function needed to be demolished}] \times [\text{demolishment costs of function}]
\]

Demolishment costs for flexible building;
\[
[\text{Remaining value of existing supply} \times 80\% \text{ to be resold}] - [\text{Surface area of function needed to be demolished}] \times [\text{demolishment costs of function}]
\]
The demolishment costs per function can be found in the tab sheet ‘Function’. The choice for the building with the lowest remaining value, and the price of demolishing that building can be found in tab sheet ‘Progress’. The eventual demolishment costs and benefits taken into account for optimization can be found in the sheet ‘Optimize’.

**Acquisition**

As mentioned in paragraph 6.1.1, acquisition stand for new built, as there the model is build with the perspective of one investor in mind for the entire area. Initial construction costs consist only of the direct construction costs, and are excluding taxes and additional building costs. An overview of the building costs can be found in appendix 7. Basically traditional building costs vary from 500 Euros’ per square meter of surface area for a closed building block, to 2070 Euros’ for social commercial facilities (Oosterdorp, 2009). And the building costs for the same functions constructed flexible are 10% to 30% less (www.ifd.nl, www.staltechniek.nl, and www.sev-realisatie.nl/ifd-projecten, consulted at 3rd of August 2010.).

In ADURAM2100, this results in the following formulas;

**Construction costs**

\[
\text{Construction costs} = \left[ \text{Surface area of function needed to be added} \right] \times \left[ \text{construction costs of function} \right]
\]

The construction costs per function can be found in tab sheet ‘Functions’. The eventual construction costs taken into account for optimization can be found in the sheet ‘Optimize’.

**6.3.5 Variables of the network layer**

The variables in the occupancy layer basically directly result from the decisions the investor makes. Indirect consequences of these decisions occur in the network layer. In this paragraph these consequences are described.

**Ground prices**

The ground price of a plot of land is determined by the location of the land, and the costs of preparation of the plot. The ground price paid for a plot of land determines what type of function can be constructed on this, as the development needs to feasible. On the other hand, to remain as flexible as possible, a plot of land that is prepared to the highest standards, can facilitate any future function. As associate partner at ECORYS Dick Regenboog told me: ‘The minute you start delimiting your options, is the minute you compensate your flexibility’.

To be able to research the financial consequences of the extensive preparation of land needed to facilitate flexibility, in ADURAM2100, a flexible square meter of land demands the higher ground prices. The model tests the percentage of the program that is realized flexible at each interval. And the highest percentage of flexibility that is found at these intervals, is the percentage of ground that initially needs to be invested in by paying the highest price, so later on, sufficient flexibility can be guaranteed.

Ground prices in ADURAM2100 are linked to the initial functional program realized, and vary from 211 Euros’ per square meter for welfare surfaces, to 468 euro’s per square meter for urban villa’s (Bosch, 2010). An overview of the ground prices can be found in appendix 7.

In ADURAM2100, this results in the following formulas;

**Ground costs**

\[
\text{Ground costs} = \left( \left[ \text{percentage not flexible} \right] \times \left[ \text{total ground surface area} \right] \times \left[ \text{maximum ground price} \right] \right) + \left( \left[ \text{percentage flexible} \times \left[ \text{total ground surface area} \times \left[ \text{normal ground prices for initial program realized} \right] \right] \right)
\]

The ground prices per function can be found in tab sheet ‘Functions’. The eventual price paid for the ground can be found in the sheet ‘Optimize’.
Network costs
Additional to the infrastructure underground, the level of flexibility also influences the infrastructure above ground. Some functions are in need of more intense accessibility than other functions. This influences both the costs for general infrastructure in the area, as well as the ground floor area that is left to built upon. The average ground surface area needed for main roads and infrastructure in a living & working environment is 17.1%. The highest levels of infrastructure that can be needed is 22.7% for office functions (Ritsema van Eck, Van Amsterdam and Van der Schuit, 2009). As an expansion of the office space needed is an option in the future development of the living & working environment, flexible real estate demands an increase in infrastructural ground surface area of 75%. This means an increase in ground surface area to build upon of 6.7%.

Moreover, these infrastructural intensifications also need to be paid. For an suburban main road, a price of 2776 euro/m is assumed (www.bouwkosten-online.nl, consulted at August 15th 2010). The width of the main road is set on 30 meters (Neufert and Jones, 1998), so it can accommodate cars, bicycles, pedestrians and potentially public transport methods. This give the main road a price of 76 euro’s per square meter.

In ADURAM2100, this results in the following formulas:

**Additional network costs:**

\[\text{Additional network costs} = (\text{percentage not flexible} \times [0.171 \times \text{total surface area of zoning plan} \times 76]) + (\text{percentage flexible} \times [0.227 \times \text{total surface area of zoning plan} \times 76])\]

**Remaining ground surface area to build upon:**

\[\text{Remaining ground surface area to build upon} = \text{(percentage not flexible} \times \text{maximum ground surface area in case of 100\% traditional build}) + \text{(percentage flexible} \times \text{maximum ground surface area in case of 100\% flexible build})\]
7. Results
The following chapter will describe the results of the different scenarios as described in paragraph 6.3.3, as they are tested in ADURAM2100. Each of these tests will start with a description of the output without altering variables. The cost and benefit variables that have been initially implemented in each of these scenario’s can be found in appendix 7. To further test the consequences of adaptive urban area development concepts, it is necessary to run the model with altered variables, and analyse the output. The model will be tested on the consequences of;
- The additional network costs
- The sensitivity of the occupancy variables
- The sensitivity of the network costs
- The sensitivity of this scenario
- The influence of the time frame

7.1 Scenario Global Economy
In general, this scenario has a continuously growing quantitative demand. The model continuously builds additional quantitative supply. The only moment of demolishment is at interval 3, the year 2025, as at that interval area 3 (see appendix 2) changes from creative and recreational to a purely residential area with closed building blocks and U-block dwellings, as demanded by the municipality of Rotterdam (as described in paragraph 6.3.2).

The initial building costs of flexible constructions are 10% (single family dwellings) to 30% (industrial buildings) less than those of traditional constructions. This difference will be the same in every scenario, as these are a direct result of the characteristics that were entered for flexible constructions. Most of the flexible functions are constructed for 85% of the building price of traditional constructions. The total building costs for the entire scenario are 15.6% less expensive when constructed flexible. The building costs form 18.9% of all the costs that are made from 2010 till 2100.

The maintenance costs in this scenario are on average 1.3 times as high for the maintenance of flexible building as the maintenance of traditional buildings (figure 25). The maintenance costs form 59.0% of the total costs that are made from 2010 till 2100, of which 57% for flexible functions.

Figure 23 Surface area demanded in 2100, Global Economy scenario

Figure 24; Ratio of large maintenance costs for flexible functions in comparison to traditional functions
Demolishment costs on this scenario are minimal. As the scenario itself does not entail shrinkage, the only moment of demolishment is at interval 3, when area 3 changes its functional occupancy. This results in demolishment costs of traditional constructions that form less than 0.01% of the total costs from 2010 till 2100. The demolishment of flexible constructions result in a profit of nearly €15 million, which forms over 0.14% of the total benefits.

The rental revenues of the total program form the other 99.86% of the total benefits, and are equal for flexible and traditional constructions, as follows from the identical rental characteristics of these functions. The fact that demolishment of flexible constructions is mostly beneficial, and construction time is less, makes that flexible constructions provide for 50.24% of the benefits, while traditional buildings provide for 49.76% of the benefits.

The total return of flexible buildings is between 33.5% less (social commercial functions) and 20.2% more (industrial functions) than those of traditional buildings, when the additional network costs are included. When the network costs are excluded, the difference lies between 17.5% less (social commercial functions) and 3% more (industrial functions). Social commercial facilities, welfare services, and all residential functions become more profitable in comparison to traditional functions when the additional network costs are included, the other functions become less profitable in comparison to traditional functions.

In the network layer, the expected annual damage, infrastructural costs and ground price influence the total return negatively. The total expected annual damage over time costs over €900 million, and forms 17.3% of the total development costs over time. Over half of the expected annual damage results from the traditional supply, 54.3% and 45.7% of the EAD results from the flexible part of the program. This means that the EAD of traditional constructions is 19% higher than for flexible constructions. The additional infrastructural costs above ground, paid to provide a adequate traffic flow, however the flexible real estate transforms over time, results in 32.7% additional infrastructural costs. As the total infrastructural costs form less than 0.5% of the total development costs however, this does not have a large influence on the total return of the development over time, it decreases by 0.15%.

The total price paid for the ground is nearly €228 million, which forms 4.4% of the total costs of the scenario. Over 58% of these costs are a result of the flexible functions, which means that ground prices for flexible constructions on average for this area are 41.7% more expensive than for traditional constructions.

In stead of integrating the expected annual damage. An investor can also opt to raise the ground level. To heighten the ground level 0.8 meter. According to the flood scenarios as described in paragraph 6.3.4, no more flood will occur. The price of heightening 1 square meter of land with 1 meter of sand is €7.58. This results in a total of €43.872.583 for the entire area (1.194.670 m2), which is much lower...
then the total EAD of €900,049,896. When the return of the first interval is decreased by the time it would take to heighten the area, say 3 years (in the best year this is an income of €456,718,544), this result in the total cost of €500,591,127. This is still lower then the total expected annual damage over time of €900,049,896, so heightening the ground level is a more profitable option then paying the expected annual damage.

When we take a look at the ‘Global Economy’ scenario in general, a total return of over €5.18 billion is found, of which 47.8% results from flexible functions. This means that flexible constructions in this scenario are 8.6% less profitable then traditional functions, of which 1.6% results from additional network costs. The lower profitability of an adaptive urban area concept is slightly compensated, as it would be 11.5% when the lower expected flood damage would be excluded. The flexible functions on their own do provide a positive return of €2.48 billion (figure 29). From 2015 onwards, the cash flows are positive (figure 28). From 2025 onwards, the sum of cash flows becomes positive (figure 29).
7.1.1  Sensitivity analysis occupancy layer
For the sensitivity analysis, the total return including the expected annual damage and the additional network costs for ground and infrastructure are used as a reference. The sensitivity of occupancy layer, network layer and the ‘Global economy’ scenario will be analysed by altering the variables in these parts of ADURAM2100.

Lowering the construction costs of flexible functions
When the construction costs of flexible functions are lowered an extra 8% on top of the decrease as can be found in appendix 7, the total return on flexible function becomes higher than the return on traditional functions. The building costs for flexible buildings are now between the 62,5% and 82,5% less expensive than the building costs of traditional constructions (figure 30). The building costs now form 8,2% of all costs, where this was 8,6% (figure 25).

Lowering the maintenance costs of flexible functions
As can be seen in figure 33, maintenance costs of flexible buildings form 33,4% of the costs of the entire development. This is much higher than the maintenance costs of traditional buildings, which form only 25,6% of all costs over time. When the maintenance costs of flexible buildings are lowered by 14%, this results in an 9,6% increase of the total return on flexible functions over time, making flexible functions more profitable than traditional functions. In reality, maintenance costs of flexible buildings generally mean the replacement of parts. As this is easier in building that are demountable, the maintenance costs could well be lower than for traditional buildings.

Increasing the return on demolishment of flexible functions
The return on demolishment results from the fact that a large part of the constructions can be recycled after demountation. The initial assumption is that 80% of all construction parts can be re-used. The re-selling value also needs to be decreased by the remaining value of the construction part after depreciation. When the ratio of construction parts that can be resold after demountation would be increased to 100%, the total return on flexible buildings over time only increases with 0,2%, which is not enough to make flexible constructions more profitable. This can merely be explained by the fact that in this scenario, the need for demolition is near to none.

Increasing the rental benefits of flexible functions
The rental income resulting from flexible functions can be raised by 30% to reflect the increased space use efficiency (duurzaambouwen.senternovem.nl, consulted at 10th of July 2010). This increase in efficiency will not directly translate to a 30% increase of all the rental incomes, but to a 30% increase in the GFA/LFA ratio of utility functions (figure 31). When this change is implemented, the model shows that the total return of flexible functions becomes €2,75 billion, and are now more profitable than traditional functions.
7.1.2 Sensitivity analysis network layer
The following tests will show the sensitivity of the additional network costs like the expected annual damage, the infrastructural costs and the ground costs.

Lowering the expected annual damage for flexible functions
The expected annual damage that is integrated in ADURAM2100 already considers the fact that flexible functions can be restored about 40% faster, and the building costs are lower. To further lower the expected annual damage one could envision that a flexible building offers the opportunity to restore only those parts that are affected. So as a flood of for example 0.4 m depth occurs, the façade can partially be disassembled and replaced. A decrease in EAD of 10% is assumed. This lowers the EAD for flexible buildings to 7.2% of all costs over time, where this was 7.9% and is 9.5% for traditional building. To contribution of flexible function to the total return over time increases with 1.6% to €2.52 billion.

Lowering the infrastructural costs for flexible functions
Flexible functions are assumed to need 22.7% infrastructure on the ground layer, to be able to facilitate any future function, like for example office space. If this percentage is lowered to 20%, this would increase the total return over time of flexible function with 0.1%. The costs for infrastructure of flexible functions now are 17% higher then those for traditional functions, where this was 37.2%. Lowering the costs of infrastructure is not very likely though, as is the basis on which flexibility can be provided. As soon as quantity and quality of infrastructural facilities in an area lowered, the level of flexibility that can be provided decreases too.

Lowering the ground costs for flexible functions
When the ground price that needs to be paid is lowered from the price for urban villa’s (€468/m2/bvo) to the price for for example offices (€411/m2/bvo), the total ground costs shrink from nearly €228 million to €211 million. The part of these costs destined to be build upon by flexible function has decreased from 58.6% to 55.4%. But even if the ground destined for flexible occupation would be given again for free, this will not make flexible occupancy more profitable then traditional occupancy.

7.1.3 Sensitivity analysis scenario
Besides the variables of the occupancy layer and the network layer, the end result of ADURAM2100 is also influenced by the scenarios. In this paragraph the financial consequences of these scenarios will be tested.

The occurrence of a severe flood
The expected annual damage integrated in the model shows a linear increase in EAD over the years. In reality though, the expected annual damage is not a continuously growing financial risks, but occurs incidentally, producing clusters of damage costs. To test how this influences the total return of the scenario, a flood is simulated. For example, in 2040 a flood occurs, so severe, that all of the buildings on ground level need to be replaced (figure 39). As the addition damage costs for flexible buildings are 16% lower then those for traditional buildings, the profitability of flexible functions increases from 47.75% to 47.82%. The expected annual damage now forms 18.9% of all costs over time, where this was 17.3%, the part of these costs caused by flexible functions decreases 0.1% from 45.7% to 45.6%

Increasing the fluctuation of demand
To test the influence of the demand simulated by the scenario ‘Global economy’, more fluctuation in demand will be simulated. If every 3rd year the demand is
increased by 5%, and every 6th year the demand is decreased by 6%, this results in a decrease in total return of 0.9%. The profitability of traditional and flexible functions shifts with an extra 0.2% profitability towards flexible functions. In the fluctuations are increased to 10% and compensated every 4th and 7th year, the profitability shifts another 0.2% towards flexibility, but overall, the effect on the profitability is small.

**Shortening the scenarios’ time frame**

Figure 35 has already shown that previous to 2100 there are no intervals in which the sum of cash flows of flexible functions is more profitable than traditional developments. Figure 40 shows more clearly that this is also the case in the first 40 years of development. Though the profitability of flexible and traditional functions diverges from the first interval onwards, alterations in variables that positivity influence the profitability of flexible functions aren’t more likely to make the flexible function more profitable in the first few years, then in later on.

### 7.1.3 Summary Global Economy

As a logical result from the standard input for each scenario, results show that the building costs of flexible functions in total is lower than those of traditional functions. This scenario has a continuously growing quantitative demand. The model continuously builds additional quantitative supply. Demolishment costs and potential benefits therefore are minimal. Maintenance costs are a the most dominant costs factor. Rental revenues of a flexible building concept are slightly higher than those of a traditional building concept.

When the network costs are included, the flexible functions become more profitable in comparison to traditional function, then before the network costs are included. The flexible functions in general are still less profitable though. The expected annual flood damage costs for traditional buildings is higher for flexible buildings. But it is less expensive to heighten ground levels then to pay the expected annual flood damage.

By lowering of the construction, lowering of the maintenance costs, or increasing the GFA/LFA efficiency offer opportunities to make an adaptable urban area concept more profitable than a traditional one. An increase of the remaining value of demounted constructions parts does not offer this opportunity.

A lower expected annual damage, a smaller infrastructural network or lower ground costs do not effect the total return enough to make flexible building concept more profitable than traditional ones.

If the Global Economy scenario is shortened, no difference in financial returns results. A additional fluctuation of the demand according to this scenario does make flexible building concept more profitable, however, the difference in minimal. The same result is seen when a severe flood is simulated.
7.2 Scenario Strong Europe

The ‘Strong Europe’ scenario shows moderate growth that is continues from 2010 till 2100. Only work related function, the offices and industrial functions, undergo a light form of shrinkage from 2040 onwards.

The initial building costs are initiated the same as shows in appendix 7. The total construction costs of all functions sum up to over €835 million, and form 17% of all costs made over time. The fact that this is less then in for example the ‘Global Economy’ scenario, where the construction costs formed 18,8% of all costs made over time can be explained by the fact that this scenario has a lower initiative demand, and so less additional supply is constructed. The construction of flexible functions on average is still 15,5% less expensive then the construction of traditional functions.

The maintenance costs in this scenario sum up to €2.925 million for traditional and flexible functions together. These costs are on average 29% higher for the maintenance of flexible buildings as the maintenance of traditional buildings. The maintenance costs form 59,6% of the total costs that are made from 2010 till 2100, of which 56% can be traced back to the maintenance of flexible buildings (figure 36).

Demolishment costs for traditional functions in this scenario form 0,01% of all costs made over time, while demolition of flexible functions results in a profit of over €248.113, 0,01% of all benefits over time. Demolishment of flexible functions is continuously beneficial, with an exception in 2045 for the demolition of some U-block dwellings.

Rental incomes from flexible functions are 0,7% higher, as the construction time of these functions is shorter. Together with the benefits of recyclable buildings, flexible functions are responsible for 50,8% of all benefits, summing up to €4.851 million, while the benefits from traditional buildings sum up to €4.812 million (figure 37).

The total return of flexible buildings is between 33,1% less (social commercial functions) and 19,1% more (industrial functions) then those of traditional buildings (figure 43), when the additional network costs are included. When the network costs are excluded, the difference lies between 17,1% less (social commercial functions) and 1,9% more (industrial functions). Only retail functions, industrial buildings and traditional offices perform better with flexible functions, where the net benefits are between 28,5% and 0,8% higher.
offices become less profitable in comparison to traditional functions when the additional network costs are included, the other functions become more profitable in comparison to traditional functions.

The network layer consisting of the expected annual damage, infrastructural costs and ground price influence the total return negatively. Only the first one influences the profitability of flexible functions positively compared to traditional functions. The lowered expected annual damage, and higher infrastructural and ground costs of flexible functions decreases the total return over time by 1.6%.

The total expected annual damage over time costs over €900 million, and forms 18.3% of the total development costs over time. Less then half of the expected annual damage results from the flexible supply, 45.7% and 54.3% results from the of the traditional supply in the program. This means that the EAD of flexible constructions is 15.9% lower then for traditional constructions.

As explained before, instead of integrating the expected annual damage, an investor can also opt to raise the ground level. As the maximum income possible in this scenario is €663,659,149, and the ground costs remain €43,872,583, this would result in a maximum investment of €442,068,072, which is still less then the €900 million the expected annual damage would costs. So also in this scenario, it is most beneficial to raise the ground rather then await the damage that will result from floodings.

The additional demand for main roads above ground, to be able to provide any type of transformation for the flexible program in the are, means that a part of the area needs not 17.1% of its ground surface to be main infrastructure, but 22.7%. Where infrastructural costs for traditional functions form 0.19% of all costs over time, the provided infrastructure for flexible functions entail 0.26% of all costs over time, an increase of 32.7%. The total return of the entire development only decreases with less then 0.001% due to the extra infrastructural demand for flexible functions.

In acquisitioning the ground in this scenario, the investor will spend exactly the same as in the other scenarios as the percentage of flexibility, nor the initially planned development hasn't changed. The total ground price remains €228 million. In this scenario though, these costs form 4.6% of all costs over time, of which once again over 58.6% is a result of the flexible functions.

The ‘Strong Europe’ scenario in general raises a total return of €4,753 million from 2010 till 2100. A near 47.6% of these returns result from flexible functions, and over 52.4% of these functions results from traditional functions. Flexible functions
are 9.2% less profitable than traditional functions, of which 1.7% results from additional network costs, but flexible functions remain profitable on their own, providing a return of €2.262 million. The lower profitability of an adaptive urban area concept is slightly compensated, as it would be 12.3% when the lower expected flood damage would be excluded. An overview of the cash flows over the years, and the sum over the cash flows per interval can be found in figure 45 and 44.

7.2.1 Sensitivity analysis occupancy layer
For the sensitivity analysis, the total return including the expected annual damage and the additional network costs for ground and infrastructure is used as a reference.

Lowering the construction costs of flexible functions
When the constructions costs of flexible buildings are lowered an additional 8% to the 10% to 30% they initially where lower, flexible constructions become more profitable than traditional functions. The decrease in constructions costs can be seen in figure 38. On average, the constructions costs are now 23.7% lower than these of traditional construction, and form 7.4% of all costs over time.

Lowering the maintenance costs of flexible functions
Lowering the maintenance costs of flexible buildings by 14% is sufficient to make flexible functions more profitable than traditional functions. The maintenance costs of flexible functions now form 30.3% of all costs made over time, but still are 11% more expensive than the maintenance costs of traditional constructions. The total maintenance costs now are only 92.1% of what they used to be.

Increasing the return on demolishment of flexible functions
If in this scenario, all demounted parts of a flexible building would be recyclable, flexible function remain about as profitable as they where before, as nearly no demolishment is needed in this scenario. They could raise the return on flexible
building to from 47,59% to 47,61%. The benefits due to reselling demountable parts increases with 28,8%, but has little effect on the end result. In comparison to the total benefits, the €9 million this contributes, still accounts for only 0,09%.

**Increasing the rental benefits of flexible functions**
When the rental benefits are raised with 30% for utility functions, as described in paragraph 7.1.1 and figure 31, this increases the rental income with 5,2%, making flexible functions more profitable than traditional functions. The total return on flexible function in comparison to the total return on traditional functions has increased with 11,1%, and flexible functions are now responsible for 50,2% of the total return. This transition from traditional buildings being more profitable to flexible buildings being more profitable takes places when the efficiency of flexible utility functions is increased by 28% or more.

7.2.2 **Sensitivity analysis network layer**
The following tests will show the sensitivity of the additional network costs like the expected annual damage, the infrastructural costs and the ground costs.

**Lowering the expected annual damage for flexible functions**
A decrease of 10% is assumed for the flexible part of the program. This lowers the EAD for flexible buildings to 7,6% of all costs over time, where this was 8,4% and is 10% for traditional building. The total damage costs for flexible buildings are reduced from €411 million to €368 million. The contribution of flexible functions to the total return over time increases with 0,5% from €2,26 to €2,30 billion.

**Lowering the infrastructural costs for flexible functions**
The total costs of infrastructure only account for less then 0,45% of the total development and management costs made over time. So if the percentage of ground level space needed for flexible functions was lowered from 22,7% to 20%, the increase of the total return over time of flexible function is very limited, a minimum 0,03%. The total costs of infrastructure for flexible functions drop from €12,5 million to €11 million. The costs for infrastructure of flexible functions now are 17% higher than those for traditional functions, where this was 37,2%.

**Lowering the ground costs for flexible functions**
The ground price that is accounted for flexible functions is the highest of all traditional functions, €468/m2/bvo just like for a traditional urban villa. When the ground price that needs to be paid would be lowered from the price for urban villa’s to the price for for example offices (€411/m2/bvo), the total ground costs shrink from nearly €228 million to €212 million, just like in the other scenarios. This decreases the total costs of the development over time by 0,3%, of which the ground costs for flexible buildings forms 2,4%, where before, this was 2,7%.

7.2.3 **Sensitivity analysis scenario**
In this paragraph the financial consequences of the scenario variables will be tested. These scenarios entail the quantitative demand of the ‘Strong Europe’ scenario, the time frame of the scenario and the flood scenarios integrated in ADURAM2100.

**Increasing the fluctuation of demand**
To test the influence of the demand simulated by the scenario ‘Regional Communities’, more fluctuation in demand will be simulated in the same way as described in paragraph 7.1.3. A fluctuation of 5% results in a decrease in total return of 0,8%. The profitability of traditional and flexible functions shifts with an extra 0,32% profitability towards flexible functions. In the fluctuations are increased to 10% and compensated every 4th and 7th year (figure 40), the profitability shifts another
0.2% towards flexibility, but overall, the effect on the profitability is small, and traditional functions remain more profitable.

The occurrence of a severe flood
When the same flood is simulated as described in paragraph 7.1.3 and figure 39, the profitability of flexible functions increases from 47.59% to 47.64%. Where the expected annual damage resulted in a total cost of about €900 million before, this is now €1.068 million, an increase of 18.7%. The expected annual damage now forms 21.75% of all costs over time, of which 45.7% is caused by flexible functions. The total return of the development over time shrinks with 3.5% to €4.585 million.

Shortening the scenarios’ time frame
To see whether flexible functions become more profitable when the time frame studied is shortened, the cash flow of the scenario needs to be studied. A close look at the first 8 intervals shows that even though the initial building costs of flexible functions are much lower than these of traditional functions, this is directly compensated by the fact that the maintenance of flexible functions is more expensive. There are no time frames in which flexible functions are more profitable than traditional functions (figure 41).

7.2.4 Summary Strong Europe
Resulting from this scenario, an adaptable urban area concept appears to be less profitable than a traditional urban area concept. This scenario shows moderate growing quantitative demand, with a stabilization and little shrinkage of business related functions after 2040. Demolishment costs and potential benefits are even smaller than in the Global Economy scenario. Maintenance costs are the most dominant costs factor. Rental revenues of a flexible building concept are slightly higher than those of a traditional building concept.

When the network costs are included, the flexible functions become more profitable in comparison to traditional function, then before the network costs are included. The flexible functions in general are still less profitable though. The expected annual flood damage costs for traditional buildings is higher for flexible buildings. But it is less expensive to heighten ground levels than to pay the expected annual flood damage.

By lowering of the construction, lowering of the maintenance costs, or increasing the GFA/LFA efficiency offer opportunities to make an adaptable urban area concept more profitable than a traditional one. An increase of the remaining value of demounted constructions parts does not offer this opportunity.

A lower expected annual damage, a smaller infrastructural network or lower ground costs do not effect the total return enough to make flexible building concept more profitable than traditional ones.

If the Strong Europe scenario is shortened, no difference in financial returns results. A additional fluctuation of the demand according to this scenario does make flexible building concept more profitable, however, the difference in minimal. The same result is seen when a severe flood is simulated.
7.3 Scenario Transatlantic Market

The ‘Transatlantic Market’ scenario shows both growth and shrinkage. The demand for residential functions generally stabilizes after 2040, with small fluctuations. The demand for work related functions completely stabilizes after 2020, but increases again after 2040. The demand for recreational functions increases till 2040 and merely shrinks afterwards.

The initial building costs of the total supply over time sum up to nearly €805 million, and form 16,7% of all costs over time. Over 45,7% of these costs result from the construction of flexible functions, a mere €368 million, which means that the construction of traditional functions is 18,8% more expensive.

The maintenance costs of the total development over time sum up to a total of €2.864 million, which form over 59,4% of all costs over time. A near 57,3% of these maintenance costs are a result of the maintenance of flexible buildings, which means that on average, the maintenance of flexible buildings is about 28,7% more expensive then that of traditional buildings.

The demolition costs in this scenario form 0,007% of all costs resulting from the demolition of traditional buildings. The benefits resulting from the demolition of flexible functions are over €10,2 million, and form 0,11% of all benefits over time.

The rental revenues of the total program form the other 99,89% of the total benefits, and are equal for flexible and traditional constructions, as follows from the identical rental characteristics of these functions. The fact that demolition of flexible constructions is mostly beneficial, and construction time is less, make that flexible constructions provide for 50,11% of the benefits, while traditional buildings provide for 49,79% of the benefits.

The total return of flexible buildings is between 29,36% less (social commercial functions) and 20,05% more (industrial functions) then those of traditional buildings (figure 45), when the additional network costs are included. When the network costs are excluded, the difference lies between 15,5% less (social commercial functions) and 2,62% more (industrial functions). Only retail functions, industrial buildings and offices become less profitable in comparison to traditional functions when the additional network costs are included, the other functions become more profitable in comparison to traditional functions.

The total expected annual damage over time.

In the network layer, the expected annual damage, infrastructural costs and ground price influence the total return negatively. The total expected annual damage over

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**Figure 42; Surface area demanded in 2100, Transatlantic Market scenario**

**Figure 43; Difference in total return for flexible functions, in comparison to traditional functions**
time costs over €900 million, and forms 18,7% of the total development costs over time. Over half of the expected annual damage results from the traditional supply, 54,3% and 45,7% of the EAD results from the flexible part of the program. This means that the EAD of traditional constructions is 19% higher then for flexible constructions.

The additional infrastructural costs above ground, paid to provide an adequate traffic flow, however the flexible real estate transforms over time, results in 32,7% additional infrastructural costs. As the total infrastructural costs form less then 0,5% of the total development costs however, this does not have a large influence on the total return of the development over time, it decreases by 0,15%.

The total price paid for the ground is nearly €228 million, which forms 4,7% of the total costs of the scenario. Over 58% of these costs are a result of the flexible functions, which means that ground prices for flexible constructions on average for this area are 41,7% more expensive then for traditional constructions.

When the expected annual damage is compared to the price of raise the ground level as described in paragraph 7.1, this results in the maximum possible costs of €437.046.186 of which €43.872.583 are the ground costs, and €393.173.603 is the maximum potential loss of income. So the costs of raising the ground level of the entire area by 0,8 meter, is still is much lower then the total EAD of €900.049.896. Heightening the ground level is a more profitable option then paying the expected annual damage.

When we take a look at the ‘Transatlantic Market’ scenario in general, a total return of over €4,81 billion is found, of which 47,8% results from flexible functions. This means that flexible constructions in this scenario are 8,6% less profitable then traditional functions, of which 1,7% results from additional network costs. The lower profitability of an adaptive urban area concept is slightly compensated, as it would be 11,7% when the lower expected flood damage would be excluded. The flexible functions on their own do provide a positive return of €2,30 billion. From 2015 onwards, the cash flows are positive (figure 46). And from 2025 onwards, the sum of cash flows becomes positive (figure 47).
7.3.1 Sensitivity analysis occupancy layer

For the sensitivity analysis, the total return including the expected annual damage and the additional network costs for ground and infrastructure are used as a reference. The sensitivity of occupancy layer, network layer and the ‘Transatlantic’ scenario variables will be analysis by altering the variables in these parts of ADURAM2100.

Lowering the construction costs of flexible functions

When the construction costs of flexible functions are lowered an extra 8,5% on top of the decrease as can be found in appendix 7, the total return on flexible function becomes higher then the return on traditional functions. The building costs for flexible buildings are now between the 61,5% and 81,5% less expensive then the building costs of traditional constructions. The building costs now form 7,3% of all costs, where this was 7,6%.

Lowering the maintenance costs of flexible functions

As can be seen in figure 50, maintenance costs of flexible buildings form 33,4% of the costs of the entire development. This is much higher then the maintenance costs of traditional buildings, which form only 26,0% of all costs over time. When the maintenance costs of flexible buildings are lowered by 13,5%, this results in an 9,5% increase of the total return on flexible functions over time, making flexible functions more profitable then traditional functions. The maintenance costs of flexible building now account for 30,3% of all costs over time, and sum up to more then €1.394 million.

Increasing the return on demolishment of flexible functions

When the ratio of construction parts that can be resold after demountation would be increased from 80% to 100%, the total return on flexible buildings over time only increases with 0,04%, which is not enough to make flexible constructions more profitable. This can merely be explained by the fact that the initial contribute of recyclable flexible parts to the total benefits of flexible parts was just 0,11%.

Figure 46; Cashflow per interval of scenario Transatlantic Market in Euros

Figure 47; Sum of cashflows per interval of scenario Transatlantic Market in Euros
Increasing the rental benefits of flexible functions
When the rental benefits are raised with 30% for utility functions, as described in paragraph 7.1.1 and figure 31, this increases the rental income with 5.3%, making flexible functions more profitable than traditional functions. The total return on flexible function in comparison to the total return on traditional functions has increased with 11.5%, and flexible functions are now responsible for 50.4% of the total return. This transition from traditional buildings being more profitable to flexible buildings being more profitable takes place when the efficiency of flexible utility functions is increased by 25.5% or more.

7.3.2 Sensitivity analysis network layer
The following tests will show the sensitivity of the additional network costs like the expected annual damage, the infrastructural costs and the ground costs.

Lowering the expected annual damage for flexible functions
The expected annual damage costs for flexible buildings are €411 million, and for traditional buildings €489 million. A decrease in expected annual damage of 10% is assumed for flexible functions. This lowers the expected annual damage for flexible buildings to 7.7% of all costs over time, where this was 8.5% and is 10.2% for traditional building. The contribution of flexible function to the total return over time increases with 1.9% to €2.4 billion.

Lowering the infrastructural costs for flexible functions
Flexible functions are assumed to need 22.7% infrastructure on the ground layer, to be able to facilitate any future function, like for example office space. If this percentage is lowered to 20%, this would increase the total return over time of flexible function with 0.1%. The costs for infrastructure of flexible functions now are 17% higher then those for traditional functions, where this was 37.2%.

Lowering the ground costs for flexible functions
When the ground price that needs to be paid be lowered from the price for urban villa’s (€468/m²/bvo) to the price for for example offices (€411/m²/bvo), the total ground costs shrink from nearly €228 million to €211 million. The part of these costs destined to be build upon by flexible function has decreased from 58.6% to 55.4%. But even if the ground destined for flexible occupation would be given away for free, this will not make flexible occupancy more profitable than traditional occupancy.

7.3.3 Sensitivity analysis scenario
Besides the variables of the occupancy layer and the network layer, the end result of ADURAM2100 is also influenced by the scenarios. In this paragraph the financial consequences of these scenarios will be tested.

Increasing the fluctuation of demand
To test the influence of the demand simulated by the scenario ‘Global economy’, more fluctuation in demand will be simulated. If every 3rd year the demand is increased by 5%, and every 6th year the demand is decreased by 6%, this results in a decrease in total return of 0.9% (figure 48). The profitability of traditional and flexible functions shifts with an extra 0.09% profitability towards flexible functions. In the fluctuations are increased to 10% and compensated every 4th and 7th year, the profitability shifts another 0.2% towards flexibility, but overall, the effect on the profitability is small.

Figure 48; Scenario Transatlantic Market with 5% fluctuation
The occurrence of a severe flood
The expected annual damage integrated in the model shows a linear increase in EAD over the years. In reality though, the expected annual damage is not a continuously growing financial risks, but occurs incidentally, producing clusters of damage costs. To test how this influences the total return of the scenario, a flood is simulated. For example, in 2040 a flood occurs, so severe, that all of the buildings on ground level need to be replaced (figure 49). As the addition damage costs for flexible buildings are 16% lower then these for traditional buildings, the profitability of flexible functions increases from 47.79% to 47.86%. The expected annual damage now forms 21.4% of all costs over time, where this was 18.7%, the part of these costs caused by flexible functions decreases 0.1% from 45.7% to 45.6%.

Shortening the scenarios’ time frame
Figure 52 has already shown that previous to 2100 there are no intervals in which the sum of cash flows of flexible functions is more profitable then traditional developments. Figure 52 shows more clearly that this is also the case in the first 40 years of development.

7.3.4 Summary Transatlantic Market
The Transatlantic Market scenario shows that an adaptable urban area concept appears to be less profitable then a traditional urban area concept. This scenario shows moderate growth in quantitative demand of residential functions, with a stabilization of business related functions and shrinkage of recreational functions. Though this scenario has the highest percentage of shrinkage so far, the benefits resulting from demolition are not the highest. Maintenance costs remain the most dominant costs factor. Rental revenues of a flexible building concept are slightly higher than those of a traditional building concept.

When the network costs are included, the flexible functions become more profitable in comparison to traditional function, then before the network costs are included. The flexible functions in general are still less profitable though. The expected annual flood damage costs for traditional buildings is higher for flexible buildings. But it is less expensive to heighten ground levels then to pay the expected annual flood damage.

By lowering of the construction, lowering of the maintenance costs, or increasing the GFA/LFA efficiency offer opportunities to make an adaptable urban area concept more profitable then a traditional one. An increase of the remaining value of demounted constructions parts does not offer this opportunity.

A lower expected annual damage, a smaller infrastructural network or lower ground costs do not effect the total return enough to make flexible building concept more profitable than traditional ones.

If the Transatlantic Market scenario is shortened, no difference in financial returns results. A additional fluctuation of the demand according to this scenario does make flexible building concept more profitable, however, the difference in minimal. The same result is seen when a severe flood is simulated.
7.4 Scenario Regional Communities

The 'Regional Communities' scenario shows a decrease in demand for residential functions. This can mainly be explained by the decrease in population in this scenario. Functions related to work show a decrease till 2040, but more or less stabilizes afterwards. Recreational functions show an increase in demand especially in the first few intervals.

The initial building costs are initiated the same as shows in appendix 7. The total construction costs of all functions sum up to over €807 million, and form 16,8% of all costs made over time. The fact that this is less then in for example the 'Global Economy' scenario, where the construction costs formed 18,8% of all costs made over time can be explained by the fact that this scenario has many intervals in which the program shrinks, and instead of additional supply being needed, demolishment is executed. The construction of flexible functions on average is still 15,6% less expensive then the construction of traditional functions.

The maintenance costs in this scenario are on average 29% as high for the maintenance of flexible buildings as the maintenance of traditional buildings. The maintenance costs form 59,3% of the total costs that are made from 2010 till 2100, of which 56% can be traced back to the maintenance of flexible buildings (figure 52).

Demolishment costs for traditional functions in this scenario form 0,8% of all costs made over time, while demolishment of flexible functions results in a profit of over €8 million, 0,1% of all benefits over time. What stands out is that the demolishment of closed building blocks and U-block tends not to be beneficial most of the time. As the demolishment costs are often higher then the remaining value of the building after depreciations and recycling.

Rental incomes from flexible functions are 0,6% higher, as the construction time of these functions is shorter. Together with the benefits of recyclable buildings, flexible functions are responsible for 50,2% of all benefits (figure 53).

The total return of flexible buildings is between 33,6% less (social commercial functions) and 19,6% more (industrial functions) then those of traditional buildings (figure 51), when the additional network costs are included. When the network costs are excluded, the difference lies between 17,3% less (social commercial functions) and 1,5% more (industrial functions). Only retail functions, industrial buildings and offices become less profitable in comparison to traditional functions when the additional network costs are included, the other functions become more profitable in comparison to traditional functions.

![Figure 50; Surface area demanded in 2100, Regional Communities scenario](image)

![Figure 51; Difference in total return for flexible functions, in comparison to traditional functions](image)
The network layer consisting of the expected annual damage, infrastructural costs and ground price influence the total return negatively. Only the first one influences the profitability of flexible functions positively compared to traditional functions. The total expected annual damage over time costs near to €900 million, and forms 18.7% of the total development costs over time. Less then half of the expected annual damage results from the flexible supply, 45.7% and 54.3% results from the of the traditional supply in the program. This means that the EAD of flexible constructions is 15.9% lower then for traditional constructions.

The additional demand for main roads above ground, to be able to provide any type of transformation for the flexible program in the are, means that a part of the area needs not 17.1% of its ground surface to be main infrastructure, but 22.7%. Where infrastructural costs for traditional functions form 0.2% of all costs over time, the provided infrastructure for flexible functions entail 0.3% of all costs over time, an increase of 32.7%. The total return of the entire development only decreases with less then 0.001% due to the extra demand for flexible functions.

In acquisitioning the ground in this scenario, the investor will spend exactly the same as in the other scenarios as the percentage of flexibility, nor the initially planned development hasn’t changed. The total ground price remains €228 million. In this scenario though, these costs form 4.7% of all costs over time, of which once again over 58% is a result of the flexible functions.

As explained before, instead of integrating the expected annual damage, an investor can also opt to raise the ground level. As the maximum income possible in this scenario is €621.774.212, and the ground costs remain €43.872.583, this would result in a maximum investment of €416.937.110, which is still less then the €900 million the expected annual damage would costs. So also in this scenario, it is most beneficial to raise the ground rather then await the damage that will result from floodings.

The ‘Regional Community’ scenario in general raises a total return of €4.495 million from 2010 till 2100. A near 47.6% of these returns result from flexible functions, and over 52.4% of these returns results from traditional functions. Flexible functions are 9.3% less profitable then traditional functions, of which 1.8% results from additional network costs, but flexible functions remain profitable on their own, providing a return of €2.138 million. The lower profitability of an adaptive urban area concept is slightly compensated, as it would be 12.6% when the lower expected flood damage would be excluded An overview of the cash flows over the years, and the sum over the cash flows per interval can be found in figure 61 and 62.

7.4.1 Sensitivity analysis occupancy layer
For the sensitivity analysis, the total return including the expected annual damage and the additional network costs for ground and infrastructure is used as a reference.
Lowering the construction costs of flexible functions
When the constructions costs of flexible buildings are lowered an additional 8% to the 10% to 30% they initially where lower, flexible constructions become more profitable then traditional functions. The decrease in constructions costs can be seen in figure 37. On average, the constructions costs are now 23,6% lower then these of traditional construction, ad form 7,3% of all costs over time.

Lowering the maintenance costs of flexible functions
Lowering the maintenance costs of flexible buildings by 14% is sufficient to make flexible functions more profitable then traditional functions. The maintenance costs of flexible functions now form 30,1% of all costs made over time, but still are 11% more expensive then the maintenance costs of traditional constructions. The total maintenance costs now are only 92,1% of what they used to be.

Increasing the return on demolishment of flexible functions
If in this scenario, all demounted parts of a flexible building would be recyclable, flexible function would nearly be as profitable as traditional functions. They could raise the return on flexible building to 49,4%. The benefits due to reselling de-mountable parts increases with 29%, as quite some demolishment is needed in this scenario. In comparison to the total benefits, the generous €10 million this contributes, still accounts for only 0,1%.

Increasing the rental benefits of flexible functions
When the rental benefits are raised with 30% for utility functions, as described in paragraph 7.1.1 and figure 31, this increases the rental income with 5,3%, making flexible functions more profitable then traditional functions. The total return on flexible function in comparison to the total return on traditional functions has increased with 11,5%, and flexible functions are now responsible for 50,3% of the

Figure 54; Cashflow per interval of scenario Regional Communities in Euros

Figure 55; Sum of cashflows per interval of scenario Regional Communities in Euros
total return. This transition from traditional buildings being more profitable to flexible buildings being more profitable takes places when the efficiency of flexible utility functions is increased by 27% or more.

7.4.2 Sensitivity analysis network layer
The following tests will show the sensitivity of the additional network costs like the expected annual damage, the infrastructural costs and the ground costs.

Lowering the expected annual damage for flexible functions
A decrease of 10% is assumed for the flexible part of the program. This lowers the EAD for flexible buildings to 7.7% of all costs over time, where this was 8.6% and is 10.2% for traditional building. The total damage costs for flexible buildings are reduced from €411 million to €368 million. The contribution of flexible functions to the total return over time increases with 2% to €2.18 billion.

Lowering the infrastructural costs for flexible functions
The total costs of infrastructure only account for less then 0.5% of the total development and management costs made over time. So if the percentage of ground level space needed for flexible functions was lowered from 22.7% to 20%, the increase of the total return over time of flexible function is very limited, a minimum of 0.03%. The total costs of infrastructure for flexible functions drop from €12.5 million to €11 million. The costs for infrastructure of flexible functions now are 17% higher then those for traditional functions, where this was 37.2%.

Lowering the ground costs for flexible functions
The ground price that is accounted for flexible functions is the highest of all traditional functions, €468/m2/bvo just like for a traditional urban villa. When the ground price that needs to be paid would be lowered from the price for urban villa’s to the price for for example offices (€411/m2/bvo), the total ground costs shrink from nearly €228 million to €211 million, just like in the other scenarios. This decreases the total costs of the development over time by 0.3%, of which the ground costs for flexible buildings forms 2.5%, where before, this was 2.8%.

7.4.3 Sensitivity analysis scenario
In this paragraph the financial consequences of the scenario variables will be tested.

Increasing the fluctuation of demand
To test the influence of the demand simulated by the scenario ‘Regional Communities’, more fluctuation in demand will be simulated in the same way as described in paragraph 7.1.3. A fluctuation of 5% results in a decrease in total return of 1.3%. The profitability of traditional and flexible functions shifts with an extra 0.05% profitability towards flexible functions. In the fluctuations are increased to 10% and compensated every 4th and 7th year (figure 63), the profitability shifts another 0.2% towards flexibility, but overall, the effect on the profitability is small, and traditional functions remain more profitable.

The occurrence of a severe flood
The same flood is simulated as described in paragraph 7.1.3 and figure 40. The profitability of flexible functions increases from 47.56% to 47.64%. The expected annual damage now forms 21.5% of all costs over time, of which 45.7% is caused by flexible functions.

Shortening the scenarios’ time frame
If the time frame of ADURAM2100 is shortened to for example 40 years, the sum of all cash flows shows that there are no intervals in which flexible constructions are more profitable then traditional constructions.
7.4.4 Summary Regional Communities

According to the calculations of ADURAM2100, the Regional Communities scenario an adaptable urban area concept appears to be less profitable than a traditional urban area concept. The Transatlantic Market scenario shows that an adaptable urban area concept appears to be less profitable than a traditional urban area concept. This scenario shows moderate growth in quantitative demand of recreational functions, with a stabilization of business related functions and shrinkage of residential functions.

Though this scenario shows shrinkage of residential demand due to a decrease in the number of inhabitants of the Netherlands, the benefits resulting from demolition are not the lowest. Maintenance costs remain the most dominant costs factor. Rental revenues of a flexible building concept are slightly higher than those of a traditional building concept.

When the network costs are included, the flexible functions become more profitable in comparison to traditional function, then before the network costs are included. The flexible functions in general are still less profitable though. The expected annual flood damage costs for traditional buildings is higher for flexible buildings. But it is less expensive to heighten ground levels then to pay the expected annual flood damage.

By lowering of the construction, lowering of the maintenance costs, or increasing the GFA/LFA efficiency offer opportunities to make an adaptable urban area concept more profitable than a traditional one. An increase of the remaining value of demounted constructions parts does not offer this opportunity.

A lower expected annual damage, a smaller infrastructural network or lower ground costs do not effect the total return enough to make flexible building concept more profitable than traditional ones.

If the Regional Communities scenario is studied over a shorter time frame, no difference in financial returns results. A additional fluctuation of the demand according to this scenario does make flexible building concept more profitable, however, the difference in minimal. The same result is seen when a severe flood is simulated.

7.5 Bandwidth results

The following paragraph will describe the influence of the different variables analysed in the previous four paragraphs. Similarities and differences in these results will be put apart, and possible causes for these results are described. The results will be described according to the occupational layer, the network layer and the scenarios used.

7.5.1 Occupational layer

The variables influencing the financial consequences of an adaptive urban area concept from an investors’ viewpoint in the occupancy layer are the construction costs, the maintenance costs, the demolition costs and benefits and the rental benefits. The following paragraph will describe the influence of these variables according to the results of the four scenarios tested in the previous four paragraphs.

Initial building costs

The total construction costs for flexible function are between 15,5% and 15,8% less expensive than traditional building costs. The initial building costs of flexible constructions are between 10% (single family dwellings) and 30% (industrial buildings) less than those of traditional constructions. This difference is the same in every scenario, as these are a direct result of the characteristics that were entered for flexible constructions, based on case studies and literature references. Most of the flexible functions are constructed for 85% of the building price of traditional constructions.

To make flexible functions more profitable than traditional functions, the additional building costs would have to lowered on average an additional 8% to 8,5%. Figure 57 shows per function the difference between the discount in construction costs of flexible buildings in comparison to traditional buildings as found in the case studies and literature and the decrease in constructions costs as resulting from ADURAM2100 to make flexible building more profitable over time then traditional buildings.

The depreciation needed is strongly related to the maintenance costs per function over time. As figure 64 shows, the construction costs of flexible industrial buildings can even be 0,5% higher then those of traditional industrial buildings, while the
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Flexible construction still remains more profitable. This can be translated back to the fact that the maintenance costs of flexible industrial buildings sum up to 5,55 times the initial building costs, and these of traditional industrial buildings are 5,83 times the initial building costs.

Maintenance costs

The fact that the maintenance costs over a period of 90 years of industrial buildings are lower when the buildings are constructed flexible are an exception to the rule. On average, the maintenance costs over a period of 90 years of flexible buildings are 1,3 times as high as those of traditional buildings. The maintenance costs for flexible functions lower then 3 layers are 5,55 times the initial building costs, and for buildings higher then 3 layers this is 5,7 times the initial building costs. For traditional buildings this is 4 times the initial building costs for utility functions, 5,83 times for industrial building and only 3,12 times for residential buildings. In ADURAM2100, the flexible supply accounted for 56% to 57% of the maintenance costs. If the maintenance costs of flexible functions are lowered by 13,5% to 14%, this make the total return on flexible functions more profitable then the total return of traditional functions. Even though after lowering the maintenance costs, the maintenance of flexible functions remains 11% more expensive then that of traditional functions, this is compensated by the lower initial construction prices of flexible functions.

Whether in reality, the maintenance costs of flexible functions could be decreased by 14% is questionable. Though larger maintenance can be faster and easier as this entails replacement more so then restoration and repairs, regular and operational maintenance will not differ that much from the maintenance of traditional functions.

Demolishment costs

The return on recyclable flexible building parts in general turned out to be profitable even after subtracting the demountation costs of flexible functions. An exception to this finding where the closed building blocks and U-block dwelling in the ‘Regional Communities’ scenario and some U-block dwellings in the ‘Strong Europe’ scenario, as the remaining value of these dwellings had dropped below the demountation costs. The contribution of the demountation profits varied from 0,07% to 0,14% depending on the quantity and interval on which demolishment was needed. The demolishment costs of traditional buildings are non beneficial, and continuously contributed 0,01% of the total costs of development and maintenance.

Increasing the percentage of recyclable flexible construction parts from 80% to 100% increases the total return on flexible functions by less then 0,1% and so does not make a significant enough difference to make flexible functions more profitable then traditional functions. More over, it is not very realistic to think that all construction part would be reusable.

Benefits

Rental income of flexible functions accounted for 50,1% to 50,13% of all benefits, and on average was 0,3% more profitable then traditional functions. This can be explained by the fact that flexible functions are constructed 40% faster then traditional functions, and so, positive rental cash flows start earlier. An increase in rental revenues can be gained by the higher GFA/LFA efficiency pos-
sible in utility functions. Though an increased efficiency of 30% was suggested in the literature, this was not integrated in ADURAM2100 to potentially compensate a lower income due to a negative social stigma on flexible real estate. This compensation is somewhat misplaced, as this negative stigma mostly concentrates on residential functions, and not on utility functions. In testing the sensibility of the rental income, it turned out that an increase of less then 30%, namely 25,5% - 29%, was already efficient enough to make flexible buildings more profitable then traditional buildings (figure 58).

7.5.2 Network layer
Including the additional network costs turned out to affect the total return on flexible real estate positively as well as negatively. Retail, industrial buildings and offices where continuously negatively affected by the additional network costs, mainly because the expected annual damage for these functions was lower, and the higher ground costs did not differ that much from their initial ground costs. Most affected were the single family dwellings and industrial buildings. Flexible single family dwelling went from as much a 33,5% lower return in comparison to traditional functions to a 15,5% lower return when additional network costs were added. Flexible industrial buildings went from being 20,2% more profitable than traditional functions to only being 1,5% more profitable.

Expected annual damage
The expected annual damage continuously added up to a sum of round about €900 million, of which 45,7% resulted from the flexible part of the program developed. This is a result of lower building costs, and a faster restoration time. To further lower the expected annual damage one could envision that a flexible building offers the opportunity to restore only these parts that are affected. So as a flood of for example 0,4 m depth occurs, the façade can partially be disassembled and replaced. A decrease in EAD of 10% was assumed in every scenario. This resulted in an increase on the total return on flexible functions of 1,6%, which was never enough to make flexible functions more profitable than traditional functions.

Instead of integrating the expected annual damage an investor can also opt to raise the ground level. To heighten the ground level 0,8 meter, according to the flood scenarios as described in paragraph 6.3.4, no more floods will occur. The price of heightening 1 square meter of land with 1 meter of sand is €7,58. This results in a total of €43.872.583 for the entire area (1.194.670 m2). When the return of the first interval is decreased by the time it would take to heighten the area, say 3 years (max. €663.659.149), this results in the total cost of €500.591.127. This is still lower than the total expected annual damage over time of €900 million, so heightening the ground level is a more profitable option than paying the expected annual damage.

Additional network costs
To be able to guarantee flexibility, flexible function need to be facilitated by the highest level of infrastructure. The result is that flexible functions account for 58% of all infrastructural costs. Lowering the infrastructural facility level to for example 20% only increased the total return on flexible functions by 1,6%, which was never high enough to make flexible functions more profitable than traditional functions. Moreover, this limits the flexibility of a site.

The increase in ground space needed for infrastructure can also decrease the ground space left to develop upon, and in this way affect the total return on an
area. In this case study, the demand never outgrew the ground supply and restrictions set by the municipality. Quickly calculating though, this increase in ground space could decrease the realisation of supply by (22.7% - 17.1%) 5.6%, which has a substantial effect on the total return of flexible buildings, and therefore is important to keep in mind when developing a zoning plan.

**Ground costs**  
Ground costs for flexible functions are set to be the highest possible (urban villa’s €468/m2/bvo), to be able to facilitate any function later on. The total price paid for ground sums up to €228 million, of which 58% is directly linked to flexible functions. The ground costs for flexible functions only account for 0.3% of all costs made over time.

When the ground costs would be lowered for flexible functions, or even given away for free, this only increases the total return on flexible functional with a maximum of 1.3%, which is never enough to make flexible function more profitable then traditional functions.

### 7.5.3 Scenario
The scenarios as described in paragraph 6.3.3 are implemented in ADURAM2100 and steer the quantitative demand of all functions integrated. More over, the expected annual damage is also based on flood scenarios. In this paragraph the different results of these scenarios will be described.

**Time frame**  
The scenarios are all executed over a time frame of 90 years, from 2010 till 2100. This time frame was chosen to be able to be able to research what the financial consequences of an adaptable urban area concept were when the technical life-span of a traditionally constructed building were surpassed. And as data on future spatial development on such a far horizon is rare, the year 2100 was chosen as it matched the research on spatial development of the Spatial Information Laboratory at the VU University Amsterdam. To test whether this time frame influenced the profitability of flexible developments, the cash flow per interval of every scenario was studied. All four different scenarios have shown that there is no interval or time frame on which the total return on flexible functions is more profitable then that on traditional functions. The only exception is the fact that flexible industrial buildings become more profitable that traditional industrial buildings after 30 years.

**Fluctuation**  
To test the influence of the demand simulated by the scenarios, more fluctuation in demand was be simulated. First, every 3rd year the demand was increased by 5%, and every 6th year the demand was decreased by 5%. Though the total return on investment over time of the entire development decreased in general, an extra 0.05% to 0.32% of this return was accounted for by flexible functions. When the fluctuations were intensified to 10% growth every third year and compensated every 4th, the profitability shifts another 0.2% towards flexibility, but overall. As these shifts towards the profitability in general were small, this never resulted in flexible functions being more profitable then traditional functions.

**Flood**  
To test the sensitivity of the flood scenario integrated in ADURAM2100, the occurrence of a severe flood was simulated. In 2040 a flood of such devastation occurs, that all of the buildings on ground level need to be replaced. This resulted

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![Figure 59: Return on investment of adaptable urban area concept in comparison to traditional concept](image-url)
The financial consequences of an adaptable urban area concept from an investors perspective

in damage costs for the year 2040 of €397 million, making to total expected annual damage over time €1.068 million.

As the addition damage costs for flexible buildings are 16% lower then these for traditional buildings, the profitability of flexible functions in the form of their contribution to the total return increased an additional 0,06% to 0,08%. However, this was never enough to make flexible functions more profitable then traditional functions.

7.6 Interpretation

In general, the adaptive urban area concept has proven to be less profitable than a traditional urban area concept, mainly because the shorter technical life span of flexible construction parts leads to frequent replacement of which the costs are not sufficiently compensated by the lower initial building costs. The ratio of initial building costs versus large maintenance costs for flexible building concepts is consistently higher than that of traditional building concepts, with the exception of industrial real estate.

In the occupational layer, the return on investment of an adaptive urban area concept is mostly positively influenced by the lower initial construction costs due to the choice of the flexible building concept and the shorter construction span. The financial benefits of flexible constructions where slightly higher then those of traditional constructions. This resulted from higher rental incomes and profitable demolishment. The rental income of a flexible function is slightly higher as these are constructed faster, and so rental income starts earlier. Demolishment can be profitable as in case of flexible functions, the different construction parts can be reused. The remaining value of demounted flexible construction parts due to changing demands or shrinkage also positively influenced the financial return on an adaptive urban area concept. This return was very small however, as the costs of demountation sometimes even showed to be higher then the remaining value of the construction parts (as was mostly the case for closed building blocks and U-block dwelling). These high demountation costs resulted from the fact that recyclable construction parts need to be demounted and transported with care, the opposite of how traditional constructions are demolished.

In the network layer, the additional investments needed in infrastructure above ground as well as under ground have a negative influence on the total return on investment for flexible buildings, in comparison to traditional buildings. This is a result of the additional margin in infrastructure needed, in order to be able to facilitate flexibility in any future development. The influence of the infrastructural costs is very small however, in comparison to the affect of the maintenance costs. The potential flood damage is lower for flexible functions then for traditional functions. This mainly results from the lower replacement and repairing costs of flexible constructions, and the fact that flexible constructions are more resilient,
they can be repaired faster. The positive financial affect of the lower potential flood damage is larger then the negative financial affect of the higher infrastructural costs. Therefore, in total, the network costs have a positive influence on the return on investment of an adaptable urban area concept.

The difference between the financial returns of the four different scenarios is minimal. This can mainly be explained by the fact that especially maintenance costs but also the construction costs, and rental benefits resulted to be dominant factors in the total financial return, and these costs are initially the same in every scenario. And as the positive effect of the higher rental incomes of flexible functions is larger then the positive effect of reused construction part in scenarios of shrinkage, scenarios of growth give a higher profitability for flexible functions then scenarios is with the demand stagnates or even shrinks.

The revenues from demounted construction parts make that if additional fluctuation in the demand of the scenarios is simulated, the profitability of adaptable urban areas increases a little, but this shift is not large enough to make adaptable urban area developments more profitable. A similar result is seen when a major flood is simulated: the profitability of adaptable urban areas increases a little bit, but maintenance costs remain dominant, and as these are higher for flexible constructions, adaptable urban area developments remain less profitable.

7.7 Discussion
Thought the financial consequences of an adaptable urban area development might be negative in comparison to a traditional urban area development, it is not said that this concept is financially infeasible. Further development and implementation of this concept offers potential now and in the future because;

1. This research has solely focussed on the primary financial consequences of the implementation of an adaptable urban area concept. Potential social and ecological benefits, and the secondary positive financial consequences these benefits might have are not included.

2. The sensitivity analyses have shown that there is potential to improve the profitability of an adaptable urban area concept. First of, a further decrease in initial building costs resulting from further industrialisation and implementation on a larger scale can make an adaptable urban area concept just as profitable if not more profitable as a traditional urban area concept. And second, a flexible building concept offers the possibility to adapt a floor plan to its occupants. For utility functions, this can results in a higher ratio of lettable floor area per square meter of gross floor area, increasing the rental income sufficiently to make an adaptable urban area concept more profitable than a traditional urban area concept.

3. Though the case study with ADURAM2100 at the Merweharbor in Rotterdam showed that on average an adaptable urban area concept is less profitable than an traditional urban area concept, it is not said that an adaptable urban area development is financial infeasible. Only when the costs that were now excluded in calculations (those that where equal for the traditional and the adaptable concept) will be included, can conclusions be drawn on the total financial feasibility of an adaptable urban area concept.

Sensitivity tests revealed that increasing the recyclebility of flexible construction parts, decreasing the margin of infrastructure offered, decreasing the ground costs or decreasing the potential flood damage costs might increase the financial return on an adaptable urban area concept, but offered no potential to make an
urban area concept actually more profitable than a traditional urban area concept. Moreover, increasing the ground level of the area at the start of the development turned out to be less expensive then paying the potential flood damage for the entire timespan.

An increase in maintenance costs might offer some potential to make an adaptable urban area concept more profitable than a traditional one, however, the feasibility of the decrease in costs needed is questionable.

The sensitivity analyses also revealed some realistic potential to make an adaptive urban area development more profitable than a traditional one. First of, a decrease in initial construction costs has a large effect on the profitability of flexible constructions, as it also positively affects the maintenance costs and expected annual flood damage. A decrease in construction costs offers feasible potential, as flexible building concepts are based on industrialisation, while momentarily being executed on individual and smaller project basis. As this concept is implemented on a larger scale, construction costs can be decreased. Besides lowering the initial building costs of a flexible building concept, one could also opt to lengthen the technical life span of a flexible construction part, but this makes it more difficult to introduce new technical developments into this building concept, as construction parts will be replaced less often.

Secondly, reference documentation has shown, that the rental income resulting from flexible utility functions can be increased resulting from a higher space use efficiency (increased GFA/LFA ratio). This results from the fact that flexible constructions can be altered and customized more easily to its occupants, both initially as well as occupants change over time. This increase is marginally enough to also compensate the lower profitability of residential functions, and thereby making an adaptive urban area concept more profitable than a traditional one.
8. Conclusions
The detailed research questions can be answered mainly according to the literature study, and result in the following conclusions:

What is sustainable urban area development?
A sustainable urban area development is a development in which all involved actors integrate planning and spatial investments for an area, to result in the execution and life cycle management of a spatial plan based on mitigation, that is adaptable so it can meet the needs of the current generation without risking the provision of needs of future generations.

How can flexibility be adapted into an urban area concept?
To be able to achieve a sustainable urban area in a dynamic and complex world that changes every second the occupational layer and the network layer need to cooperate, the occupational layer being flexible through its real estate, and the network layer able to adapt to the changes of the occupational layer. A flexible occupational layers contains real estate that is physically capable of adapting is supply to changing demands, both quantitative as qualitative. An adaptable network layer is a network layer that is able to facilitate changes in the occupational layer without having to physically change itself. Therefore, the network layer needs to be designed with an extra marge in quality and quantity, both underground as well as above ground.

For which types of developments are flexible building concepts suitable?
Flexible building concepts are mainly suitable for functions with a longer technical life span than functional life span. These functions can be residential, work related, industrial, welfare facilities, events, project based, cultural or recreational. Flexible building concepts are mostly suitable for the rental sector, as the dynamic and often temporary character of a flexible building concept does not correspond with the general perspective of a occupant-owner, assuming that the property has a continuous function, quality and therefore value. More over, the rental sector offers the opportunity to manage the property from an portfolio perspective.

Calculations with ADURAM2100 of developments in the Merweharbor in Rotterdam from now till 2100, viewed from an investors' perspective, result in the following main conclusion:

What are the financial consequences of an adaptable urban area concept from an investors' viewpoint?
An adaptable urban area concept on average is 8.9% less profitable than a traditional urban area concept. This is not a result of the higher initial investment costs in the network layer however, but is mainly caused by the shorter technical life span of flexible construction parts which is not sufficiently compensated by the lower initial building costs. The ratio between the lower initial building costs and the higher large maintenance costs resulting from the frequent replacement needed due to the shorter life span is higher than that of traditional building concepts.
Which limitations does the integration of flexible real estate and adaptive urban area development entail?
Adaptive urban area development entails mainly social, legal and financial limitations. Social limitations entail the level of recognition of an area by its occupant. This means an area should not be 100% flexible, as the occupants of an area need some form of continuity in identity to be able to bind to an area and appreciate it. Legal limitations relate to the lack of rules and regulations open to future flexibility. The Spatial Planning Act focuses too much on current developments, and developments in the near future, where there is no room for future uncertainties. Legislation will have to be innovated. Financial feasibility mainly focuses on the higher initial investment costs of adaptable urban area concepts, and the intense technical maintenance cycle needed to manage flexibility on the long term.

Which additional costs and benefits are related to adaptable urban area development?
Building techniques like IFD entail higher initial investment costs in the network layer as this has to accommodate and facilitate any transition possible of the flexible real estate. Costs related to an adaptive network layer can be split up into underground costs and costs above ground. The underground costs are mainly related to underground infrastructure like transportation systems, gas, water, communication lines and electricity. Whether a plot of land will be occupied by a couple of single family dwellings or a 8 stories high office building becomes uncertain over time when the area entails an adaptable development concept. The additional investment in the preparation of land result in elevated ground prices. Above ground, the infrastructure also needs to accommodate and facilitate any transition of a flexible building. For this reason, main road need to be developed with extra capacity. This extra capacity does not only result in additional initial investments, but also in a decrease of land left to develop other functions upon. Besides costs, an adaptable urban area concept also has an additional benefit: the expected annual damages are lower, when an area is more resilient. This is a result of the lower building costs of flexible building techniques, and the shorter restoration time, securing an earlier return of rental incomes.
The financial consequences of an adaptable urban area concept from an investors perspective
9. Recommendations
Thought the financial consequences of an adaptable urban area concept might be negative in comparison to a traditional urban area concept, it is not said that this concept is financially infeasible. Further development and implementation of this concept offers potential now and in the future because:

1. This research has solely focussed on the primary financial consequences of the implementation of an adaptable urban area concept. Potential social and ecological benefits, and the secondary positive financial consequences these benefits might have are not included.

2. The sensitivity analyses have shown that there is potential to improve the profitability of an adaptable urban area concept. First of, a further decrease in initial building costs resulting from further industrialisation and implementation on a larger scale can make an adaptable urban area concept just as profitable if not more profitable as a traditional urban area concept. And second, a flexible building concept offers the possibility to adapt a floor plan to its occupants. For utility functions, this can result in a higher ratio of lettable floor area per square meter of gross floor area, increasing the rental income sufficiently to make an adaptable urban area concept more profitable than a traditional urban area concept.

3. Though the case study with ADURAM2100 at the Merweharbor in Rotterdam showed that on average an adaptable urban area concept is less profitable than an traditional urban area concept, it is not said that an adaptable urban area development is financially unfeasible. Only when the costs that where now excluded in calculations (those that where equal for the traditional and the adaptable concept) will be included, can conclusions be drawn on the total financial feasibility of an adaptable urban area concept.

To be make the calculations on the financial consequences of an adaptable urban area more reliable, additional knowledge is needed on the following subjects:
- The costs of implementing an adaptable urban area concept. Experiences with the development and recyclability of flexible building concepts are still incidental and insufficiently documented. Central documentation and research into the use and reuse of this concept will make calculations more reliable.
- The expected annual flood damage. The expected annual damage per function is calculated with the help of some reference building provided by the UNESCO-IHE Institute for Water Education. These references only entail residential functions, and therefore make flood damage costs calculation of other functions less reliable. Additional research is needed on the damage curves of utility functions.
- Large maintenance costs. Knowledge on large maintenance cycles of different types of real estate has proven to be rare and inconclusive on a general perception in maintenance planning. Additional knowledge and research needs to be done on maintenance cycles improve the reliability of calculation on future returns.

Besides the financial challenges that will need to be faced before an adaptable urban area development can be implemented, the following subjects will need additional attention and development too:
- The main focus of the Spatial Planning Act (Wet Ruimtelijke Ordening) is on current developments, and developments in the near future. There are no specific tools to plan for the long term, an armamentarium for flexible real estate and adaptable urban developments needs to be developed.
- A big drawback of flexible real estate currently existing is the great social, cultural and economical difficulties future users can have with the principle that a building is temporary. ‘Temporary’ is often associated with buildings of a low aesthetical quality (or even containers), and users not caring for their environment as it is temporary anyway. The social stigma of flexible building entails constructions of low aesthetical quality needs to be transformed by promoting successful flexible projects.
10. Epilogue
Starting with a subject as wide as ‘sustainability’ made it difficult to narrow the field of research. After a couple of months of literature study, I was under the impression that the time spend writing about sustainability was about 100 times as much as the time executing it, and it was difficult to align what my final focus and viewpoint would be. Using the layered approach (VROM, 2006) helped me to focus on the research direction I wanted to take. Graduating at Dura Vermeer during my study gave me the time and occasion to reflect upon my subject together with others and learn from their field knowledge.

The choice to develop a computerized calculation model to answer some of my research questions helped me to concentrate on the subjects that really contributed to answering my research questions, the essence of the research, and leave out the things that do not influence the end results. Designing a model confronted me with new dilemma’s every day, and though solutions were not always that hard to design, finding the data corresponding with these solution to implement into the model often was.

The obligation to put everything in quantitative data and formulas forces you to make decisions in which much of the refinement of the subject at hand can get lost. The risk of such a quantitative model is that the connection with the sources and causes of the data becomes weak, after which it can be difficult to trace back what the origin of the output is.

The outcome of a model should therefore never by assumed to be the absolute truth. The model should not be used as a tool to research the feasibility of certain concepts, but should strictly be used to compare consequences. Users should be well up to date of the input and process of the model, to be able to interpret the outcome correctly. Working in a model also makes it harder to collaborate upon decisions with third parties, as it is difficult to explain a complex and quantitative process in words.
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### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADURAM2100</td>
<td>Adaptive Urban Area Model timeframe 2010-2100</td>
</tr>
<tr>
<td>CBS</td>
<td>Centraal Bureau voor de Statistiek</td>
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<td>Cbz</td>
<td>College bouw zorginstellingen</td>
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<tr>
<td>CPB</td>
<td>Centraal Planbureau</td>
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<td>EAD</td>
<td>Expected Annual Damage costs due to flooding</td>
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<td>GE</td>
<td>Global Economy scenario</td>
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<tr>
<td>GFA</td>
<td>Gross Floor Area</td>
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<td>IFD</td>
<td>Industrial, Flexible and Demountable building techniques</td>
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<td>LFA</td>
<td>Lettable Floor Area</td>
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<td>M</td>
<td>Meter(s)</td>
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<td>MNB</td>
<td>Milieu- en Natuurplanbureau</td>
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<td>RICARDO</td>
<td>Real Investment Calculator (of) Area Redevelopment Design Optimalization</td>
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<td>RC</td>
<td>Regional Communities scenario</td>
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<td>RPB</td>
<td>Ruimtelijk Planbureau</td>
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<td>SBR</td>
<td>Kennisplatform voor de bouw</td>
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<td>String Europe scenario</td>
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<td>SEV</td>
<td>Stuurgroep Experimenten Volkshuisvesting</td>
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<td>TM</td>
<td>Transatlantic Market scenario</td>
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<td>UAD</td>
<td>Urban Area Development</td>
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<td>VROM</td>
<td>Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer</td>
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</table>
The financial consequences of an adaptable urban area concept from an investors perspective

Pictures

Titel page, source: www.flickr.com, photo of explosion at Nederlands Architectuurinstituut, photographer unknown

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Page 12, Index, source: www.flickr.com, photo of Das Park Hotel, photographer unknown

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City harbors of Rotterdam

The city harbours of Rotterdam will form the study field for a case study on which the final tool will initially be modelled, later to become a general model able to be applied to any setting.

The transformation of the city harbours of Rotterdam is an extensive and complex project. Municipality and dock industry have formulated five strategically starting points. Dozens of stakeholders and companies have tested these strategies and added their own ideas. In order to speed up the transformation projects have already started. Initial projects should also attract more investors and innovation. On the long run, a quality improvement has been initiated. The end result will take some decades to reveal itself.

The transformation of the city harbour of Rotterdam is split up into three time frames. For the smallest time frame, 2015 is the guideline. This way, means provided by the governmental under the policy of ‘Randstad Urgent’ are available to Rotterdam. The middle to long-term approach has 2025 as its horizon; this is also the period in which a cooperation agreement between the Havenbedrijf (harbour company) and the municipality of Rotterdam is operative. On the long run, the vision of ‘Randstad 2040’ is leading.

The five strategies for a new future are:
- re-inventing delta technology
- volume & value
- crossing borders
- floating communities
- sustainable mobility

Results on the long run:
- 5000 dwellings before 2025
- 60 hectare of maritime services in Waalharbor East, containing about 1,2 of offices and brown fields
- 30 hectares renovation of the RDM-area
- 40 hectares of creative technology in the Merwe- en Vierhabour
- 10 hectare of urban functions in the Rijn-Maas harbour area
- Doubled container transfer capacity will 2025, and growing
- Intensifying de harbour area for mixed cargo
- Education for at least 1000 students
- New city attractions, 200,000 visitors yearly
- 13,000 new job opportunities
Quick scan of potential case study locations

Heijplaat

The name Heijplaat is initially appointed to a workers community between the Waalhaven and the Eemhaven. In the direct surroundings of this community however, initiatives related to Research, Development & Manufacturing are being developed. Taking these developments into account, the surface area of this location is close to 200 hectares. Heijplaat as community is nominated to become protected city area (beschermd stadsgezicht) and many of the RDM buildings are listed as monuments.

Besides the workers community and the RDM (Rotterdam Droogdok Maatschappij) terrain, this location is still dominated by harbour related and industrial activities. Future developments are divers but focussing on education and technological development, both on land as well on water, as this location is outsight the dyke ring. As the network of this location is now mainly facilitating transport routes between large industrial complexes, it will at least have to be intensified. Documentation on this location is sufficient.

Katendrecht

In-between the Rijnhaven and the Maashaven but outsight the dyke ring, 56 hectares of headland form Katendrecht. Katendrecht is a residential area with occasionally some daily facilities and offices, in additions to this main use, the ship ‘SS Rotterdam’ has docked at Katendrecht, offering internships related to leisure activities. In the future the residential function of Katendrecht will be further enforced when density is intensified by residential buildings, and even a floating community south of Katendrecht. The network layer of Katendrecht has recently been altered, though still in progress, this means less need for investments in the future. Documentation on this location is sufficient.
Merwehaven-Vierhaven

The Merwehaven and Vierhaven together form a 125 hectare flood risk area still functioning as harbour, mainly trading fruit and fruit juices. Though the fruit cluster is still growing, it will move to the Waalhaven and Eemhaven, making room for new developments in the Merwehaven-Vierhaven, focusing on innovation and sustainability. A thriving factor in this development will be the Climate Campus, initiating knowledge valorisation of science and business in the field of energy and water management. Besides new dwellings on land, a floating community will be developed in the Merwehaven. In completion the area will have a dynamic mix of harbour activities with some monumental industrial buildings, dwellings, offices, education and supporting facilities in leisure and retail. The infrastructure in this area is still mainly focussed on heavy transport, so will have to be adapted to the new developments. Plans in this area are open to adaptive concepts, within the Vierhaven the Macronifreezone is appointed, especially reserved for temporary functions. Documentation on this location is good.

Nederlek

The IHC (Industrial Trade Combination) Stroommolen terrain in Krimpen aan de Lek (municipality of Nederlek) was a thriving shipyard in the seventies. Now, this 9 hectare terrain situated on the banks of the Lek river is abandoned and neglected. Future developments will be residential and in the higher segment. As this is a flood risk area, these dwellings will be developed with experimental techniques. The area is nearly empty at the moment, so a completely new infrastructure will be needed for these developments. Documentation on this location is excellent.
Noordereiland

The Noordereiland is a residential island of 33 hectares. Besides some daily facilities in retail and leisure the island is mainly occupied by dwellings. Future plans are minimal as the zoning plan calls for residential development only, a small park will be developed to fit the existing residential grid. The Noordereiland is a protected city area (beschermd stadsgezicht) and contains many monuments, but floods frequently. The infrastructure is adequate for residential use. Documentation is insufficient.

Verolme

The Verolme terrain currently is a somewhat neglected brown field of 18.5 hectares. Though it is situated outside the dyke ring, future developments involve 1500 dwellings with fitting daily facilities. To realize this, the area and its infrastructure will have to be completely redeveloped. Documentation on this location is poor.

Conclusion

Concluding from this quick location analyses, Heijplaat and the Merwehaven-Vierhaven are the best options to test the model. As the future programme of the Merwehaven-Vierhaven complies more with the initial criteria for dynamic functions like work, this will be the location chosen for further case studies.
Initial quantitative input

Figure 63: Zoning plan Merweharbore, green stands for merely residential, blue for merely work related functions and turquoise is a mix of functions.
<table>
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<tr>
<th>Area</th>
<th>Surface m²</th>
<th>Functional requirements</th>
<th>Spatial requirements</th>
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<td>U-block dwellings</td>
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<td>Max FSI</td>
<td>Max Layers</td>
<td>Total Area (m²)</td>
<td>Buildings/Spaces</td>
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<td>Mix business park after 2025, with possibility to work at home</td>
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<td>Single family dwellings 10.619, 5.310, 106&lt;br&gt;Apartment building 4.779, 1.195, 80&lt;br&gt;Offices 54.191, 8.363&lt;br&gt;Business 7.964, 7.964</td>
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<td>Intense mix of close building blocks, apartment buildings, urban villa’s, U-block dwellings, office space, retail, leisure, catering, welfare services and social commercial facilities.</td>
<td>Max FSI</td>
<td>Area (m²)</td>
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<td>Apartment building</td>
<td>Urban villa</td>
<td>U-block dwellings</td>
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</tr>
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<td>Urban villa</td>
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<td>Retail</td>
<td>858</td>
<td>858</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Leisure</td>
<td>1.051</td>
<td>1.051</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>Food &amp; beverages</td>
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<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>Welfare services</td>
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<td>788</td>
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<tr>
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<td>Social commercial facilities</td>
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<tr>
<td>16</td>
<td>18.437</td>
<td>Till 2025 maintain existing industry, afterwards intense mix of closed building blocks, apartment buildings, urban villa’s, U-block dwellings and office space.</td>
<td>Max FSI 2.0</td>
<td>36.874 m²</td>
<td></td>
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<td>1.696</td>
<td>339</td>
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<td>95.930</td>
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<td>221.046 m²</td>
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<td>Apartment building</td>
<td>1.203</td>
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<td>Urban villa</td>
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<td>20</td>
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<tr>
<td></td>
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<td>U-block dwellings</td>
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<td>629</td>
<td>629</td>
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<tr>
<td></td>
<td></td>
<td>Leisure</td>
<td>963</td>
<td>963</td>
<td>20</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Food &amp; beverages</td>
<td>1.415</td>
<td>1.415</td>
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<tr>
<td></td>
<td></td>
<td>Welfare services</td>
<td>2.166</td>
<td>1.083</td>
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<td></td>
<td></td>
<td>Social commercial facilities</td>
<td>14.441</td>
<td>7.220</td>
<td>20</td>
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<td></td>
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</tr>
<tr>
<td>18</td>
<td>Till 2025 maintain existing industry, afterwards intense mix of close building blocks, apartment buildings, urban villa’s, U-block dwellings, office space, retail, leisure, catering, welfare services and social commercial facilities. Max FSI 2.0 Max 5 layers 29.716 m² From 2025 on;</td>
<td>Close building block 471 94 6 Apartment building 449 90 7 Urban villa 860 120 7 U-block dwellings 449 90 6 Office 3.103 415 Retail 147 147 Leisure 224 224 Food &amp; beverages 110 110 Welfare services 505 253 Social commercial facilities 1.684 842</td>
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<tr>
<td>19</td>
<td>Till 2025 maintain existing industry, afterwards single family dwellings Max FSI 2.0 Max 5 layers 36.302 m² From 2025 on;</td>
<td>Single family dwellings 9.000 4.500 90</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>20</td>
<td>Till 2025 maintain existing industry, afterwards intense mix of closed building blocks, apartment buildings, urban villa’s, U-block dwellings and office space. Max FSI 1.5 Max 5 layers 33.896 m² From 2025 on;</td>
<td>Close building block 2.328 466 28 Apartment building 1.247 249 21 Urban villa’s 4.781 665 42 U-block dwellings 2.217 443 21 Offices 15.673 2.095</td>
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<td>21</td>
<td>Till 2025 maintain existing industry, afterwards mix of closed building blocks, apartment buildings, urban villa’s, U-block dwellings and office space. Max FSI 2.0 Max 5 layers 46.802 m² From 2025 on;</td>
<td>Close building block 2.147 429 26 Apartment building 1.534 307 26 Urban villa’s 3.674 511 32 U-block dwelling 2.045 409 26 Offices 17.649 3.220</td>
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<tr>
<td>Period</td>
<td>GFA m²</td>
<td>Ratio</td>
<td>Max allowed bvo</td>
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## Functions

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<th>Layers</th>
<th>Examples</th>
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<td>2</td>
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<td>Closed building block</td>
<td>87</td>
<td>5</td>
<td></td>
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<tr>
<td>Apartment building</td>
<td>64,8</td>
<td>5</td>
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<tr>
<td>Urban villa</td>
<td>87,48</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>U-block</td>
<td>86,4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>600</td>
<td>1</td>
<td>Industrial halls and ground bound businesses.</td>
</tr>
<tr>
<td>Office</td>
<td>518,4</td>
<td>5</td>
<td>Schools, day care, doctor, pharmacy, dentist, physiotherapist, police station, fire department</td>
</tr>
<tr>
<td>Welfare services</td>
<td>450</td>
<td>1</td>
<td>Employment agency, travel agency, real estate broker, postal office, bank, financial services,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hairdresser, beauty spa, copy shop, cobbler, dry cleaner, garage, veterinarian</td>
</tr>
<tr>
<td>Social commercial facilities</td>
<td>450</td>
<td>1</td>
<td>Musea, sport facilities, zoo, theme parks, theater, movie theater</td>
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<tr>
<td>Retail</td>
<td>207,36</td>
<td>1</td>
<td>Shops</td>
</tr>
<tr>
<td>Leisure</td>
<td>600</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Food &amp; beverage</td>
<td>103,68</td>
<td>1</td>
<td>Restaurant, bar, take out</td>
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Scenarios

Regional Communities
European countries rely on collective arrangements to maintain an equal distribution of welfare. At the same time, governments are unsuccessful at modernising welfare-state arrangements. A strong lobby of vested interests blocks reforms in various areas. Together with an expanding public sector, this situation puts a severe strain on European economies. The European Union cannot adequately cope with the Eastern enlargement and fails to reform its institutions. As an alternative, a core of rich European countries emerges. Cooperation in this sub-group of relatively homogeneous member states gains a more permanent character. The world is fragmented into a number of trade blocks, and multilateral cooperation is modest.

Global Economy
European countries find a new balance between private and public responsibilities. Increasing preferences of people for flexibility and diversity, and growing pressure on public sectors, give rise to reforms. New institutions are based on private initiatives and market-based solutions. European governments concentrate on their core tasks, such as the provision of pure public goods and the protection of property rights. They engage less in income redistribution and public insurance, so that income inequality grows.

International developments also reflect increasing preferences for diversity and efficiency. Political integration is not feasible, as governments assign a high value to their national sovereignty in many areas. Moreover, policy competition becomes standard in many policy areas. Economic integration, however, becomes broader (not always deeper), as countries find it in their mutual interest to remove barriers to trade, investment and migration. With a limited amount of competences and a focus on the functioning of the internal market, the European Union finds it relatively easy to enlarge further eastwards. Similarly, negotiations in the WTO are successfully completed. Regional and global integration puts poor countries on a path of catching-up and high growth. As international cooperation in non-trade issues fails, the problem of climate change intensifies, while European taxes on capital income gradually decline under tax competition.

Strong Europe
European countries maintain social cohesion through public institutions. As a result, society accepts that the more equitable distribution of welfare limits the possibilities to improve economic efficiency. Yet, governments respond to the growing pressure on the public sector by undertaking selective reforms in the labour market, in social security, and in public production. Combined with early measures to accommodate the effects of ageing, these policies help to maintain a stable and growing economy. In the European Union, member states learn from each other’s experience, which creates a process of convergence of institutions within Europe. Reform of the process of EU decision-making lays the foundation for a successful, strong European Union. The enlargement is a success, and integration advances—geographically, economically and politically. European leadership is important for achieving broad international cooperation, not only in the area of trade but also in other areas like climate change.

Transatlantic Market
European countries limit the role of the state and rely more on market exchange. This boosts technology-driven growth and increases inequality. The inheritance of a large public sector in EU countries is not easily dissolved. New markets (e.g. for education and social insurances) lack transparency and competition, which brings about new social and economic problems. The interests of the elderly dominate policy decisions, which make it difficult to dismantle the pay-as-you-go pension systems in continental Europe. Government failures thus compound to market failures.

EU member states focus primarily on national interests. EU decision-making is not reformed, which complicates further integration in the European Union. The EU redirects its attention to the United States, and agrees upon transatlantic economic integration. This intensifies trade in services, which yields welfare gains on both sides of the Atlantic. The prosperity of the club of rich countries is in sharp contrast with the poverty in Eastern Europe and in developing countries.
Flood risk

Flood consequences
Real estate management tends to limit the consequences of flooding to the physical damage to the building, and the time it takes to repair this, expressed in a loss in potential income. Consequences of floods are more extensive though, and can be classified in a number of categories:
- Casualties: fatalities and mental injuries
- Damage to buildings, infrastructure and other material goods
- Direct economic losses to industry and agriculture
- Indirect economic losses due to the disruption of production chains
- Ecological and cultural losses

As stated above, an distinction can be made between direct, and indirect damages. Direct damages often take place within the flood prone area, whereas indirect damages manifest outside of the flood prone area. Further more, a distinction can be made between tangible and intangible damages, damages become intangible when no market prices exist are known. Casualties, and ecological and cultural losses are often intangible. Damage to structures or disruption of economic activities are well tangible, and therefore can be adapted into flood risk management equation more easily. Figure 64 shows a classification of various types of damages caused by a flood.

There are some main factors influencing the extend of the flood damage;
- The time period that objects have been partly or wholly saturated with water.
- Polluted water will cause greater damage than clean water.
- The land use and population distribution
- The nature of the buildings (form, height, use of materials and orientation)
- The amount of debris in the streaming water.

<table>
<thead>
<tr>
<th>Tangible and priced</th>
<th>Intangible and unpriced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>Intangible</td>
</tr>
<tr>
<td>Residences</td>
<td>Societal disruption</td>
</tr>
<tr>
<td>Capital assets and</td>
<td>Psychological traumas</td>
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<tr>
<td>inventory</td>
<td></td>
</tr>
<tr>
<td>Business interruption</td>
<td></td>
</tr>
<tr>
<td>(inside the flooded area)</td>
<td></td>
</tr>
<tr>
<td>Vehicles</td>
<td></td>
</tr>
<tr>
<td>Agricultural land and cattle</td>
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</tr>
<tr>
<td>Roads, utility and communication infrastructure</td>
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</tr>
<tr>
<td>Evacuation and rescue operations</td>
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</tr>
<tr>
<td>Reconstruction of flood defences</td>
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</tr>
<tr>
<td>Clean up costs</td>
<td></td>
</tr>
<tr>
<td>Indirect</td>
<td></td>
</tr>
<tr>
<td>Damage for companies outside the flooded area</td>
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</tr>
<tr>
<td>Adjustments in production and consumption patterns outside the flooded area</td>
<td></td>
</tr>
<tr>
<td>Temporary housing of evacuees</td>
<td></td>
</tr>
<tr>
<td>Inconvenience and moral damages</td>
<td></td>
</tr>
<tr>
<td>Utilities and communication</td>
<td></td>
</tr>
<tr>
<td>Historical and cultural losses</td>
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</tr>
<tr>
<td>Environmental losses</td>
<td></td>
</tr>
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</table>

Figure 64; Different dimensions of flood consequences
Damage assessment methods
As urban areas are multi-facetted and very dynamic, it is often difficult to assess the influence of climate changes and the resulting flood risk. To be able to make a thorough estimate of the potential damage, the next steps are critical:

1. Identification of the land use in the study area, and the maximum damage amounts.
2. Determination of flood characteristics like water depth and velocity.
3. Establishing the relation between the flood parameters and the consequences, for example through stage-damage functions.

Identification of land use
The maximum amount of damage that can be caused can be assessed by looking at the land use in the urban area. Various perspectives exist regarding damage appraisal, valuation of financial and economic damage can be based on market values or imputed values including the depreciation of the assets (based on historical values of replacement values). A damage appraisal can be determined per damage object, an object can either be a building, a square meter of land or for example a meter of road. Damage amounts are often generalized per damage object, and are assumed to be the same nation-wide. Naturally, in reality damage will differ per object, so generalization had to be done with great care and detail. The type of object will have to be documented well, so when damage assessments methods are copied to different locations, users will be able to retrieve the detail of every object type and interpret them.

When the use of land is assessed direct and indirect potential maximum damages can be determined. To estimate indirect damage to business flows, the interconnectedness between economic agents needs to be analysed. When the economic system is clearly determined, the impact of stochastic shocks on this system can be evaluated. Direct damage components can be both qualitatively and quantitatively. The features classes (buildings, infrastructure, public space), function (residence, business) and typology (apartment, row houses) determine how high the maximum damage can be. Furthermore, the age distribution of the buildings stock will influence the potential damage. Because many cities host a culturally valuable body of monumental buildings, damage clustering over age might help to identify vulnerabilities within historical urban centres.

Figure 66 shows the maximum amount of direct physical damage for different asset categories. The categories are: general land use (for example urban area), infrastructure (for example rail roads), households (house types), companies (for example industry) and public facilities (for example pumping stations). Note that every category can be assessed according to its own measurement unit.

Determination of flood characteristics
In the determination of flood characteristics resulting in damage to objects, the flood duration, contamination and velocity are most important. The determination

Figure 65; Schematization of the assessment of direct physical damages due to catastrophe flooding

Figure 66; Maximum amount of direct physical damage for different asset categories.
of flood characteristics is called spatial damage-cluster identification. In spatial-damage clusters, the patterns of spatial distribution of expected flood damages are provided. To be able to map this spatial distribution a geographic information system (GIS) is used. Using the GIS method, an overlay of data coming from different sources based on a common spatial attribute is retrieved, which can be an (x,y) coordinate or a zip code. A grid with fixed intervals, like 100x100 m, is used for the simulation of flood scenarios and corresponding flood damage (shown in the GIS based flood analysis in figure 65). When necessary, higher grid resolutions can also be applied, like 25 x 25 m, which is for example used in the Netherlands for the assessment of damage in the coastal zone due to erosion during storm surges.

Relation between the flood parameters and the consequences

Direct damages associated with the physical impacts of a flood hazard are generally estimated by what is referred to as unit damage functions or stage-damage functions. These functions result in economic damage curves, determining a specified relationship between the flood characteristics and the characteristics in land use. The equation (figure 67) on the right side of this page describes how the elements in the direct damage model are combined to estimate the total of physical damages in a flooded area.

Simplified stage-damage curves might reduce the amount of flood characteristics that are taken into consideration, and only consider the flood depth. In figure 10
shows a simplified stage-damage curve for different types of land-use. When the water depth has been determined, the economic consequences of the flood result by multiplying the related damage factor with the maximum possible damage amount (see figure 68).

For each of the damage categories in figure 23, specific stage-damage functions are estimated. These stage-damage functions can be used for the direct physical damage assessment. These stage-damage curves have derived from correlating historical damage data. Indirect damage, like the interruption of a business process, is calculated according to a so-called ‘input-output model’ assuming that 50% of the production loss is overtaken by areas outside the dike-ring.

As described in the past few paragraphs, damage assessment is a complex process in which events have to be registered, interpreted and qualitative data has to be translated into quantitative data. Further more, damage assessment results have to be documented with a high level of precision to make the data generally usable. Stage damage curves therefore are susceptible to a number of influences comprising the precision and reliability of the results. Overestimated damage assessments might result from retrofitting measures already applied to individual buildings or an extensive evacuation response time (extreme river discharges in the Netherlands can be predicted up to several days’ ahead, extreme sea water levels have a prediction time of 6-10 hours). On the other hand, the outcome might be an underestimation of actual damage levels as a result from omitted industrial sectors from damage assessment, inaccurate stage-damage curves for historical buildings, or an underestimation of the possible pollution or general size of the flood.

**Expected annual damage**

The expected annual damage is a method that relates damage to an object and a time frame. When the damage to an object or area has been assessed with a stage-damage curve as explained in the previous paragraph, the economic impact of a certain flood is known. This flood is related to an occurrence probability, for example once every 250 year. When the total economical damage of a flood is divided by the number of years in which it will reoccur, the expected annual damage results.

\[
\text{Economic damage in case of flood hazard A to area X} \times \frac{\text{Annual probability that flood hazard A will effect area X}}{\text{Expected annual damage}} = \text{Expected annual damage}
\]
As seen in figure 66, damage can be related to a wide variety of objects, each having their own measurement unit, this is the same when appointing the expected annual damage, this can be done for a square meter of land, an object or a entire neighborhood. Absolute damage levels are strongly related to the size of the building stock and infrastructural extent within the municipalities; the denser and more urbanized the area, the higher the expected annual damage. To be able to compare results, it is therefore important to synchronize the measurement units assessed. When addressed correct, he expected annual damages can provide an insight into the cost effectiveness of retrofitting measures as opposed to replacement strategies. In the Netherlands we have multiple probable sources of floods (rivers, the North sea, the Ijsselmeer) and that there can be multiple causes of floods as well as multiple locations of flooding at the same time. Each of these flood scenarios have their own flood probability. So when assessing the expected annual damage of a certain object or area, one has to keep in mind that it will probably not just be at risk of one type of flood, but of several as the same time. The expected annual damage therefore, is often a sum of various scenarios.
### Flood damage

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<th>10000</th>
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<th>4000</th>
<th>10000</th>
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<td>0,15</td>
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**Average flood depth for entire area (m)**

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**Overstromingsdiepte in cm huidige scenario (m)**

- **Herhalingstijd in jaren**
- **Overstromingsdiepte in cm G+ 2050 (m)**

**Overstromingsdiepte in cm**

- **Overstromingsdepth in cm**
- **Herdalings depth in cm**
- **Overstromingsdiepte in cm G+ 2050 (m)**

**Overstromingsdiepte in cm G+ 2050 (m)**

- **Herdalings depth in cm G+ 2050 (m)**

---

**Appendix VI**
## Data model

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<th>Function</th>
<th>New built</th>
<th>Demolish</th>
<th>Income</th>
<th>Object</th>
<th>Maintenance</th>
<th>Building duration</th>
<th>Groundprice</th>
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<td>m2 bvo</td>
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