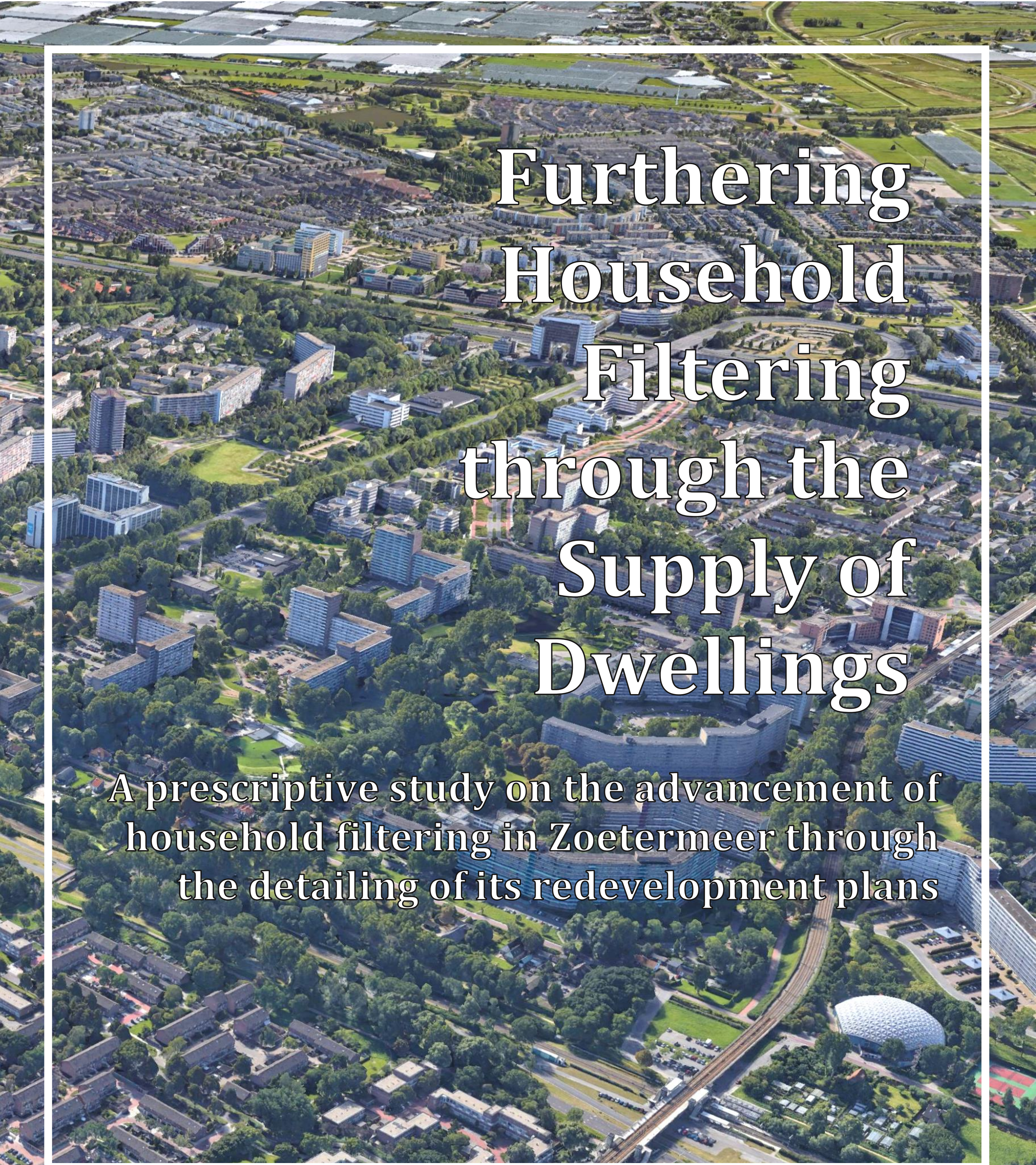

Furthering Household Filtering through the Supply of Dwellings

A prescriptive study on the advancement of household filtering in Zoetermeer through the detailing of its redevelopment plans

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Graduation Thesis

MSc Management in the Built Environment

A master track of Architecture, Urbanism & Building Sciences

TU Delft

Built the chains you want to see

Colophon

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I Preface

This thesis was written as part of the graduation program of the Master track Management in the Built Environment at the faculty of Architecture, Urbanism and Building Sciences at the Delft University of Technology.

It came into existence in collaboration with the municipality of Zoetermeer, which had stated the request for research on a number of topics concerning its housing program and housing stock. I became interested after being introduced to the subject and the problems Zoetermeer was facing due to the fact that it is a problem which many municipalities are facing and providing a solution could thus have a larger impact than 'just' one municipality. Furthermore, since this is my graduation project, I will be entering the housing market shortly after having graduated and I saw this as a possibility to not only learn more about that market, but also to possibly provide a solution to the ever increasing problems the market was facing, especially those of stress in the lower and middle segment.

Throughout this research I was given a great insight into the workings of a municipality concerning its housing programs and was met with a great deal of eagerness to learn about new ways of analysis processes, whilst also learning many new things myself.

I would first and foremost like to thanks the municipality of Zoetermeer and especially Jeroen Scholten for providing me with all the information a needed and making me feel right at home in their new offices. Another special thanks goes out to Elianne van Dam, who throughout my research provided me with the data to conduct the research and dealt with many of my requests concerning many iterations of how the data was aggregated. Additionally, I would like to thank many of the employees at the municipality of Zoetermeer for providing me with many different insights, much information and a general sense of being welcome. I hope all input you gave me, will be met by useful output of this research.

I would also like to thank Peter Boelhouwer and Rein de Graaf for providing me with many points of feedback and letting me pick their brains on specific topics. From the start, they provided me with many useful starting points and as I found my way through them and progressed in my research, they also knew when to reign me back to my original path, as I sometimes to bit of a little more than I could chew.

Last but not least, I would like to thank my family, my girlfriend and my friends for supporting throughout this sometimes stressful period.

II Abstract

Zoetermeer is facing two challenges currently. The first is a housing program which is defined only at a superficial level. Secondly, the municipality has expressed the ambition to also take into account the migration of households, but has no data on which dwellings facilitate migrations the best. This research thus set out to first define the migrations chains which are found in Zoetermeer and then subsequently use this information in designing a suiting housing program.

The outcome of the Markov chain theory, which was used to determine residential migration chain length, showed that a number of dwellings facilitated migration the most. These were the more expensive dwellings in general and middle segment dwellings for households residing for social rental apartments specifically. Second, to construct the housing program, detailing on the living environments and dwelling models was defined and combined with ambition of the city.

Around this information an LP decision-making model was built which could use these constraints and find the optimal solution, if one existed. Ten different housing programs were designed, each with a different aim, and the results were assessed. Out of the ten programs, one seemed the most appropriate overall, as it achieved reasonable values in a number of important variables, including number of migrations, spread and value of newly added dwellings and area requirement. A surprising find was however that one of the programs, which in advance was seen as an extreme, proved to fit the ambitions of Zoetermeer in terms of increasing the city's monetary value and attracting a new type of resident with new dwelling types.

Lastly, a program was designed with the aim of combining all benefits of the other programs into one. This program showed the results of the most overall appropriate program as well as adding a lot of value and the new types of dwellings. To conclude, this research found that the link between the two challenges could be made relatively easily and that the results of the model were very well received after even the first iteration. It should however be mentioned that the input of the model turned out to be very influential and that the municipality had difficulty in defining this input throughout this research as a shift in focus had recently occurred, which resulted in a change of thinking from quantitatively to qualitatively defining goals.

Finally, the two models designed proven to work for Zoetermeer, but were also designed to be used by any other party desiring to either determine migrations patterns, design a housing program or doing a combination of the two.

Keywords: Household filtering, residential migration chains, decision-making models, linear programming, living environments, Zoetermeer

Word count: 48,979

III Bestuurlijke samenvatting

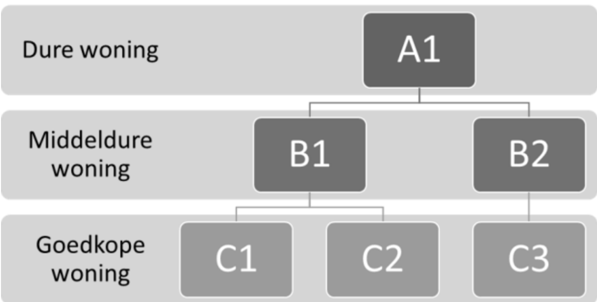
De gemeente Zoetermeer heeft de ambitie om 10.000 tot 16.000 nieuwe woningen te realiseren. Door de juiste nieuwe woningen te realiseren kan met deze woningen echter voorzien worden in de woningbehoefte van veel meer inwoners van Zoetermeer dan enkel het huishouden dat de nieuwe woning betrekt. Dit doordat de bewoner van de nieuwe woning vaak een andere woning achterlaat en deze woning vervolgens bewoond kan worden door iemand die op zoek was naar een dergelijke woning. Door deze keten van verhuizingen optimaliseren te benutten kan maximaal voorzien worden in de woningbehoefte van de inwoners van Zoetermeer. In dit onderzoek zijn deze verhuisketens en het woningbouwprogramma onder verschillende scenario's geoptimaliseerd op basis van een wiskundig beslismodel. Met het model is aangetoond dat tot wel 23.000 verhuizingen gefaciliteerd kunnen worden met de realisatie van 10.000 nieuwe woningen, wat inhoudt dat ongeveer een derde van Zoetermeer kan verhuizen naar een woning die beter past bij hun woonwensen.

Context

De aanleiding van dit rapport was een de wens van de gemeente Zoetermeer om meer inzicht te krijgen in de uitwerking van de woningbouwopgave en het bevorderen van de doorstroming binnen de huizenmarkt. Om in het eerste een start in te maken is er door de raad voorgesteld om het college opdracht te geven om *"invulling te geven aan een woningbouwprogrammering voor nieuwbouw/transformatie, uitgesplitst naar productsegmenten, doelgroepen en type woonmilieus"* (Aptroot, 2016). De eerste opzet hiervan is het woningbouwprogramma van Bureau073 waarop wordt voortgeborduurd in dit verslag. Daarnaast heeft J. H. Scholten (2016) al eens gepast benoemd dat de stad door middel van het bevorderen van de doorstroming *"met één nieuwe woning meerdere huishoudens aan een door hen gewenste woning helpen"*. Dit rapport zal de twee doelstelling proberen te verenigen om zo maximaal te kunnen voorzien in de woningbehoefte van de inwoner van Zoetermeer.

Doorstroming

Een van de doelstellingen van het woningbouwprogramma is om de gehele wooncarrière van de inwoners van Zoetermeer te faciliteren en het onderzoek naar de doorstroming is dan ook uitgevoerd voorafgaan aan het ontwikkelen van dit programma. Dit is gedaan op basis van gerealiseerde verhuizingen over de afgelopen drie jaar, van 2015 tot 2017, en hiervoor zijn gegevens uit het Basisregister Adressen en Gebouwen (BAG) en Basisregister Personen (BRP) gebruikt.



Het proces van doorstroming ontstaat door een opeenvolging van verhuizingen. Over het algemeen verhuist men naar een woning die beter aansluit op de situatie van het huishouden en dit kan onder andere zijn op basis van financiën, ruimtelijke kwaliteit, fysieke kwalitatief of kwaliteit van de locatie. Wanneer men niet "omhoog" verhuist, zal men vervolgens voorkeur hebben voor een woning die dezelfde kwaliteit heeft als de huidige woning en er dus geen verschil zal zijn, bijvoorbeeld van B1 naar B2. Tot slot kan het voorkomen dat men "omlaag" verhuist op de hiërarchie, maar dit komt slechts beperkt voor, aangezien er in dit geval vaak een dwingende factor tot verhuizing moet zijn.

Om te onderzoeken welke woningtypen de langste ketens hebben binnen Zoetermeer is er gebruik gemaakt van de Markovketen theorie. De uitkomst van deze analyse is dat voor het faciliteren van de meeste huishoudens er het beste dure woningen (>€250.000) toegevoegd kunnen worden aan de woningvoorraad. Deze faciliteren naast het huishouden dat naar de toegevoegde woning verhuist nog eens 1.24 tot 1.41 verhuizingen. Daarnaast worden huishoudens die nu in sociale huisvesting wonen, het beste gefaciliteerd om te verhuizen door het toevoegen van middel-dure huur en goedkope koop woningen. Een van de minder effectieve woningtypen is de sociale eengezinswoning, met slechts 1.14 verhuizingen.

Het verschil tussen 1.14 of 1.41 huishoudens lijkt wellicht niet groot, maar het effect wordt duidelijk wanneer gerekend wordt met de gehele woningbouwopgave. 10.000 toegevoegde woningen vertalen zich namelijk naar 11.400 en 14.100 verhuizingen. Dit houdt in dat door het bouwen van de juiste woningen er ruim 2.000 extra huishoudens een woning kunnen krijgen die beter past bij hun woonwensen.

Woningbouwprogramma

Om een woningbouwprogramma te ontwerpen is er gekeken naar de door Zoetermeer gewenste de woningtypen en woonmilieus. In essentie bepalen de woonmilieus de eigenschappen van een gebied en moet de verdeling van woningen voldoen aan deze eigenschappen per gebied. Naast deze eisen zijn er ook nog doelstellingen op het niveau van de stad en hieraan moet het totale programma voldoen, bijvoorbeeld specifieke aantallen sociale huur.

Om de verdeling van de woningen te maken is er een nieuw model ontwikkeld. Het model is een wiskundig besluitmodel, en maakt gebruikt van een proces wat lijkt op de huidige manier van het ontwerpen van een woningbouwprogramma, enkel zonder een aantal van de negatieve aspecten.

Het huidige proces gaat namelijk vaak op basis van het maken van een ontwerp en een opvolgende beoordeling van het ontwerp aan de hand van de eisen van de actoren, bijvoorbeeld de afdeling Stedelijke ontwikkeling binnen de gemeente. Vervolgens zijn er vaak meerdere versies nodig om tot een goed ontwerp te komen en elke versie vergt weken tot maanden om te maken. Dit betekend dus dat het gehele proces relatief lang kan duren.

Het model dat is ontwikkeld voor Zoetermeer heeft deze lange doorlooptijd niet en is in staat de definities van de woonmilieus, de uitkomsten van het onderzoek naar doorstroming, de definities van de woningmodellen en doelstellingen op stadsniveau te verenigen in een ontwerp waarin verschillende variabelen zijn geoptimaliseerd. Dit is in dit onderzoek gedaan door tien verschillende woningbouwprogramma te ontwerpen en ieder van deze programma's had een andere doelstelling. Zo waren er programma's die de waarde van de totale ontwikkeling maximaliseerde, het aantal verhuizingen maximaliseerde en werd ook de het huidige woningbouwprogramma getest op doorstroming. Hieronder zullen de vier meeste interessant programma's besproken worden.

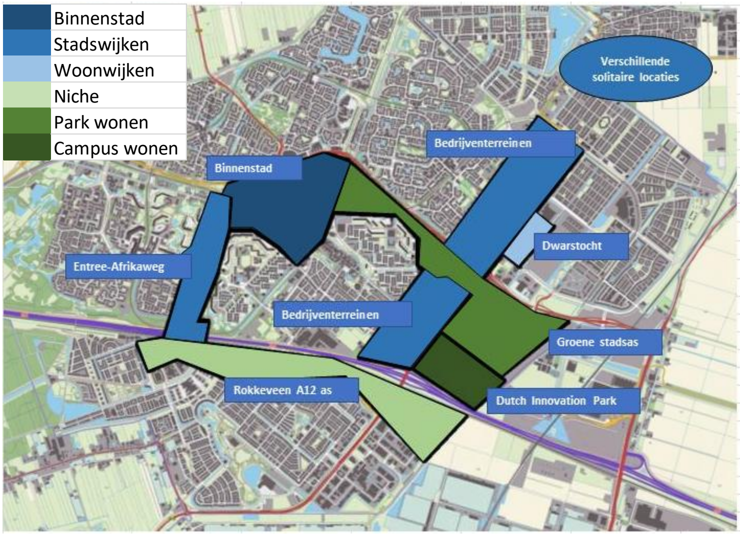
Uitkomst

Van de tien ontworpen woningbouwprogramma's, hierna afgekort als WP's, waren er vier waar de gemeente Zoetermeer potentie in zag. Deze vier waren WP 5, 7, 7b en 9. Daarnaast zal het huidige programma, WP 2, zoals deze beschreven staat in het Woningbouwprogramma van juni 2017 als eerste besproken worden. Deze is ook doorgerekend en geldt als de ondergrens voor alle andere programma's.

WP 2, genaamd "Wat Fakton Adviseert", geldt als ondergrens omdat dit de staat van het programma was voordat dit onderzoek werd gestart. Het is hiermee dus ook het programma waarop daarop daadwerkelijke beleidsdocumenten gebaseerd zouden worden zonder de interventie van dit onderzoek. De resultaten van het doorrekenen van dit WP 2 laten echter zien dat het onderzoek sterk nodig was. De tabel hieronder geeft de vijf belangrijkste uitkomsten weer.

Woningbouwprogramma 2	
Nieuwbouw karakteristieken	Voornamelijk goedkope en middel-dure woningen 29% sociaal, 25% huur, 46% koop
Verhuizingen	22.200 verhuizingen 7.403 sociaal, 4.318 huur, 10.497 koop
Kavel opp.	83 hectare
Versch. woningtypen	13
Gem. woning waarde	€241.000

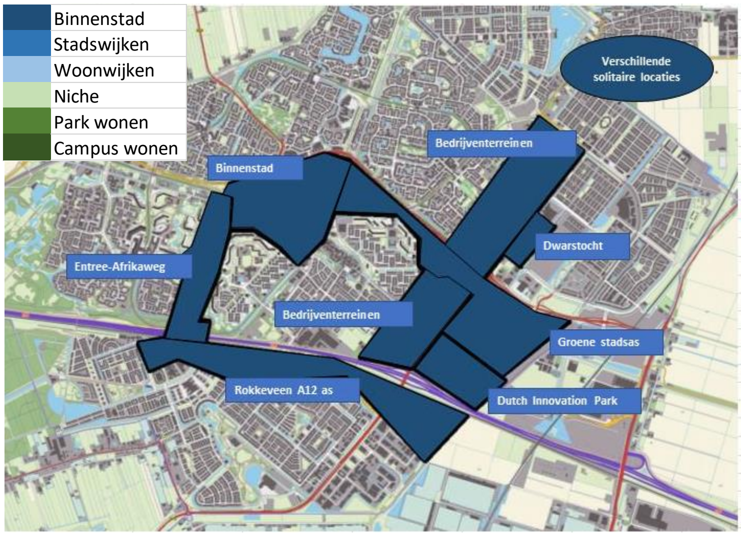
In de tabel is te zien dat het programma een kleine 22.000 verhuizingen faciliteert, wat niet alleen het kleinste aantal gefaciliteerde verhuizingen is, maar op basis van de hierna besproken programma's kunnen betere resultaten relatief eenvoudig geboekt worden, zonder in te leveren op andere doelstellingen. Daarnaast is er een totaal uitgeefbaar oppervlak nodig van 83 hectare, wat het grootste oppervlak is van alle tien de WP's. Tot slot voegt het woningbouwprogramma woningtypen toe die Zoetermeer al in grote aantallen heeft; goedkope en middel-dure woningen. Op basis van dit onderzoek zou men dus kunnen stellen dat WP 2, en daarmee het huidige woningbouwprogramma, erg slecht presteert.



WP 5 was vooraf een van de WP's die veelbelovend leek, aangezien het keek naar zowel het maximaliseren van het aantal verhuizingen als de vraag naar nieuwbouw. Doordat naar beiden is gekeken zal het positieve effect van het geheel maximaal moeten zijn voor de inwoners van Zoetermeer. Het programma heet dan ook "Wat het Volk Wil". Dit bleek ook het geval, want met 22.550 verhuizingen en een verdeling van nieuwbouw die redelijk in lijn is met de vraag, presteert het programma goed op beide vlakken. Wanneer men dit namelijk vergelijkt met de resultaten van WP 2, faciliteert deze verdeling al 300 verhuizingen meer.

Woningbouwprogramma 5	
Nieuwbouw karakteristieken	Voornamelijk appartementen verspreid over prijssegmenten 27% sociaal, 35% huur, 38% koop
Verhuizingen	22.500 verhuizingen 7.145 sociaal, 5.502 huur, 9.903 koop
Kavel opp.	73 hectare
Versch. woningtypen	13
Gem. woning waarde	€255.000

Daarnaast werd er een aanbod van verschillende woningmodellen toegevoegd aan de voorraad en een gedetailleerder beeld van de uitkomsten laat zien dat dit ook is in segmenten die nu nog minder aanwezig zijn in Zoetermeer, zoals de middel-dure en dure huur. Ook het feit dat de gemiddelde waarde van de woningen relatief hoog ligt sprak de gemeente erg aan. Een duidelijk nadeel was echter dat er totaal 73 hectare uitgeefbare grond nodig was voor dit programma en dat 22.550 verhuizingen nog niet optimaal is, zoals later zou blijken.



De volgende twee programma's hebben het nadeel van een groot grond oppervlak niet. WP 7 en 7b hadden als doelstelling de verstedelijking te maximaliseren en programmeerde alle nieuwe ontwikkelingen in de gebieden dus volgens het woonmilieu Binnenstad. De uitkomst van WP 7 was veel gefaciliteerde verhuizingen, in een divers scala aan woningmodellen, maar dit deed het door slechts drie verschillende woningmodellen en geen enkele sociale huurwoning toe te voegen.

Woningbouwprogramma 7	
Nieuwbouw karakteristieken	Enkel appartementen, voornamelijk middel-duur segment 0% sociaal, 60% huur, 40% koop
Verhuizingen	23.100 verhuizingen 4.018 sociaal, 8.264 huur, 10.818 koop
Kavel opp.	11 hectare
Versch. woningtypen	3
Gem. woning waarde	€242.000

Het primaire aanbod was dus beperkt in diversiteit, maar de drie modellen waren die nog niet veel te vinden zijn in Zoetermeer waardoor wel een doelgroep aangetrokken kan worden die nu nog weinig in de stad woont. Tot slot waren de verhuizingen geconcentreerd rond het middel-dure segment en koopwoningen.

WP 7b was een tweede iteratie van WP 7 en probeerde deze dus te verbeteren. Dit werd gedaan door het toevoegen van slechts één aspect en was dat de gefaciliteerde verhuizingen moesten gebeuren binnen de volgende verhoudingen:

- 27% ± 10% sociaal
- 25% ± 10% huur
- 48% ± 10% koop

Woningbouwprogramma 7b	
Nieuwbouw karakteristieken	Enkel appartementen, voornamelijk middel-duur en duur segment 9% sociaal, 60% huur, 31% koop
Verhuizingen	23.100 verhuizingen 5.136 sociaal, 8.341 huur, 9.623 koop
Kavel opp.	11.5 hectare
Versch. woningtypen	5
Gem. woning waarde	€251.000

Zoals te zien is in de tabel hiernaast, produceert ook dit programma de voordelen van veel verhuizingen, weinig benodigd oppervlak en worden er woningtypen toegevoegd die nog niet veel aanwezig zijn. Echter is de verdeling van verhuizingen in dit programma iets gematigder en in plaats van een focus van nieuwbouw op middel-dure koop, is ook hier de verhoudingen tussen de segmenten en typen gelijker en worden er vijf woningtypen toegevoegd. Daarnaast is de gemiddelde woningwaarde nog hoger in dit programma en voegt het dus nog meer waarde toe aan de woningmarkt van Zoetermeer.

Tot slot is WP 9, als combinatie van verschillende WP's, ontworpen. Dit ontwerp gebruikte weer alle woonmilieus zoals WP 5, verplichte het gebruik van alle dertien woningtypen en gebruikt dezelfde verhoudingen voor het door verhuizingen vrijgekomen aanbod als WP 7b. Het had de doelstelling de verhuizingen te maximaliseren. Het resultaat heeft 64 hectare nodig, wat aanzienlijk meer is dan 10 hectare, maar dit is 10 tot 20 hectare minder dan veel van de andere WP's die niet besproken zijn. Daarnaast worden er 23.000 verhuizingen worden gefaciliteerd en dat gebeurt, net als in WP 7b, op een verspreidde wijze wat betreft prijs, type en eigendomstype.

Het nieuwbouwaanbod sluit tevens weer goed aan op de hiervoor genoemde voorkeuren van de gemeente; groot aandeel middel-duur en duur, groot aandeel huur, voornamelijk appartementen en een hoge gemiddelde woningwaarde.

Woningbouwprogramma 9	
Nieuwbouw karakteristieken	Voornamelijk appartementen, voornamelijk middel-duur en duur segment 5% sociaal, 54% huur, 42% koop
Verhuizingen	23.000 verhuizingen 4.536 sociaal, 7.697 huur, 10.767 koop
Kavel opp.	64 hectare
Versch. woningtypen	13
Gem. woning waarde	€273.000

Concluderend kan men dus stellen dat, wanneer de gemeente Zoetermeer daadwerkelijk wil focussen op de doorstroming binnen de woningmarkt, zoals aangegeven is in het meest recente coalitieakkoord van 2018-2022, dat moet zij niet doorgaan met het woningbouwprogramma zoals deze nu bekend is. In plaats daarvan moet zij kijken naar de doelstellingen die zij wil behalen. Een voorbeeld kan zijn het zo goed mogelijk huisvesten van *alle* inwoners van Zoetermeer en dit is een proces waar doorstroming een belangrijke rol in speelt.

Dit wordt enigszins bereikt met het huidige woningbouwprogramma, maar door middel van meer of minder ingrijpende aanpassingen van het programma, kunnen eenvoudig al veel betere resultaten geboekt worden. Ook houdt het in dat, zoals aangetoond in dit onderzoek, de huidige verdeling van 27% sociaal, 25% vrije markt huur en 48% koop niet strikt gevolgd of in ieder geval heroverwogen zal moeten worden, omdat dit naar slechts één aspect van de nieuwbouw kijkt.

Dit onderzoek heeft het gemeentelijk apparaat namelijk een tweede 'bril' heeft geven waarmee naar het toevoegen van woningen gekeken kan worden. De huidige, en enige, 'bril' kijkt enkel naar de directe vraag naar nieuwbouw, maar laat hierin achterwege welke andere effecten deze woningen kunnen hebben. Deze nieuwe 'bril' geeft dus een andere kijk op een bestaande handeling en bied de gemeente de mogelijkheid om effecten van het toevoegen van woningen, die op het moment nog onzichtbaar zijn, maximaal te benutten.

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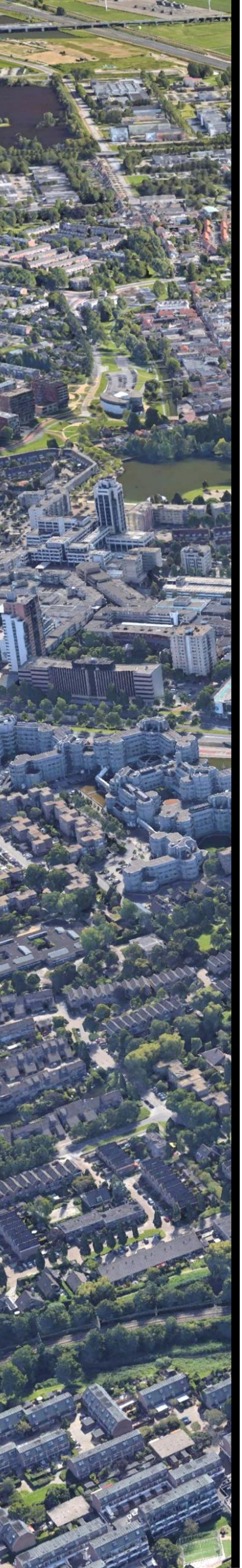
VII List of abbreviations

AP	Apartment
BAG	Primary registry for Addresses and Buildings
BRP	Primary registry for Individuals
DAS	Designing Accommodation Strategies
DMM	Decision-making Model
DoD	Driver of Development ("Woningbouwaanjager")
FSI	Floor Space Index
GFA	Gross Floor Area ("BVO")
GSI	Ground Space Index
L	Layers
LFA	Lettable Floor Area ("VVO")
LP	Linear Programming
MCM	Markov Chain Model
MCT	Markov Chain Theory
O	Owner-occupied
OSR	Open Space Ratio
R	Rental
RMC(s)	Residential Migration Chain(s)
ROS(s)	Run Objective Set(s)
S	Social
SF	Single Family



Introduction

This first chapter will discuss the goals, methods and structure which are at the basis of the report. The problem at the core of this research will be defined and it will be translated into a research goal. Following the research goal, the research questions will be established and methodology for answering these questions will be discussed shortly. Finally, goals will be set concerning the deliverables of this research and the relevance to general and scientific society will be explained. This chapter will close with a short description on the structure of the remainder of this report.

1.1 Problem statement

At the end of 2016, the local council of the municipality of Zoetermeer agreed to add 10,000 dwellings over the following 15 years (Aptroot, 2016) and explore the possibilities of adding a further 6,000 dwellings. This was in line with plans of the Southern Randstad region to add a total of 230,000 dwellings to its regional housing market and was also based on an annual demand of about 700 dwellings (Versteeg et al., 2016). The task at hand is however made more difficult, as Zoetermeer will have to develop most of these dwellings in areas which are currently in use by other functions or through increasing the density of these areas (Chi, 2016).

Another part of the same agreement stated that the council asked the municipal board to provide clarity on a number of points. The most important one was to determine a development plan for housing in the city, which looked at newly constructed dwellings and transformations of existing structures and provided an indication of product segmentation based on price, target or focus group and types of living environments (Aptroot, 2016). This had to be provided before July of 2017 and as a result Bureau073 was assigned the task of developing this program.

In this report by Bureau073 (2017), a development plan for the addition of 10,000 to 16,000 dwellings is formulated and eight focus points were used. These point are:

- 1) Growth of the number of inhabitants and 2) the economy
- 3) Inner-city redevelopment 4) with a long term view
- 5) Quality of housing and 6) public space
- 7) Accommodating the entire living cycle 8) within the city

The report by Bureau073 states that, to start the process of household filtering, the focus should be on the construction of dwellings for starters, empty nesters and families (Bureau073, 2017). However, the report does not provide the municipality with a comprehensive solution to its inner city redevelopment hurdle, as it merely specifies broad terms and with general indications as to how many dwellings should be realised. Furthermore, the report does not provide clear indications of product segmentation based on price and type of living environment. Lastly, the totality of the three mentioned focus groups encompass quite a large proportion of the population and thus the questions of ‘Who doesn’t Zoetermeer want to provide for?’ follows.

The obstacle the municipality of Zoetermeer is thus facing, is the fact that it now has a broad vision on what it wants to achieve for the entire city (Bureau073, 2017), but that this has not yet been translated into a more specified vision for each of the redevelopment neighbourhoods. This could result in the redevelopment of several areas and a subsequent conclusion that the city-wide goals are no longer achievable within the remaining areas without compromising on said goals. For example, if five out of eight areas have been developed, but each of these has seen lower numbers of social housing than would have been needed, then either the other three areas will need to have larger shares of social housing or the city-wide goals will have to be changed, both of which might be undesirable changes. For this reason, the next step for the municipality is to start defining goals on the level of the neighbourhoods, as to prevent a situation like this from happening.

This means that for each of the previously mentioned redevelopment areas, a global indication at least, or a detailed program at most, is desired, as is also specified in the second paragraph on this page. This research will thus continue were Bureau073 has left the problem, which means that a number of steps will have to be taken, but this will be discussed in further detail in the next section.

In a different agreement signed by the municipal council, the plan of action for household filtering in Zoetermeer ("Aktieplan lokale doorstroming in Zoetermeer") (J. H. Scholten, 2016) was discussed. The plan focusses on the fact that the municipality could increase effectiveness of added dwellings by looking not only at its primary facilitation of housing, but also taking into account its secondary effects of household filtering. It stated that by *"developing the right dwellings, more than one household could be given access to their desired housing condition"* (J. H. Scholten, 2016, p.3 [translation by researcher]). These effects have however not yet been investigated by the municipality since the agreement and little is known about the process within the municipality.

The problem faced by the municipality is thus twofold. The first problem is to determine the next step in the development program for the city. The foundation for this was constructed by Bureau073, but has proven to be insufficiently detailed to have a clear use in the development of the city. Secondly, the city wants to optimize the program based on a characteristic of its housing stock of which little is known; the household filtering of different types of dwellings. This thus means that to address the first problem, the second problem should first be solved as it can only then be taken into account when developing the housing program.

1.2 Research goal

As stated in the previous section, the problem of Zoetermeer is twofold and thus the goal of this research is too. The first step is to determine which dwellings have what effect on the household filtering, or migration of the inhabitant of Zoetermeer. Determining the effects of adding a single dwelling of a certain type on the overall migration within the city will provide the second part of the research with clear overall effects of proposed development plans.

The second part of this research will be concerned with the development of the program. This process will take into account many still unspecified characteristics of the problem, such as marginally defined living environments, unspecified dwelling types and limited knowledge on the secondary migration effects of these dwellings. Defining these will aid the municipality in two ways. Firstly, the better defined aims and goals can be used to more effectively enter into discussions with the developing parties. Stating what, for example, a living environment is to Zoetermeer will reduce the amount of steering a developer can do, as it gives clear guidance on the desired future state of an area. At the same time, these should however not be over-defined, as this will inhibit these parties from wanting to get involved. Secondly, it will help in the development of the program which will be developed in this research.

The last objective of this thesis is to then develop a redevelopment plan proposing a distribution of dwelling types and numbers for the eight redevelopment areas. This plan will take into account the demands set by the municipality and the findings of the first part of the research and will be designed using a decision making model, a concept which will be discussed in the second chapter of this report. The result will be an answer to the second problem which Zoetermeer is facing and provide clear development goals for each of the neighbourhoods.

The model which will be provided to the municipality of Zoetermeer could be a starting point of discussion and negotiation position for the development of eight areas within the city. It will provide this, while also taking into account the achievement of general criteria set for the entirety of Zoetermeer. Furthermore, the establishment of goals on the neighbourhood level will also provide the municipality with a better idea of what the impact of a specific plan for a specific neighbourhood is on the overall goals of the municipality. If a developers is, for example, suggesting to build more expensive and less cheap dwellings in an area compared to the numbers defined by the model, then the result is that these dwellings either 1) should be built elsewhere, or 2) will not be built at all. Knowing the effect of specific interventions like these will provide the municipality with a better understanding of the impact of individual decisions made on city-wide goals.

Finally, the report will conclude, based on criteria taken from the municipality, which housing program would be best fitting to the goals of the city. This means that out of a number of solutions based on different strategies, the best solution will be taken or a combination of solutions is proposed. Ideally, this housing program would be such a good fit that it is almost instantly applicable, but due to the extent of this research and the researcher's inexperience this is unlikely to be the case.

1.3 Research question

Central to this thesis is the main research question of:

> *To what extend do different dwelling types aid in household filtering in Zoetermeer and how can they be constructed within Zoetermeer in light of its redevelopment plans?*

This main question will be answered with the use of further sub-questions, which for the former part of the question are:

1A. What is the demand of inhabitants within the city of Zoetermeer in terms of newly built housing?

This question will mostly focus on determining the demand, which is being placed on the current market of Zoetermeer, but focusses specifically on the demand of the future inhabitants. Answering this question will provide an answer to the demand side of the problem of household filtering.

1B. How is the current housing stock of Zoetermeer distributed?

This research question will be focussed on the establishment of a baseline and comparable picture of Zoetermeer. This baseline can be used to compare for example the distribution of residents migrating out of the city to the overall distribution of citizens based on a characteristic of the dwellings.

1C. How long are the different residential migration chains?

This last sub-question will focus on determining the length of the current residential migration chains. This range will indicate the theoretical total number of migrations, or both primary and secondary supply combined. This chain length will be used to indicate the theoretical migrations facilitated by a given housing program and can thus subsequently be used to optimize a housing program.

In addition, the development of a housing program requires answers to a number of questions, which will aid in answering the latter part of the research question. These are:

2A. Which model type is most suitable to answer the problem of Zoetermeer?

To supply an answer to Zoetermeer's question concerning the development of the most appropriate housing for a futureproof stock, the research will assess a number of model types which are capable of developing such a housing program. It will be concerned with assessing the appropriateness of a verbal, graphical and formal decision making models in providing the answer.

2B. How does the municipality of Zoetermeer define the living environments specified in the development program?

The definitions of the living environments are of major importance due to their control on the characteristics of an area and it being the largest determinant of what an area looks like. Especially at this early stage in the process, having a clear idea of what is desired in an area in terms of dwelling types, area characteristics and, indirectly, target groups is both challenging and useful to the overall process and the definition of the program. Defining these environments also was one of the tasks set out by the local council.

2C. Which dwelling types can be used to construct the development program?

When developing a housing program for the municipality it is naturally important to know which dwelling types can be used to construct the program. This question will thus aim to further detail the different dwelling models which will be used and will build on the distinction as made by Fakton. This too was one of the tasks assigned to the municipal board by the council.

2D. Which variables should be optimized for in the model?

This question is of importance because of the nature of the decision making model or DMM. Especially in a mathematical DMM, a specific variable will be maximized or minimized, i.e. profits for the developer will be maximized, land use will be minimized or cost coverage for the municipality is maximized. The value that will be optimized can thus influence the outcome of the model greatly, as its relative pull affects the variables. If, for example, developer's profit is maximized, then other requirements such as a need for less expensive, and thus less profitable, dwellings can be affected adversely.

1.4 Methodology

1.4.1 Type of study

Within the field of research there are several methodologies. They differ on several points, but the two more important for this report are empirical and operations research. The former is focussed on knowledge-related problems and has the aim to produce knowledge and formulate explanations. It looks at the past and tries to understand what happened. This type is also called descriptive research, due to its describing nature. (Barendse, Binnekamp, De Graaf, Van Gunsteren, & Van Loon, 2012)

The empirical aspects of this research will be done through both quantitative as well as qualitative research. The difference between the two has been of much discussion throughout the past decades (Krantz, 1995). In his article, Krantz provides a table by Reichardt and Cook, which shows a number of differences between quantitative and qualitative research. Most notable are:

Qualitative	*Quantitative*
Subjective	Objective
Insider's view	Outsider's view
Process oriented	Outcome oriented
"Real", "rich" and "deep" data	"Hard" and replicable data
Ungeneralizable data; small sample	Generalizable data; large sample

Table 1: Selection of Qualitative vs. Quantitative research characteristics (Polit & Beck, 2010; Reichardt & Cook, 1979)

Qualitative research will be used to identify Zoetermeer's insider view concerning living environments and detailed requirements of redevelopment in general. These could also be found using a more quantitative approach, i.e. reviewing a larger number of cases and taking the most often occurring environment definitions, but this would result in a general answer and solution, rather than a one specific to Zoetermeer's situation.

The quantitative research will be used to answer questions concerning the household filtering. This concept will be looked into using aggregated data about residential migrations on a city-wide level and will be analysed using mathematical theory.

The second type of research, called operations research, is not focussed on the past and describing phenomena, but aims to change a situation or create an artefact to do so. This can be anything, tangible or intangible, that has an impact on a situation. Examples of artefacts are designs for buildings, proposals for organisational changes and mathematical models. These try to improve the situation at hand and thus looks at the future. This study type uses a prescriptive methodology, as it aims to prescribe a different method of doing things. (Barendse et al., 2012)

In this research, prescriptive methods are found in the designing and constructing of a model which aids in the programming of redevelopment plans. This artefact will aim to alter the future state of the dwelling stock and does so by providing possible interventions.

This research will thus use a combination of the two types of research types and methodologies described above. The first part of the study will focus on describing the current situation, i.e. the first part of the main research question and sub-questions 1A, 1B and 1C. The research will then continue to use a prescriptive methodology to translate the findings of the first part of the research into a housing program with the aid of a design tool which can be used as the foundation for further discussions on the inner-city redevelopment of Zoetermeer.

1.4.2 Methods and techniques

The following segment will describe the different types of research methods and techniques that were used in this thesis. This thesis, as explained in the previous segment, does not use one single methodology and the following segment will thus explain several methods of research that will be used throughout.

Literature review

An initial literature study will be conducted in order to establish the correct terminology and provide further research with a framework to work within. The outcome of this part of the research will delve into key concepts of the overall research, but also other research methods which are explained superficially below. The literature that was examined will not be limited by age, as the topic of household filtering already entered the field of research in the 70's and the research done in this era is still relevant in terms of their concepts. Hypothesis can also still be applied to the current situation, even though the situation has changed (Little, 1976; White, 1971).

Research structure

In general, this research will be following the methodology of the DAS framework, which received its name from and is commonly used in Designing Accommodation Strategies in corporate real estate (De Jonge et al., 2009). It can however easily be applied to accommodation strategies for residents of municipalities and subsequent development plans, due to the similarities of having a (mis)match in the current supply and current or future demand and the ability to alter the future supply through intervention (For examples see: Ensing, 2012; Hoekstra, Boelhouwer, & Gunsing, 1998).

This framework sorts a process into nine steps, which together circle through assessing the current situation, exploring the changes in the situation, generating possible futures and defining projects to alter the current situation. These steps are visualized in Figure 1 and explained below.

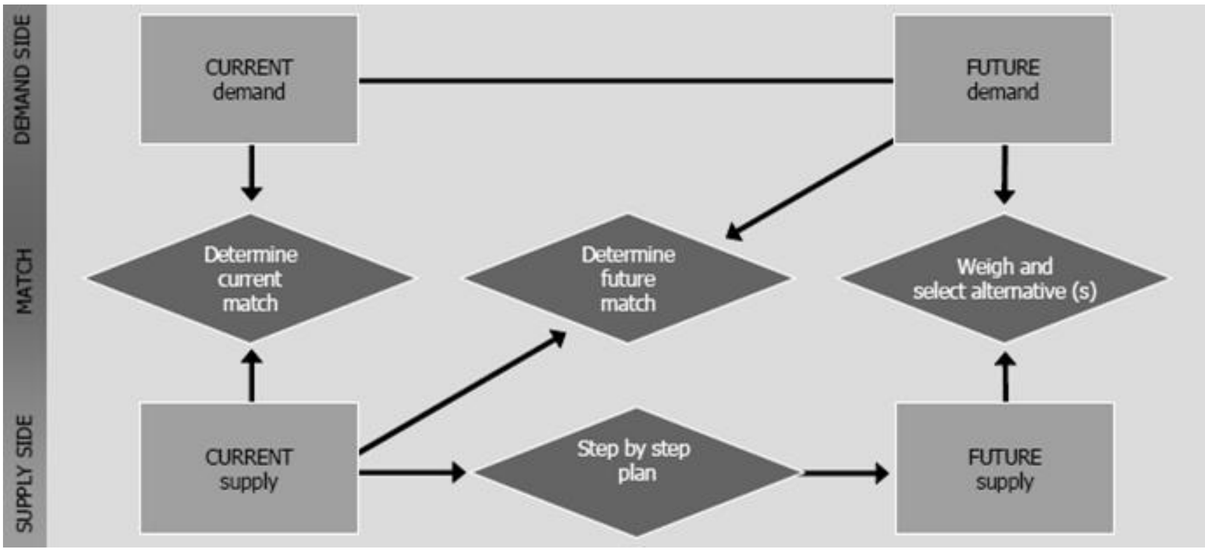


Figure 1: DAS Framework (De Jonge et al., 2009)

1. Determine the current demand
2. Determine the current supply
3. Steps 1 and 2 provide a current match
4. Exploring the changing demand *[positioned between Current demand and Future demand, but missing in Figure 1]*
5. Determine the future demand
6. A future (mis)match is concluded from Steps 2 and 5
7. To come to a future supply, different alternatives are designed and assessed
8. Determine the future supply based on Step 7
9. Design step-by-step plan to achieve the future supply

The DAS framework includes the other methods of research that will be used. The first six steps are incorporated in the data analysis, whilst the latter three steps are incorporated in the modelling that will be done at the end of the process. The DAS framework however also depicts the cyclical nature of the process, as the process of development for the betterment of an area does not stop after the realisation of a project, but will continuously have to be updated to reflect the continuously changing situations and trends. Chapter 2 will provide more information on the DAS framework.

What should be noted is that the usual process of the DAS framework is done step by step and this will not be the case in this research. Whilst the DAS framework usually relies on designing several solutions and evaluating the options (Step 7), the use of a more advanced DMM can eliminate the need for this iterative process.

Data analysis

– Markov chain theory

The third chapter of this thesis will be concerned with the data analysis of several sets of data. These will provide answers to sub-question 1C. The datasets to be analysed will contain information about the migration of residents of Zoetermeer and will be used to determine the residential migration chain lengths. This will be done with the use of the Markov chain theory (Hoekstra et al., 1998; Teule, 1996; White, 1971). This theory at its core explores the notion that a relationship exists between two subsequent states of the same object (Ross, 2014). Examples of these are the price of a stock through time, the number of students attending lectures throughout a semester or the type of dwelling that is left behind when moving to the next. Through the use of this model, a prediction can be made as to which dwelling types are most beneficial to internal migration. Further elaboration on this concept and its application will be done in Chapter 2.

Interviews and discussions

The previous paragraph focussed on the quantitative aspect of the research, but to determine a number of actor demands and living environment definitions, qualitative research will also be done. This means that interviews taken and discussions will be held with individual actors and in groups to determine their demands and views. A discussion will also be done to determine the definitions of the living environments according to the municipality of Zoetermeer, as mere literary definitions do not take into account the specifics of the city's policies.

Mathematical modelling

– Decision making model

The final method of research is the development of a decision-making model, or DMM, that is capable of combining the findings of the research described above and demands set by different parties into a provisional design solution. It will thus also use the answers of sub-questions 2A to 2D, and answer the latter part of the main research question. A DMM can take a number of forms, including verbal, graphical, and formal or mathematical. Each of these will be described in more detail in '2.1.6 Decision making model and LP model'. The latter of the three will be used in this research.

This decision was made due to the large number of actors and requirements, but also due to its relatively new use in area development. Additionally it is rather fast in use in comparison to the traditional process of design and control, i.e. graphical, which can be relatively lengthy. On the contrary, a mathematical model takes longer to get the first results, but can shorten the time taken by subsequent iterations. This is due to the fact that defining the input and the process in advance of designing takes longer due to its need for detailed input, but the process after defining it is shorter and subsequent iterations can be made in relatively little time. The differences can be compared to the differences between a traditional building contract and a 'Design and Built' contract. The former shows results faster, but can take many iterations before resulting in the final design. On the contrary, the latter takes time to see the initial designs as the program of requirements has to be formulated in high detail, but the result is a process that approaches its final design faster after the design phase is started. This of course does not account for the different types of projects in which the two of contract types are usually used.

The model that will be used to design the program is a Linear Programming, or LP, model. An LP model is a mathematical DMM, which can take into account multiple constraints and calculate the optimal solution within a specified bandwidth of variable values. An LP model will, in the case of area development, not provide its user with a graphical spatial design, i.e. a drawn design of the different areas, but will provide an answer whether a numerical solution exists and what that solution would look like, i.e. a numerical distribution of dwellings (Barendse et al., 2012). In Chapter 2, the literature review will further explain the concept of an LP model.

The model will require a range of variables, of which both the extent and the significance can be defined. This means that a model is almost tailor-made to the actors using it and these actors can exactly define what it is they want to have included in the model. The model is intended to be used by any municipality and will thus not be tailor-made for Zoetermeer, but rather for a municipality looking to design a housing program.

Based on the reports by Versteeg et al. (2016), Bureau073 (2017) and Aptroot (2016), these variables appear to be defined on a city and neighbourhood level. For the latter this would take the form of living environments, "woonmilieus" in Dutch (Bureau073, 2017; Versteeg et al., 2016). This means that a certain living environment is assigned to a neighbourhood and based on the characteristics of the living environment, the neighbourhood will be a given certain spatial goals to meet, like average value or size of the dwelling. The variables are however not fixed yet and will thus be defined in discussion with several stakeholders from several departments within the municipality of Zoetermeer.

In the case of this thesis, the model will at the end provide the municipality of Zoetermeer with an initial idea of what a possible masterplan could look like in terms of numbers of dwellings and the area required to realise these dwellings, but also provide the department of city planning with a tool to use in negotiations with several actors.

1.4.3 Data collection

Data collection is essential to the validity of this research, as the supply of dwellings to be realized has to match the demand by future households as closely as possible. To do this, the only source one has is the past and thus databases containing past migrations are required. Obtaining this is one of the hurdles that is usually encountered when using Markov Chain Theory. The theory requires for a number of conditions to be met within the dataset that is used. These will be discussed in the second chapter of the report, but meeting these requirements usually requires a large dataset of migrations, which can be challenging to researchers collecting their own data. This research however was given access to data through the Research and Statistics department of the municipality of Zoetermeer, who combined two separate databases to provide the type-to-type migration counts and detailed characteristics of the inhabited dwellings. These databases are the BAG and BRP, which are discussed below.

Since the 1st of July in 2011, governmental organisations in the Netherlands are required to register data on the addresses and buildings within their jurisdiction. This is done in a registry called the Primary registry for Addresses and Buildings ("Basisregistratie Addressen en Gebouwen") or BAG. This registry contains information on buildings in an area, in this case Zoetermeer, such as indoor area, WOZ (dwelling value used for tax purposes), the type of dwelling and whether it is a rental or owner-occupied dwelling (Ministerie van Infrastructuur en Waterstaat, 2018). The database contains many more variables, which can be found in 'Appendix A – BRP and BAG' section (2), but these won't be used.

This database however only contains information on the building and cannot provide data on migrations. For this, the Primary registry for Individuals ("Basisregistratie Personen") or BRP is used (Ministerie van BZK, 2017). This registry was preceded by the municipal registry and was updated in law on the 6th of January of 2014. The database again contains a wide variety of variables such as age, nationality and dates on which a household moved into the dwelling and from where they came. The full list can be found in 'Appendix A – BRP and BAG' section (1). This database showed an internal migration count of approximately 6400 people within Zoetermeer in 2017 and similar, albeit lower, numbers were found for the years prior. Moreover, data on households new to the city is available, which will be used in the analyses as well. Combining both databases provides detailed information on the migration patterns of the residents that move within Zoetermeer.

The databases contain highly private information on individuals and their housing situation and thus the research could not be given direct access to them. The data was thus condensed into a matrix of type-to-type migration counts. This does not affect the accuracy of the data or reliability of the outcome, as the Markov chain model looks at the type-to-type recruitment chance. The matrices provided by the municipality also do not breach the privacy of the inhabitants of Zoetermeer and do not disclose any information on the individuals.

The dataset that was provided by Zoetermeer counted approximately 18,000 internal migrations, 15,000 inhabitants moving to Zoetermeer, or arrivals, 16,000 inhabitant moving away from Zoetermeer, or departures, and spanned a period of three years, from 2015 to 2017. Data was available for the years 2012 to 2014 as well, but due to limitations in time and irregularities in the databases from year to year, the analyses was limited to the most recent years, as these also contained the most useable variables. An example of this is the number of unique entries found in the category describing the dwelling type, which ranged from as few as 11 different entries to as many as 63. The fewer entries were found in a relatively new category, which was only found in more recent years.

1.5 Conceptual model

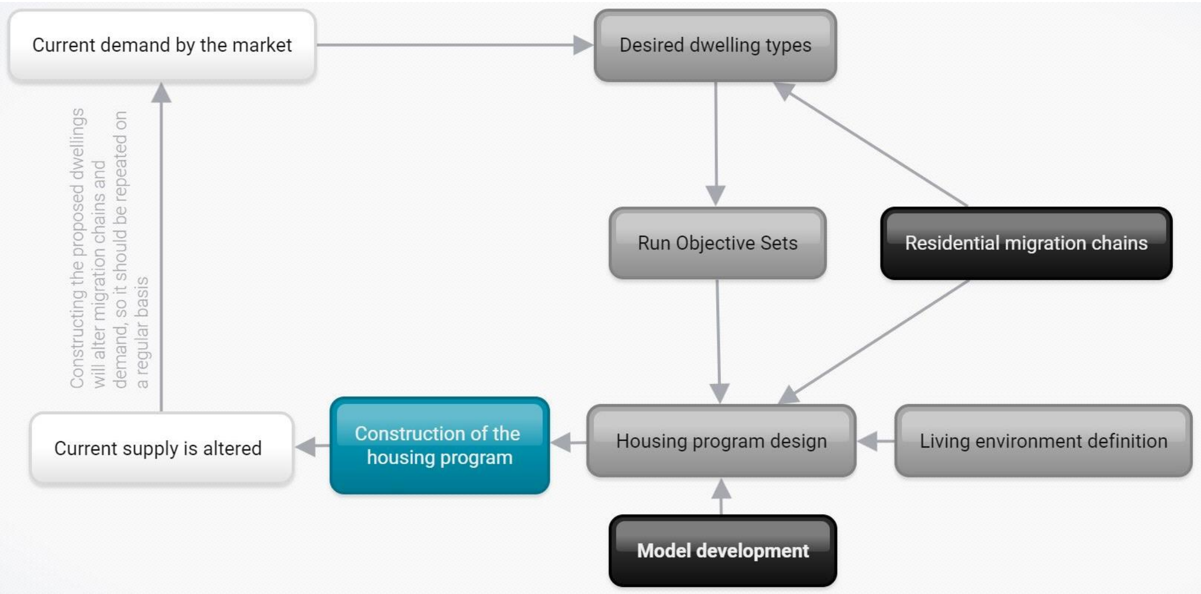


Figure 2: Conceptual model of research design (Own illustration)

The conceptual model, portrayed in Figure 2 is largely based on the previously described DAS Frame by De Jonge et al. (2009) and describes the previously mentioned methodologies in relation to each other. The black boxes represent the two major pillars of this research and the grey indicate processes needed to define the final product of a proposed housing program. The white boxes represent processes outside of the control of the research and the blue box indicates an intervention which has to be done. Each step will be discussed below briefly.

The model starts in the top left corner with determining the current demand by the market, which was done in previous research by Fakton (Versteeg et al., 2016). Within this demand, the current supply of Zoetermeer was taken into account, so thorough comparing of the two and determining the mismatch is has already been done.

Alongside this entire process, the residential migration chain lengths will be determined. This process, as explained, will involve the analysis of migration data using Markov chain theory. Together with the market demand it will provide input for both the desired dwelling types and the design of the housing program. Similarly, living environment definitions will provide input to the design of the housing programs, as these will control most of the input on the plan area level. These definitions have to be formulated however, as the current definitions are in fact vaguely described and general in nature, whereas definitions numerical and specific to Zoetermeer are required in order for a mathematical model to be able to work with these inputs.

The next step in the research is to determine run objective sets, ROSs, which represent possible focusses of the housing program for Zoetermeer. These can be described as the goals of the model and will based on different objectives which have to be accomplished within the housing program. These strategies will be formulated in close collaboration with the municipality of Zoetermeer to represent possibilities which are realistic, albeit sometimes unlikely or unwanted to be realised. An example of an unwanted, but useful, aim could be the redevelopment of all areas into highly urbanized living environments. Although this is unlikely to be realised, it could show insight into the effects of exclusively constructing apartments, which is likely to happen as a result of such an aim.

Another major part of the research is the development of the model which will use all inputs of the previous steps to actually design the housing programs. This process will result in a model capable of combining the goals, aims and wishes of the municipality and provide it with a housing program, if one exists, that will satisfy all demands. It should furthermore be capable of taking into account minor or major adjustments that emerge throughout the process. As a result of this process, a housing program will be designed which matches what Zoetermeer is aiming to achieve and this program could be implemented. The implementation is what the blue box represents, but as this involves the actual construction of dwellings, this will be done after the completion of this report.

Important to note is the cyclical nature of the model, as these newly constructed dwellings will become the new current supply which means that the cycle starts anew. Furthermore, the demand by the inhabitants is likely to change, the migration chains will change and, as a consequence of the above, the future supply will thus have to be altered on a regular basis to have the best fit between realised dwellings and the theoretical effects which are desired.

1.6 Research output

In order to complete this research, a number of objectives need to be achieved. The following paragraph describes them in chronological order and also explains the interdependencies between certain objectives. Figure 3 shows these tasks and their relationships.

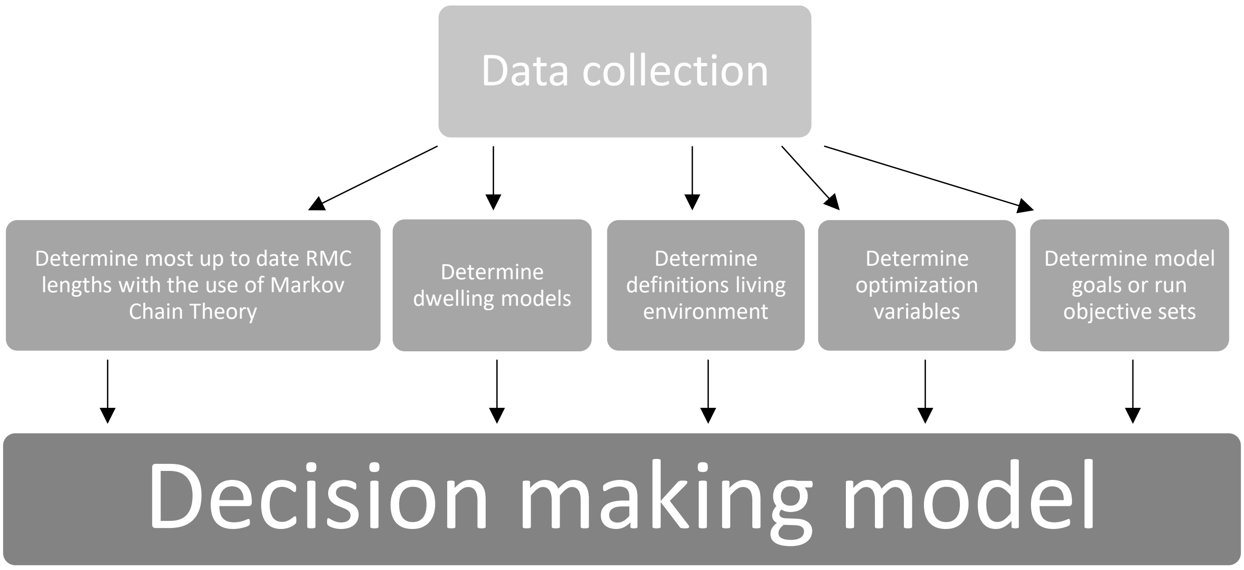


Figure 3: Main tasks and milestones (Own illustration)

The first objectives to complete is the initial collection of data. Data collection encompasses the collection of data relevant to all following tasks. The largest part of this will however be aimed at collecting data to analyse in order to determine the residential migration chains or RMCs. Besides the data need for the RMCs, data will also be collected to determine definitions of living environments and to provide backgrounds for the concepts of FSI, GSI, OSR and L.

After data collection, the processes of determining a number of factors will start. The analysis which will result in RMC lengths will use the Markov Chain Theory and the results will be indications of total number of facilitated migrations. Other important aspects of the model which have to be determined are the definitions of the living environments. These will determine most of what the municipality will be able to control in terms of what an area will look like. Both the defining the characteristics as well as defining the values of these characteristics will be done in cooperation with Zoetermeer or be based on reference or previously initiated projects. Last in terms of defining variables, the dwelling models are going to be defined. These will represent the dwellings which can be used to construct the housing program proposal.

Next, in order to provide aim for the mathematical model, the variables which will be optimized are going to be determined. This step will result in a single or multiple variables which are going to be maximized or minimized in order to achieve the best possible outcome. Lastly, a number of model goals or "run objectives sets" will be determined. A run objective set is a set of variables which have to be optimized as well as an explanation of the criteria which have to be taken into account when designing a housing program. This means that through different combinations, different objectives can be achieved, either independently or simultaneously. This will be done in order to show both the strength of the model, which is that it should be capable of quickly adapting to different inputs, as well as providing the municipality with a few different programs to use when designing the final program.

The last step in the process of this research is to combine the living environments, the RMC lengths and the characteristics of the dwellings into a numerical design for the eight neighbourhoods which are going to be redeveloped. This will be done using a mathematical DMM, which will use these variables as inputs and provide a number of outputs as a result.

1.7 Relevance

1.7.1 Social relevance

Socially, this research is relevant because of a growing trends of mismatch between the supply of several local market and the demand that is placed on specifically the middle segment of the housing market (Hekwolter of Hekhuis, Nijskens, & Heeringa, 2017). Throughout the Netherlands this trend is resulting in an increasing gap between cheaper social housing and the private rental market. This is combined with an increased knowledge of municipalities to construct not that which is directly in demand, but also look at the overall effects of adding dwelling of other types and taking into account existing stock. Through the process of household filtering, a dwelling which is in demand could still be made available, as its previous inhabitant moves up the chain of the dwelling hierarchy.

The research is also important to society in that it tries to aid in the process of developing housing programs aimed at providing housing possibilities to the entire society. The larger region to which Zoetermeer belongs has also set goals of increasing the housing stock by a fair amount and Zoetermeer has been assigned the task of constructing 10,000 dwellings. This however has to be done within its city limits and doing so provides a significant challenge. This research will also aids in this latter process, as it will not only provide a proposal of a housing program, but also an indication as to the space that is required to realise the program.

1.7.2 Scientific relevance

In previous research, the Markov chain theory and decision making models have been developed to assess residential migration and develop housing programs respectively. Both have been used in practice very little however and this research attempts to show their individual uses. What is also not shown in literature is the use of both on one subject, but a combination could be useful due to the relationships between the outcomes of the individual methods. This thesis could thus also provide new insights into and advantages and disadvantages of the combined use.

1.8 Structure

To conclude, the structure of the entire report is as follows. The report will start out with a literature review. This literature review in Chapter 2 will focus on defining key concepts and describing the methodologies, explained in the '1.4.2 Methods and techniques' segment. Chapter 3 will then describe Phase 1 of the DAS Frame, which consists of the definition of the current supply and demand. This chapter will also present the research and outcome concerning the residential migrations chains using the Markov chain theory. The results of this phase will be used in Phase 2. This second phase will be discussed in Chapter 4 and will involve the development of run objective sets.

Chapter 5 will describe Phase 3 and continue the process with the designing of the mathematical model. This model will use several inputs, which will be taken from previous steps or be defined and elaborated on in Chapter 5. The last phase, Phase 4, will be discussed in Chapter 6. The process of coming to the final numerical design will be elaborated on in this chapter and the result will be presented. After the body of the research is concluded, this thesis will end with a conclusion and reflection on the results and findings of this report.

Lastly, to clarify the indication of structure used in this report, the hierarchy of is as follows; chapter>section>segment. An example of this is Chapter 4, Section 2 and Segment 5, which is the same as 4.2.5. This will thus also be the terminology used in referring to each. Anything else will always be referred to as a 'part', independent of its size or location within a chapter.

Literature review

This chapter will involve an extensive review of the literature that is available on a multitude of subjects that surround this research. These subject are, in order of appearance, household filtering, living cycle and dwelling career, residential migration chains, DAS Framework, Markov chain theory, decision making models and the concepts of FSI, GSI, OSR and L. The relationship between these concepts and the goals of this research will be explained in the first part of this chapter.

2.1 Concept definition

To further develop a plan for the improvement of the household filtering a literature review will first be executed. This review will delve deeper into various subject, which are key to the legitimacy of the plan.

The first topics are related to concepts of household migration and are important to define in order to understand the processes which are aimed to be advanced or initiated. The first is the concept of household filtering, which is the process of household A moving to a different dwelling and, in the process, leaving their dwelling available to be inhabited by household B. This process is central to this research and is the focus of the Markov chain and will be further explained in Markov chain. The second and third concepts, living careers and residential migration chains respectively, are related to the first and concern the processes related to household filtering.

The second set of concepts is related to the various processes which will be used to form a development plan that is appropriate to the context of Zoetermeer and takes into account the local variances. These concepts include the DAS framework, the Markov chain theory, decision making models and a number of indicators of density. The former is the framework in which the process of research will be placed and describes a reasoning for determining supply, demand and a resulting mismatch in both the current state and in future scenarios. The Markov chain theory will be used to determine the lengths of migration chains, which in turn represent the amount of households relocated by adding one dwelling of a certain type. The outcome of this analysis method will be used to show the impact of proposed plans. The decision making models segment focusses on a method to translate the outcome of the Markov chain into a plan that at its core meets demand by several stakeholders. A mathematical decision making model is used in this research, but the segment will also discuss other methods and the reasons for not using those.

Lastly, the segment on density indicators will introduce a number of relatively new indicators of area density. These indicators focus on square metres rather than dwellings or people within an area. These concepts are called FSI and GSI, OSR and L and each indicate a different ratio or relationship within a built area.

2.1.1 Household filtering

The first and most central concept to this research is the concept of household filtering, or "doorstroming" in Dutch. This concept has been described by several authors and can be defined as the process of moving from one dwelling to another, leaving behind the previous dwelling for a new household to inhabit and this sequence is called the residential migration chain (Boumeester, 2004; Chase, 1991; Little, 1976; Renes & Jóvövi, 2008). This process is usually initiated by the need to improve the fit between the needs that a household has concerning their dwelling and the dwelling that is inhabited at the time (Chase, 1991; Little, 1976; Renes & Jóvövi, 2008; White, 1971). Furthermore, this change in needs is commonly altered by a change in position in the living career, which will be discussed in the segment '2.1.2 Living cycle and dwelling career'.

Household filtering is central to this research, as the advancement of it is one of the main focusses and a central driver of the redevelopment plans. Two factors which impact filtering are the supply new dwellings and the ratio between the price of renting and owning a dwelling (Renes & Jóvövi, 2008). The former is important due to the fact that it, along with the 'death' of a household, creates the initiating dwellings of the migration chains (Boumeester, 2004), or primary supply. On the other hand, the price ratio is influential due to the fact that a household needs to be financially capable of migrating between dwellings. This however means that in a market of rent regulations, like the majority of the Dutch rental housing market, household filtering between rental and owner occupied dwellings, is less prevalent (Renes & Jóvövi, 2008). This is due to the fact that people are not forced to move on, as regulation until recently forbade social housing tenants to ask for income statements after initiation of the contract. Furthermore, people were disincentivized to move on voluntarily as it usually meant an increase of cost per square metre, i.e. either costs would go up and size would remain the same or size would go down and costs would remain the same.

2.1.2 Living cycle and dwelling career

The living cycle and dwelling career are both terms that refer to paths that households pass through in their life time. The living cycle is important to household filtering, because it is assumed that households migrate in conjunction with them, i.e. when they change phase in their living cycle (Boumeester, 2004; White, 1971). This means that households are most likely to move house when, for example, a child is born, due to a promotion and increase of salary or after the death of a family member, which are each stages in the living cycle. The reason for this migration is due to the fact that a households' needs are no longer met by the dwelling they inhabit (De Groot, Manting, & Boschman, 2008). This thus causes them to attempt to improve this fit, which is, as explained before, part of the process of household filtering.

The dwelling career is closely related to the residential migration chain, which will be discussed in the next segment, as it too looks at the links between dwellings. The former identifies a link between different dwellings made by one household and looks at it from a user or consumer perspective. The latter, however, aims to identify the link between different dwellings made by different households and looks at it from a supply perspective. Furthermore, the link in the dwelling career is established over years or decades, i.e. long term, whereas the link in the residential migration chain is established over months, i.e. short duration. This difference is due to a rather slow need for chance of one household, because people do not move in rapid succession. On the other hand, the movement of a number of households can be very fast, as the becoming available of a dwelling will most likely result in a subsequent migration within a short period of time and could thus theoretically result in a number of rapid and successive migrations.

Figure 4 shows a typical dwelling career and Figure 5 shows a typical residential migration chain.

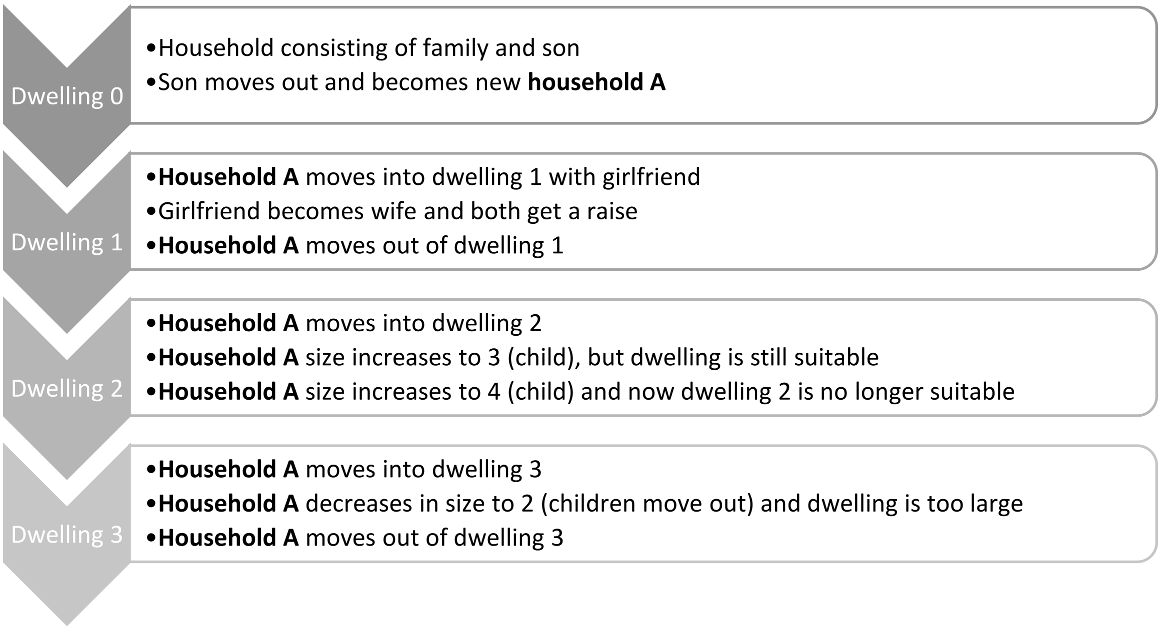


Figure 4: Typical dwelling career of a starter (Own illustration)

2.1.3 Residential migration chains

Household filtering thus is a process which requires several households to move within a confined area and in that process leave behind an empty dwelling at each step in the process (Chase, 1991; Hoekstra et al., 1998; Renes & Jóvövi, 2008; Teule & Van der Heijde, 1995; White, 1971). The chain that is formed is called the residential migration chain (RMC), or "verhuisketen" in Dutch. This chain is of varying length for different types of households and can be established by following the sequence illustrated in Figure 5.

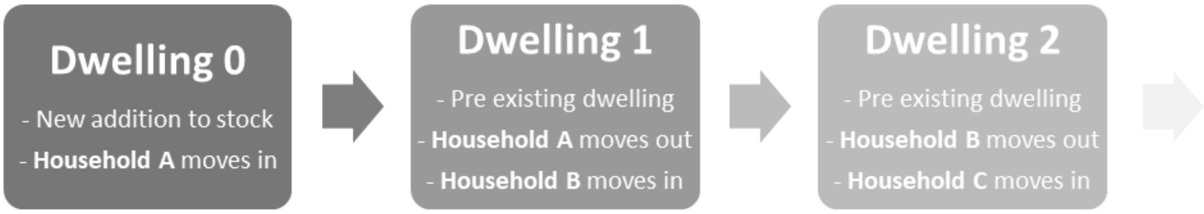


Figure 5: Typical residential migration chain (Own illustration)

This illustration shows what a typical residential migration chain looks like. The dwelling which initiates the chain is commonly a newly built dwelling or a dwelling which becomes available because a family leaves their current dwelling and moves out of the area, respectively referred to by White (1971) as the "creation" and "death" of a household. After becoming available, this dwelling is inhabited by household A, who vacate their previous dwelling, Dwelling 1 in the illustration. This dwelling can subsequently be inhabited by household B, who in turn vacate their dwelling, Dwelling 2. This will continue until the dwelling that is left by its occupier is either inhabited by a household from outside the area, a household 'death' in that area, inhabited by a household new to the market but originating from within it or through demolition of the dwelling (White, 1971).

Determining the lengths of the chains can be done in one of two ways. The first is too manually track migrating households "downstream" as it were. This means that the chain is started at the very first link of the chain, i.e. at the household moving into the newly available dwelling. The household's previous residence is then visited and the household there is interviewed to determine their previous residence. This is continued until the last link is found. However, this is a time-costly process, as a lot of face-to-face contact with the migrating households is required. A second way of finding the RMCs is to use aggregated data and the mathematical theory of Markov chains. This theory will be explained in segment '2.1.5 Markov chain' in detail, as this was the method used in this research.

These RMCs are, as stated above, of varying length for different types of dwellings. In general, the notion is that the higher the dwelling is positioned in the dwelling type hierarchy, the longer its RMC will be (Hoekstra et al., 1998; Teule & Van der Heijde, 1995). This can be validated with reason, as the logical migration throughout most of a household's live is characterised by an increase in use or size or improvement of characteristics of the dwelling that is inhabited (Little, 1976; Renes & Jóvövi, 2008; White, 1971). This means that the positions in the chain from which one is willing to move to a cheap, poorly maintained and small dwelling are very limited (Dwelling C1, C2 and C3 in Figure 6), as this is either a downgrade or achieves no improvement at all. Contrarily, the dwellings from which one is willing to move to an expensive, well-maintained and large dwelling (Dwelling A1 in Figure 6) in the hierarchy are far more abundant. Teule classified the two types as unpopular and popular dwellings (Teule, 1996).

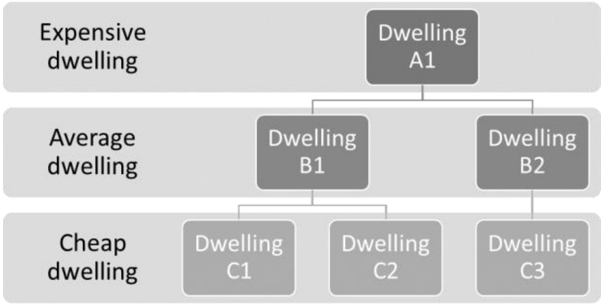


Figure 6: Example of generic dwelling type hierarchy

Figure 6 shows a generic dwelling hierarchy and illustrates the aforementioned. In this scheme, it is taken that households are determined to and financially capable of moving up in the scheme, but can also move sideways. This means that five households are gladly willing to move to dwelling A1, whereas only two households would consider moving to dwelling C1, as it would not result in an increase of housing quality.

2.1.4 DAS framework

The overall structure of the research is based on the DAS Framework, which is short for Designing an Accommodation Strategy and was developed by De Jonge et al. (2009) as a method for designing accommodation strategies for corporations.

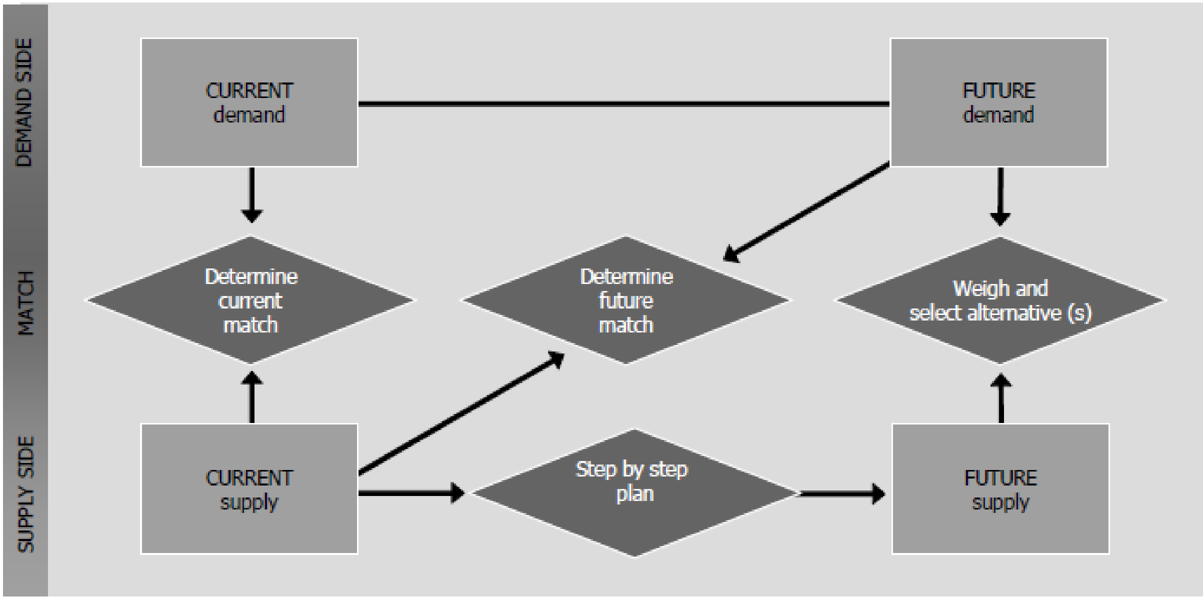


Figure 7: DAS Framework (De Jonge et al., 2009)

This framework describes the steps that one should go through to develop a fitting accommodation strategy. The process consists nine steps in four phases, which combined describe a cyclical process of 1) establishing the current state in terms of demand and supply, 2) forecasting the required future state in terms of demand, 3) weighing and selecting supply interventions that will meet the future demand to the fullest and 4) developing a plan to transform the current supply into the required future supply. Although this strategy was initially intended for corporate real estate strategies, translation to housing strategies for a municipality is relatively straight forward and has been done before as well (Ensing, 2012; Hoekstra et al., 1998).

Translating the process from the view of a corporation into a strategy for a municipality is fairly straight forward, as it requires the process to simply look at a different collection of people. Instead of accommodating 1) employees of a 2) corporation in 3) one or several offices, the process should aim towards accommodating 1) inhabitants of a 2) municipality in 3) any number of dwellings. The second group still has demands towards these dwellings, reasons for requiring or not requiring change and also has limited resources, likewise to the former group.

The DAS frame will be used as a guiding principle in designing an urban redevelopment plan for Zoetermeer and is reflected in the structure of the report. Phases 1, 3 and 4 of the process will be done with the use of two mathematical models, which will be explained in further detail in the following two paragraphs.

2.1.5 Markov chain theory

The first phase of the DAS frame which encompasses the determination of the current state of the supply and demand, will partially be answered through the analysis of combined data from the BAG and BRP. This will be done with the use of Markov Chain Theory, or MCT, and a similarly named model. The theory states that a relationship exists between two states of the same object. For residential migration this would be the assumption that a relationship exists between the current dwelling and the dwelling that was inhabited before it. The relationship is expressed in the form of a set of residential migration chains, which are characteristic to the area. The longest chains describe the type of dwelling which results in the most primary and secondary movements combined.

When using Markov chain models to predict market dynamics, four criteria should be met within this market (Chase, 1991; Hoekstra et al., 1998; Teule & Van der Heijde, 1995). These are:

1. Chance of migration should be independent
2. Chance of migration should be homogeneous
3. Chance of migration should be stable
4. The newly available dwelling should actually be occupied

The first condition is generally met because the decision to move out of a dwelling by one household is independent of the decision by a different household to move into the newly vacant dwelling. The second condition provides the research with somewhat of a contradictory situation. Homogeneous migration chances can be achieved through extensive diversification of the typologies that are used to specify movement. However, when this is done, the result could be that too many cells in the Markov chain model do not contain values, which makes the model unreliable (Chase, 1991). The goal is thus to achieve as few empty cells as possible, whilst also diversifying the types of dwellings (Hoekstra et al., 1998). This is however only the case in the analysis of data when this data in only a sample of the entire set. This was however not the case in this research, as the data used in this research contained the entire set of migration within the city.

The third condition requires the migration pattern to be the same throughout time. This is not very likely to be the case either, as housing patterns tend to change, especially over longer periods of time (Hoekstra et al., 1998). Predictions are however reliable for the nearby future and can still be used as indicative for the more distant future. Furthermore, the model can be added upon throughout time and can thus be updated to reflect the most recent changes as well as long term patterns in migration. The last condition is met by definition, as migrations are registered in the municipal database, and thus not definitive, until the movement is complete.

The type of Markov model which will be used in this research is known as an embedded, first-order Markov chain model with absorbing states. “Embedded” means that the model does not take into account time and treats the sequence as a chain of migrations, but does not provide or take into account the duration of the process. “First-order” refers to the fact that future states are only determined by the current state of the object, i.e. the only indication of what the next dwelling will be is the current dwelling. Lastly, the fact that the model has absorbing states refers to the fact that migration sequences are finite and end at some point. (Chase, 1991)

Translating movements into chains

Finding the residential migration chains means that primary supply, i.e. the dwellings which have become available through the 'creation' and 'deaths' of households, have to be adjusted to also reflect the secondary supply made available by initial and subsequent migrations. The combination of the two is called the total supply and it is found with the following formula, as proven by Scholten (H. J. Scholten, 1988):

$$b = a * M$$

Equation 1: Scholten's formula for calculation of total supply (H. J. Scholten, 1988)

In which:	b	=	the total supply, i.e. primary and secondary supply combined
	a	=	the primary supply
	M	=	the multiplier effect

The multiplier effect is found through the use of a Markov chain model. This model translates movements into the multiplier effect in several steps, each of which results in a new matrix. The starting point is the matrix showing the migrations between different types of dwellings within an area. The starting matrix would look something like Table 2.

Current dwelling	**Previous dwelling**				**Total**
	X	Y	Z	Starter	
X	30	50	40	60	**180**
Y	20	30	15	40	**105**
Z	30	50	40	80	**200**
Total	**80**	**130**	**95**	**180**	

Table 2: Movement matrix

The next step is to translate these numbers into a recruitment chance for each of the current types. This is done by dividing the number of movements in a cell by the total number of movements to the current type of that cell. An example would be to divide 15, underlined in Table 2, by the total for Y, which is 105, resulting in 15 / 105 = 0.143. The resulting number represent the share of households that moved to type Y and came from type Z, thus leaving that dwelling empty in the process. It can be interpreted as the share of dwellings made available in type Z, for every dwelling of type Y added, or for every 100 type Y dwellings added, approximately 14 of type Z become available. This however only represent the second migration in the process and does not reflect the entire chain. For Table 2, the recruitment pattern resulting from this process would look like this. The table does not include starters as they do not vacate a dwelling in the area:

Current dwelling	**Previous dwelling**			**Total**
	X	Y	Z	
X	0.167	0278	0.222	**0.667**
Y	0.190	0.286	0.143	**0.613**
Z	0.150	0.250	0.200	**0.600**

Table 3: Recruitment pattern - matrix Q

The next step in determining the multiplier matrix is finding the I-Q matrix. In this matrix, Q is the recruitment matrix shown above and I represents the unity matrix shown below in Table 4.

Current dwelling	**Previous dwelling**		
	X	Y	Z
X	1	0	0
Y	0	1	0
Z	0	0	1

Table 4: Unity matrix I

Subtracting Q from I results in the values shown in Table 5.

Current dwelling	Previous dwelling		
	X	Y	Z
X	0.833	-0.278	-0.222
Y	-0.19	0.714	-0.143
Z	-0.150	-0.250	0.8

Table 5: I-Q matrix

The process portrayed in the tables above was shown to result in migration chains for the different categories by H. J. Scholten (1988). In the dissertation, it was shown that using the previous matrices, the following step of matrix algebra and taking into account the independencies between movements, the multiplier matrix can be established.

The multiplier effect is equal to the sum of all individual multipliers per type-type match and represents the primary and secondary supply combined, see Table 6. Note that secondary supply is different from the previously mentioned 'second migration', as the former encompasses all supply after the primary supply. For type X this means that through adding one dwelling of this type, 2.38 movements are realised. The diagonal of the matrix shows the total of the primary supply, which is one dwelling, plus the secondary supply for the same type. Type Y thus has the highest degree of household filtering for itself, with an average filtering of 1.74 – 1 = 0.74, compared to the 0.47 and 0.49 for X and Z respectively.

Current dwelling	Previous dwelling			Total
	X	Y	Z	
X	1.47	0.48	0.43	**2.38**
Y	0.76	1.74	0.69	**3.19**
Z	0.55	0.44	1.49	**2.48**

Table 6: Multiplier matrix M

Translating development into migrations

In order to find the development plan's realised primary and secondary migrations within Zoetermeer a translation has to be performed. The former will supply the municipality with a number of dwellings which should be built, but in order to grasp the larger impact of the plans, the total number of facilitated migrations could further allow insight into the appropriateness of the suggested developmental plan.

In order to do this, Equation 1 is again used. The multiplier effect (M) can now be used to estimate the facilitated migrations. The primary supply (a) is the result from the LP model, discussed in '5.3 Decision making model'. The two are combined to form the following formula:

$$b_m = \sum n_i * M_i$$

Equation 2: Equation for calculation of total number of facilitated migrations

In which:

b_m = total number of facilitated migrations
N_i = newly construction dwellings
M_i = multiplier effect
i = category within a characteristic (i.e. rental apartment in middle price segment)

The first part of the formula, N_i, represents the number of primary housing possibilities for individuals available in Zoetermeer and will be the primary supply of dwellings as programmed in the development plan. M is used to compute the total number of migrations caused by the primary supply. The entire calculation is done for one period and thus shows the outcome for just that period.

Computing this for the year 2017 and using a fictional distribution of the 10,000 dwellings results in the numbers shown in Table 7:

			Newly constructed	Multipliers	Total number of migrations
Rental	Apartmer	Low	650	2.26	1469
		Middle	1,000	2.35	2352
		High	1,150	2.40	2754
	Single far	Low	300	2.15	646
		Middle	550	2.24	1230
		High	1,600	2.54	4066
Owner-occupied	Apartmer	Low	350	2.18	763
		Middle	800	2.30	1841
		High	700	2.28	1594
	Single fam.	Low	1,400	2.48	3470
		Middle	500	2.22	1108
		High	1,000	2.36	2355
		High+	-	2.07	0
			10,000		23,650
					Factor of 2.4

Table 7: Modelling of Equation 2 for the year 2017 and dwelling size based on a fictional distribution of N_i

In this model, the 'Newly constructed' (N_i) represent the dwellings added through the development plan. This group will, as has been explained, be determined by the LP model and the values shown above are thus currently arbitrary and used merely to indicate the workings of the model. When the number of newly constructed dwellings of a type are multiplied by the corresponding multiplier (M), the number of migrations for each of the types are found and the total represent the total number of facilitated migrations.

The final step, to sum the individual number of migrations into an overall total, in this example 23,650, is to compare this to the total number of newly constructed dwellings of 10,000. The difference shows that an additional 13,650 movements are generated with the current distribution of newly constructed dwellings. The effect of choosing the optimal distribution becomes apparent when the distribution of n_i is changed, whilst keeping the total amount of added dwellings stable.

			Newly constructed	Multipliers	Total number of migrations
Rental	Apartmer	Low	2,000	2.26	4521
		Middle	710	2.35	1670
		High	290	2.40	695
	Single far	Low	700	2.15	1508
		Middle	1,140	2.24	2549
		High	360	2.54	915
Owner-occupied	Apartmer	Low	772	2.18	1683
		Middle	408	2.30	939
		High	321	2.28	731
	Single fam.	Low	1,066	2.48	2642
		Middle	994	2.22	2204
		High	807	2.36	1901
		High+	432	2.07	893
			10,000		22,851
					Factor of 2.3

Table 8: Modelling of Equation 2 for the year 2017 based on Fakton's distribution of N_i (Versteeg et al., 2016)

Note that, in Table 8, the sum of the Newly constructed is equal to the respective sum in Table 7. The total number of migrations is not however and is off by -799 in the latter. This is due to the suboptimal distribution of dwellings in respect to their corresponding multipliers. The difference is relatively small however and, especially on a project level, the effects of choosing between two different types can be small. Nonetheless these secondary effects could be taken into account and 'free' benefits can be experienced from optimizing these.

Another example would be to construct all 10,000 dwellings in the category which has the highest multiplier, which is the category of single family rental dwellings in the high price range. This would result in a total of 25,413 facilitated migrations. This last example would thus be optimal from the point of migrations, but does not take into account other demands concerning area development, such as desired mix of dwellings, area characteristics or target group.

The "deaths" of households were excluded from this calculation, as it is hard to state how many people leave a single dwelling and thus the relationship between number of residents in the previous household and the future household is unknown.

Lastly, the data used only consists of migrations from within Zoetermeer and thus effects external to Zoetermeer cannot be presented. This does however not mean that they do not exist, as they very likely do, meaning that further research into the migrations within the entire southern Randstad area could show these regional benefits. Such a research was done for Zoetermeer over thirty years ago by P. Van den Berg (1983) and showed that certain types of dwellings specifically facilitate migrations towards Zoetermeer and thus have longer chains when looking at the regional, instead of local, market.

2.1.6 Decision making model and LP model

The latter part of this research will be concerned with the development of a decision-making model (DMM). DMMs can take a number of forms; verbal, graphical and formal or mathematical. The first concerns the verbal explanation or discussion of an object. An example of this would be verbally explaining the layout of a room or discussing different option for redesigning it. This process is however both time consuming as well as susceptible to imperfections as it is limited to one's knowledge of the room and the extent to which it can be expressed in words.

A graphical DMM reduces some of this susceptibility, as it introduces visual representation of the object. This would thus mean that both the transfer of information as well as discussion on redesign option can be done through drawing or 3D-modelling the object. In the example of the room, this could be done with the use of a simple drawing, given that the rules for interpreting said drawing are known to all involved parties. It is this type of process that is commonly found in current processes of designing development programs. These processes commonly still take long periods of time however, as multiple iterations of the design have to be made and discussed and each step takes a relatively long period of time.

The last type of DMM is formal or mathematical and theoretically limits this time, as new iterations can be found within a relatively short period of time. A hiatus is the fact that the first design can take longer than in a normal process, due to the demand for meticulously defining the input variables. After this has been done however, the model can be used in a pressure-cooker type session to address possible conflicts and resolve them. The model can then find a new solution to the answer in a matter of minutes, or in extreme cases hours, by going through the feasibility of potentially millions of possible distributions and determining their fit to the constraints as provided to the model. A formal model thus does not look for suitability of a given design, but instead looks to find the solution space and, if one exists, locate the optimal solution to a problem within that solution space. The concept of the solution space will be explained in the latter part of this segment of the report as well.

It is the last of these and more specifically an LP model, which will be used in this research. An LP, or Linear Programming, model, uses boundary criteria to find a solution to a problem. It is a mathematical model and will determine the dwelling distribution based on input variables and fixed restrictions. Due to the predetermination of the criteria and the unbiased view of the mathematical model, the outcome will be the most suitable outcome taking into account all criteria.

The boundary criteria are determined in the form of specifying values or bandwidths of values for variables. The variables found in the LP can be separated into input, control and output variables. Input variables, which are exogenous, are determined outside the specific system, which make them independent variables, and cannot be altered by the actor. The previously discussed Markov chain model is an example of an input variables for the LP, as it is determined outside of the system and the actor does not have control over its value.

Control variables are exogenous, independent variables, but these can be altered by the actor. This could require a process of negotiations between different, usually opposing, actors, after an impasse has been encountered in the process of designing. The model also contains output variables, which are the outcome of the system, either directly originating from adjustable variables or as auxiliary variables. (Van Loon et al., 2012)

The adjustable variable is an endogenous variable, meaning it can be altered by the system and not by the actors. In the case of this research the main adjustable variable is the dwelling count, as this variable will result in a multitude of auxiliary variables which are the ones which are optimized.

To come to an acceptable outcome of the model, these value have to be provided or negotiated on by the critical coalition. Anselin and Arias (1983) describe this group as *"user-groups representative of the community's interests who share common perceived values, objectives and problems within an urban setting"*. This group should thus represent all important groups in development and would include a multitude of departments of the municipality, such as city development, landscape architecture, urban development and city policy, but could ultimately also include actors such as the developer and citizens of Zoetermeer, albeit through the addition of a representative.

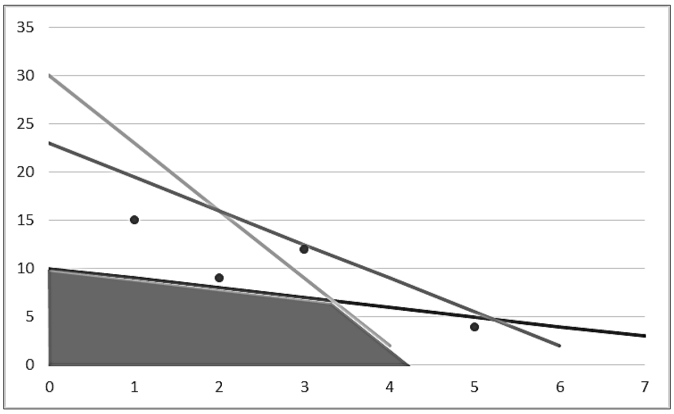


Figure 8: Solution space of three different constraints and two unknown variables (Own illustration)

What is important to note is the fact that the values of the variables are not supposed to be idealised visions of policy, but concrete solutions to the problem at hand (Van Loon et al., 2012). When these variables are constructed simultaneously and through negotiation, it will not do what DMMs are currently used for most commonly, which is to assess the solutions successively, but it will create a solution space (Van Loon et al., 2012). This solution space is illustrated in Figure 8 and is represented by the highlighted area. The optimal solution in this figure is found in the most upper-right corner of the highlighted area and is relatively easy to find, but can become increasingly restricted with the addition of constraining values, i.e. more lines that confine the area.

To illustrate how manually designing a plan can result in multiple failing attempts, any point underneath the three lines can be taken as a proposed design solution, for example one of the indicated dots. None of these apparent solutions meet all three constraints, as only the marked area does. When the problem becomes increasingly complicated, more variables are added, which could be illustrated by adding a third, fourth, fifth dimension, and so on, to the graph.

To illustrate the problem an LP model can solve, the following example was used in Van Loon et al. (2012):

*"**The decision-making problem of a housing association***
A housing association wants to build a number of blocks of residential property and facility units (shops, school, social and cultural centre, etc.) on a particular site. The site covers 14,000 m^2. The association hopes to complete the project within 16 months.

A block (construction time 2 months) covers 1,000 m^2, while a facility unit (construction time 1 month) covers 2,000 m^2. A residential block costs 8.10^6 Euros, and a facility unit costs 5.10^6 Euros; the overall budget is 80.10^6 Euros. It is not necessary to cover the entire site." (Van Loon et al., 2012)

In a newer version of the same example, a small alteration was made, which did not alter the objective of the model, but did change the wording. The model was previously focussed on optimizing the appreciation of the inhabitants, but it was altered to maximize land value according to the following formula:

MAX! 2.5 X_1 + 1.5 X_2 (land value)

Continuing with the sample example as before:

"This problem can be represented mathematically in a LP model. X_1 is the number of blocks of residential property and X_2 is the number of facility units. Two decision-makers are involved in this problem: the housing association and the future residents.
Sub:

$1\ X_1$	+	$2\ X_2$	≤	14	*(site area)*
$2\ X_1$	+	$1\ X_2$	≤	16	*(construction time)*
$8\ X_1$	+	$5\ X_2$	≤	80	*(budget)*
X_1			≥	0	
		X_2	≥	0	

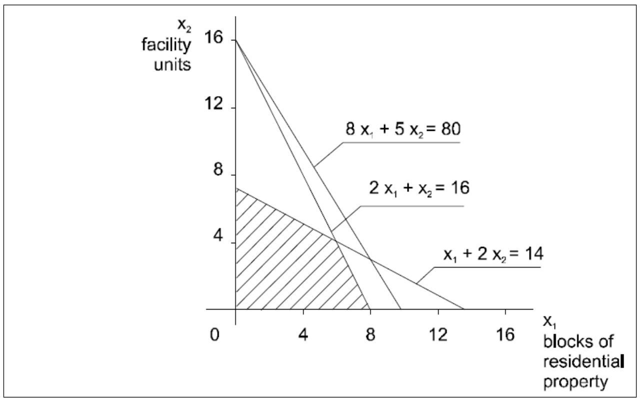


Figure 9: Figure 5 from Van Loon, Barendse, and Duerink (2012) showing the solution space of the explained problem

The simplex algorithm (a mathematical procedure which allows an LP model to be solved with 2 or more unknown variables) can be used to find the mathematical solution to this problem. Since the example has only two unknown variables, it can be solved using a simple drawing. See [Figure 9]*."(Van Loon et al., 2012)*

The solution space is again highlighted and the solution to the problem is $X_1 = 6$ and $X_2 = 4$, which corresponds to the upper-right corner of the highlighted area.

2.1.7 Density indicators

In area development it is common, at least in the Netherlands, to indicate the density of an environment by the amount of people, households or dwellings per hectare (Berghauser Pont & Haupt, 2004). The last will hereafter be referred to as 'plain density' and whilst this is a measure that is generally convenient in comparing environments of the same kinds, it does not convey a lot about area density when comparing different environments or different compositions of housing and other functions. For this reason, it is possible for two different areas with two different characteristics to have identical densities. When looking at Zoetermeer, this is the case for the neighbourhoods of Stadscentrum, Seghwaert-Zuidwest and Buytenwegh, for their location within the city see Figure 15 on page 33. The three areas all have population densities of between 72 and 80, see Figure 10, but the areas have completely different built densities, as can be expressed using a combination of the Floor and Ground Space Indices or FSI and GSI, which express the amount of m^2 of dwelling per m^2 of plan area and the built area .

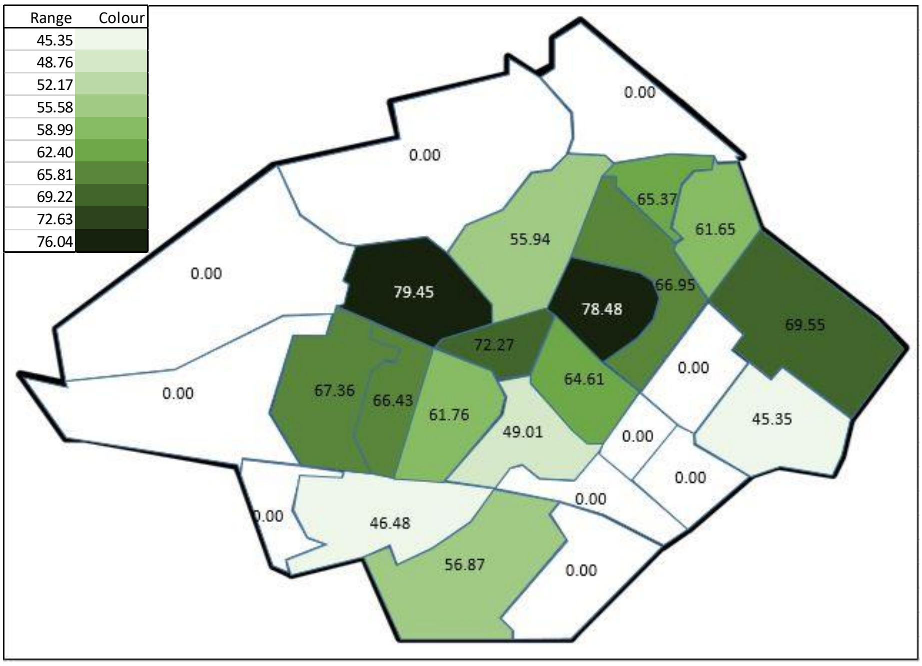


Figure 10: Map of Zoetermeer showing population density per hectare for all 26 neighbourhoods (Own illustration)

To put the indices into perspective, the following example by The Urban Task Force (2003) is used to show alternatives and portray different densities. Figure 11 shows three areas, each one hectare in size and all containing 75 dwellings. The three thus have a plain density of 75, but Area A has the dwellings stacked into a single tower, Area B has them spread out evenly and Area C has them stacked into a semi-high building block (The Urban Task Force, 2003). These areas will have completely different appearances and residents will perceive the identical density differently. This is because of different FSI's and GSI's, which respectively indicate the intensity and compactness of an area.

When calculating the different indices explained below, it is important to not compare indices on different scale levels. This is due to the fact that they can vary greatly based on the scale chosen. The indices below are based on district (Berghauser Pont & Haupt, 2004) or neighbourhood level.

The GSI indicates the compactness of an area. Area A has a low GSI and thus is more open, while Area B has a high GSI and is thus more compact. Calculating the GSI is done by $GSI = built\ area/plan\ area$, is expressed as a number ranging from 0 to 1 and can be interpreted as the percentage of an area upon which is built (Berghauser Pont & Haupt, 2004). For the areas below, the GSI's would respectively be in the ranged of 0.1 to 0.15, 0.1 to 0.35 and 0.2 to 0.4.

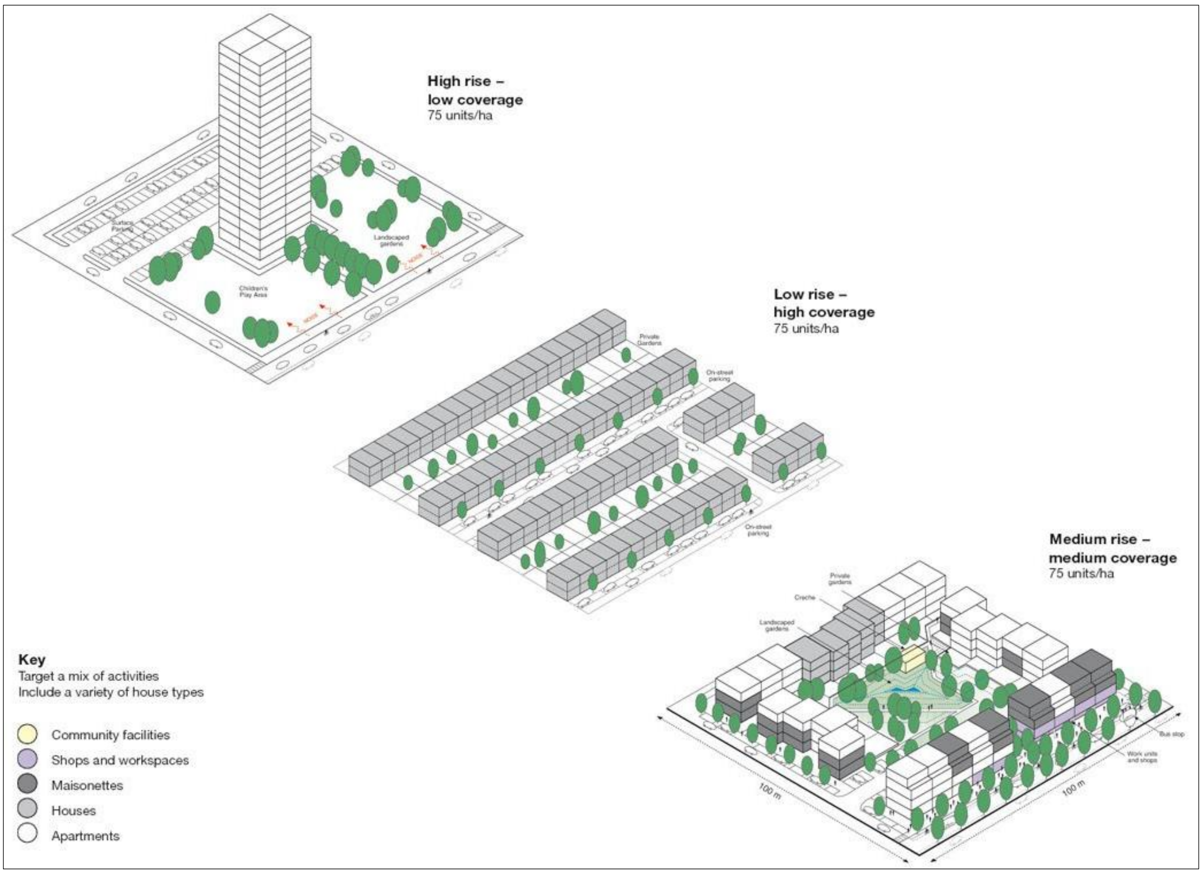


Figure 11: Identical dwelling density achieved in three different ways (The Urban Task Force, 2003)

Contrary to plain density, the FSI does take into account the size of a dwelling or property. Take for example two developments of one hectare in size, one containing one hundred dwellings of 200 m^2 each and the other containing one hundred dwellings of 40 m^2 each and assume identical GSI's of 0.3, similar to Area B in Figure 11. The former development will have a higher intensity or FSI, as it is contains more square metres of dwelling, while the latter development will have a lower intensity as it contains less square metres of dwelling. Calculating the FSI is done by $FSI = gross\ floor\ area/plan\ area$ (Berghauser Pont & Haupt, 2004), which respectively are 2 and 0.4 for the two developments, while both have identical GSI's and plain densities.

Besides the FSI and GSI, the Open Space Ratio (OSR) and Layers (L) can also be calculated based on the same three variables of plan area, built area and gross floor area. The former is an indication of the number of square metres of open space per square metre of dwelling. For the areas in the previous example, the OSR's would be 0.35 and 1.75 respectively, as the OSR is calculated as $OSR = (plan\ area - built\ area)/gross\ floor\ area$ or $OSR = (1 - GSI)/FSI$. The L represents the average number of building layers and would be respectively 6.6 and 1.3, calculated as $L = gross\ floor\ area/built\ area$ or $L = FSI/GSI$ (Berghauser Pont & Haupt, 2004). The OSR's and L's show the vast differences which can be achieved in developments with identical plain densities and GSI's.

To indicate proportional differences in the examples shown in Figure 14, Table 9 shows ranges of values representative of the area type. The highest values have been made bold to show spatial differences between environments. For illustrations on the concepts, see Appendix D – Living Environment' section (2) on page 110.

	Area A	Area B	Area C
GSI	0.1 – 0.15	0.1 – 0.35	**0.2 – 0.4**
FSI	0.8 – 1.3	0.4 – 1.0	**0.7 – 2.0**
OSR	0.7 – 1.2	**0.8 – 2.5**	0.25 – 0.7
L	**>8**	< 4	3 – 8

Table 9: Indicative FSI, GSI, OSR and L based on Berghauser Pont and Haupt (2004)

The indices explained above can also be calculated for Zoetermeer and the results show spatial differences between areas. The FSI's of Zoetermeer show a picture similar to the population density, as the neighbourhoods of Stadscentrum, Seghwaert-Zuidwest and Buytenwegh have relatively high values, but the difference between them shows a variation in intensity which illustrates the difference of environment. Stadscentrum has the highest FSI with 0.82, which is almost twice as high as Seghwaert-Zuidwest's, which is 0.44, whilst Buytenwegh is in between the two with 0.65. This indicates that whilst having very similar population densities, the perceived density is likely to be very different, which is confirmed by the fact that Stadscentrum is the inner-city shopping part of the city and the other two area are characterized by spacious low-rise dwellings and more dense mid-rise dwellings.

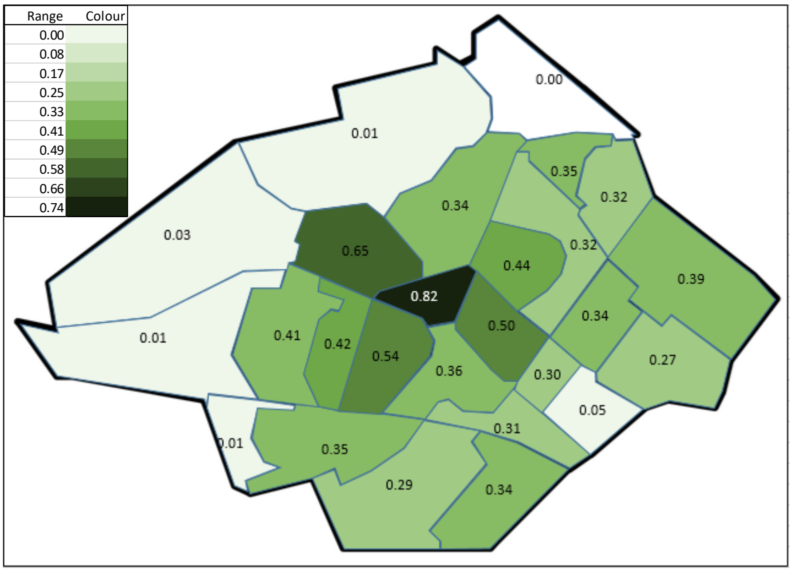


Figure 12: FSI's of all Zoetermeer neighbourhoods (Own illustration)

On the other hand, when looking at the GSI's of Zoetermeer, the three areas are again in the higher range, but are still similar and only differ by 0.06. This thus shows that compactness is similar, but intensity is different. This is to be expected, because residents will still want similar amounts of outdoor space, but the amount of m² within an area is closely related to the type of households which is to be attracted. For Stadscentrum this meant that apartments were desired most and for Buytenwegh it meant that single family dwellings had to be built and while the former can be stacked, the latter cannot, thus creating differences in amounts of GFA and FSI's accordingly.

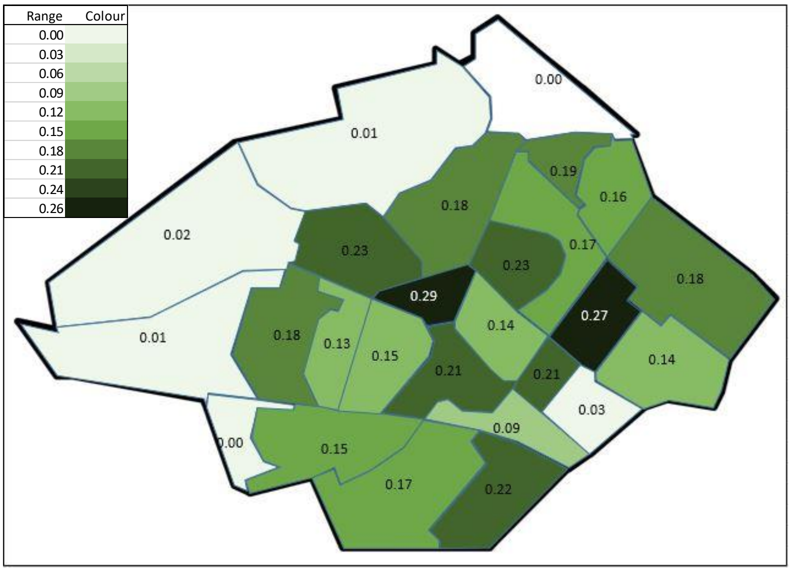
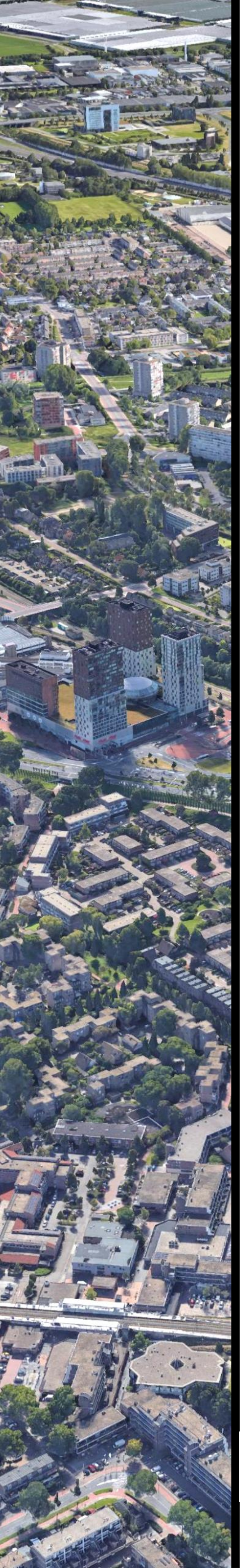


Figure 13: GSI's of all Zoetermeer neighbourhoods (Own illustration)

For all four indices calculated for Zoetermeer and their precise values per neighbourhood and enlarged images, see 'Appendix D – Living Environment' section (3).



Phase 1 Household Filtering

The first phase of the process in designing a fitting accommodation strategy for the future inhabitants Zoetermeer is to determine the current demand and supply of the population of the city. This encompasses analysing the current stock of Zoetermeer and analysing recorded migrations within Zoetermeer. These steps are respectively discussed in the first and second part of this chapter and will thus be further elaborated on the corresponding paragraphs. The third step is to determine the current mismatch between the two and thus determine whether a problem is faced within the housing stock of the city.

3.1 Current stock and supply

Determining the current stock of Zoetermeer requires easily available data, as the municipality of Zoetermeer has a database in which all dwellings and addresses are registered, the BAG. This database lists a number of characteristics of dwellings, which can be found in 'Appendix A' section (2). The first part of this section will provide the reader with some background information on the city of Zoetermeer and thus the context of the redevelopments which have been planned.

Figure 14: Location of Zoetermeer in the Netherlands (Lencer, 2008 [location of Zoetermeer added by researcher])

Zoetermeer is a city in the West of the Netherlands and is, as of writing this report, ranked the 20th largest municipality in the Netherlands, 3rd largest in the province of South Holland (CBS, 2018a) and is located between Leiden, Gouda, Rotterdam and The Hague. The city has seen rapid growth since the beginning of 1960, when it was designated to be a growth core for the city of The Hague (Gemeente Zoetermeer, n.d.). This meant that the city had to grow from 10,000 to 100,000 inhabitants, which it reached in 1991 (Bureau073, 2017). Since then it has grown even further to a population of approximately 125,000. The current housing stock thus generally is less than 50 years old and has been built almost evenly throughout those 50 years, see Figure 33 on page 104.

The tables below show the distribution of dwellings on a number of characteristics for the entire city at the start of 2018. The first table, Table 10, shows a near fifty/fifty split of rental and owner-occupied dwellings in the city. Comparing this to the composition of the entire country, albeit of 2016, shows a fairly similar distribution, as the respective percentages for The Netherlands are 43.5 and 56.5 percent (Ministerie van BZK, 2016). This split has been the case for Zoetermeer for the past five years, as the relative numbers have been mostly stable and been in this range.

Rental and owner-occupied dwellings - 01/01/2018		
	Frequency	**Percentage**
Rental	26,251	47.0
Owner-occupied	29,619	53.0
Total	**55,477**	**100.0**

Table 10: Rental- and owner occupied dwellings of 2018 (Ministerie van Infrastructuur en Waterstaat, 2018)

Indoor area of dwelling in m2 - 01/01/2018		
	Frequency	**Percentage**
0 - 25	406	.7
26 - 50	1,732	3.1
51 - 100	23,495	42.1
101 - 150	25,332	45.3
151 - 200	3,678	6.6
201 - 250	874	1.6
251 - 300	201	.4
301 +	152	.3
Total	**55,870**	**100.0**

Table 11: Distributions of area of dwellings in m^2 in 2018 (Ministerie van Infrastructuur en Waterstaat, 2018)

Table 11 shows the distribution of the Zoetermeer housing stock, separated into eight scales of indoor area of the dwelling. It shows that around 87 percent of the stock is between 50 and 150 square metres in area, which is a little over six percent higher than the national percentage of 80.8 percent (Ministerie van BZK, 2016). Whilst this range of dwelling size is broad, the focus on it does show that Zoetermeer is lacking the smaller and larger dwellings in its stock. Especially the lower ranges would be interesting to students looking for housing within Zoetermeer.

Property value in euro's - 01/01/2018 (taken on 1th of Jan. 2017)		
	Frequency	**Percentage**
0 - 50.000	242	.4
50.001 - 100.000	3,313	5.9
100.001 - 150.000	13,292	23.8
150.001 - 200.000	13,634	24.4
200.001 - 250.000	15,067	27.0
250.001 - 300.000	4,630	8.3
300.001 - 350.000	1,676	3.0
350.001 - 400.000	1,206	2.2
400.001 - 450.000	807	1.4
450.001 - 500.000	434	.8
500.001 - 550.000	284	.5
550.001 - 600.000	286	.5
600.001 +	293	.5
Unknown	706	1.3
Total	**55,870**	**100.0**

Table 12: Distribution of dwelling value in euros in 2018 (Ministerie van Infrastructuur en Waterstaat, 2018)

The next table shows the distribution of property values (WOZ) taken on the 1st of January 2017 and depicts that the majority of dwellings is priced between €100,000 and €250,000. The average property value of approximately €191,000 is low when compared to neighbouring cities. When compared to the COROP region Agglomeration The Hague, into which Zoetermeer is categorized when research is done by the government, the city is situated at the lower end of the bandwidth, with the average being €212,000 for the region (CBS, 2018c).

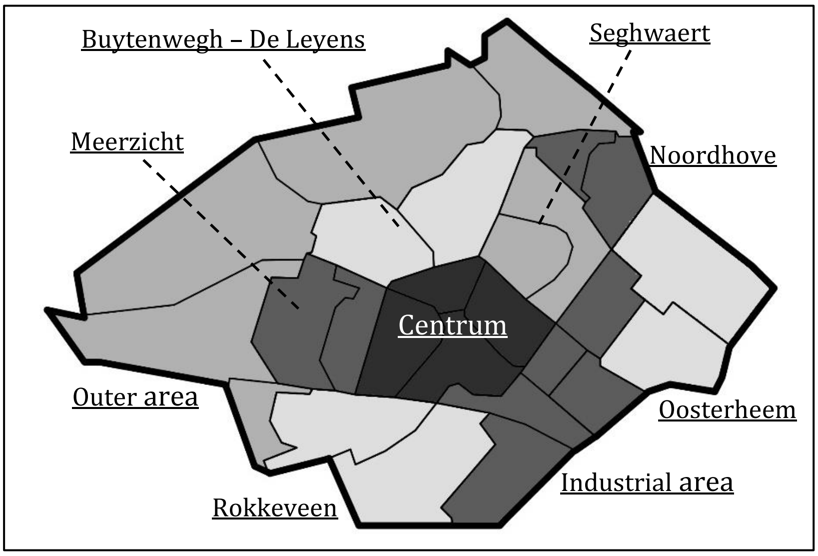


Figure 15: Districts and neighbourhoods of Zoetermeer (CBS, 2009 [edited by researcher])

The city is divided into nine larger districts and 26 smaller neighbourhoods. These each have their own characteristics and were built in succession throughout the past fifty years. Figure 15 shows the districts and their location within the city. For the neighbourhood detailing see ‘Appendix B – Characteristics of Zoetermeer’ on page 104.

Neighbourhood	Type				Total	Average property value
	Single family		Multi family			
	Rental	Owner-Occ.	Rental	Owner-Occ.		
Centrum	1027	2021	5800	2424	11272	€ 154,448
Meerzicht	1059	1845	3030	1230	7164	€ 152,317
Buytenwegh - De Leyens	2119	3514	2482	910	9025	€ 176,618
Seghwaert	1530	3524	1722	637	7413	€ 174,477
Noordhove	952	1936	306	300	3494	€ 288,152
Rokkeveen	1453	5115	1412	577	8557	€ 219,355
Oostenheem	1629	4088	1577	965	8259	€ 249,306
Industrial area	32	118	14	9	173	€ 253,312
Outer area	25	93	1	1	120	€ 463,786
Zoetermeer	9826	22254	16344	7053	55477	€ 191,496

Table 13: Neighbourhood level distribution of single and multi-family homes into rental and owner-occ. Dwellings (Bureau073, 2017)

Table 13 shows the distribution of single and multi-family homes across both rental and owner-occupied dwellings for each of the districts of Zoetermeer. Additionally it also shows the average property value of the entire district and Zoetermeer as a whole. Note the ratio between single- and multi-family dwellings; 32,080 compared to 23,397 or 57.8% compared to 42.2%. Furthermore, the newest neighbourhoods, Noordhove, Rokkeveen and Oosterheem, have the highest average property prices, which could be an indicator of the households' preferences in terms of housing, but also indicates their willingness to spend the capital to live in Zoetermeer.

The areas which have been appointed for redevelopment are primarily located within the Centrum, Meerzicht, Rokkeveen and Industrial districts, see Figure 16. The majority of the developments are also located on industrial sites or on sites currently occupied by (empty) offices, which means that a limited number of dwellings will be affected by these developments. Furthermore, Meerzicht and Centrum have the lowest two average dwelling prices indicating a possible lacking of multiple dwelling types and prices within the area.

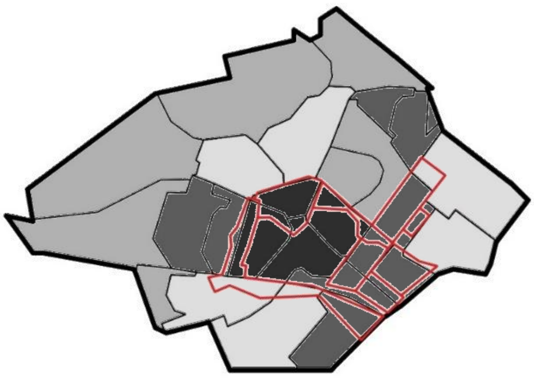


Figure 16: Redevelopment districts highlighted within Zoetermeer (Bureau073, 2017; CBS, 2009 [combined by researcher])

3.1.1 Dynamic supply

The data discussed above portrays a picture of the entire stock of the city. However, it is not the entire stock, but specifically the dynamic supply which is interesting to this research. This supply consists of the dwellings which become available through the construction of a dwelling or the "death" of a household. The former will be the result of this research, but the latter should be taken into account as well, as it essentially competes with the newly constructed supply. "Deaths" concern the migration of a household out of the area, in this case the municipality of Zoetermeer, or the dissolving of a household through an actual death, a merger or a movement into for example an elderly home of the household's resident(s) (Teule, 1996; White, 1971).

The first households included in these "deaths" are the households moving out of Zoetermeer, hereafter called 'departures'. For the years 2013 to 2017 their magnitude ranged annually from 4700 to 5800 individuals and is focussed around inhabitants between the age of 20 and 34, see Table 14. To put this focus into perspective, the distribution of the total population should be used.

Table 15 shows this distribution and as is evident from the values and respective percentages, the age distribution of the departing citizens corroborates the assumption made earlier in the report. It stated that younger inhabitants are moving out of the city in higher quantities. The two tables confirm this, as the group between the age of 20 and 34 constitute 42 to 44 percent of the departing citizens throughout the years shown, whereas they only represent 18 percent of the total population. While this difference could be defended with the argument that this is the most active group when it comes to migrating, the scale of the difference still suggests that other factors could play a role as well.

	Age departures 2013 - 2017				
	Frequency				
Age	2013	2014	2015	2016	2017
0 - 19	1,088	1,134	1,220	1,223	1,169
20 - 34	2,113	2,118	2,350	2,457	2,404
35 - 49	788	755	912	1,027	1,012
50 - 64	474	539	584	681	712
65 - 84	239	244	251	330	308
85 +	72	74	67	83	91
Total	4,774	4864.0	5384	5,801	5696.0

Table 14: Distribution of departures according to age (Ministerie van BZK, 2017)

	Ages of Zoetermeer (01/01/2017)			
	Frequency			
Age	Male	Female	Total	% of total
0-19	14,803	13,992	**28,795**	23%
20-34	11,426	11,439	**22,865**	18%
35-49	11,496	12,513	**24,009**	19%
50-64	13,264	14,406	**27,670**	22%
65-84	9,257	10,067	**19,324**	15%
85 +	688	1,429	**2,117**	2%
Total	60,934	63,846	124,780	

Table 15: Distribution of ages of citizens of Zoetermeer (Ministerie van BZK, 2017)

To the group of departures, the actual deaths, the merging of families and dissolving of families should be added as well. This however were the research faces an issue, as the data does not allow for definitive separation of different types of changes in a household's size. This is due to the fact that changes happen across an entire year, but the data shows one moment in time. Take the following two situations, which are taken to happen within the same year:

- Couple separates; one partner moves out and a friend of either partner moves into the vacant room (roommate situation). *No apparent change in household size.*
- Child is born in family, but one member of the family dies or migrates out the dwelling. *No apparent change in household size.*

Both changes in situation correspond to no change in household size, although at some point between measurements, the size did change. These scenarios represent only a small part of the total number of departures, but excluding or including any one of them for a specific reason would be questionable. This is because it would have to rely on the assumption that, for example, all changes in size of 1 are not migrations of the entire household, although this could this be the case.

As the groups mentioned before are however also represented within the departures and internal migrants, likely to be rather small compared to these two and time was limited for this research, any further expansion of the data was not done. It could however alter the findings and for a full view of the problem it could be taken into account. Lastly, the current supply and stock of housing appears to have been taking into account in the research by Fakton (Versteeg et al., 2016) and is thus taken into account indirectly in this research.

During the three years prior to 2018, the departures spread out over the following thirteen dwelling types as follows:

Ownership	Dw. type	Price range	2015	2016	2017
Rental	*Apartment*	Low	1590	1604	1420
		Middle	109	115	112
		High	6	5	15
	Single family	Low	645	599	512
		Middle	467	482	509
		High	39	41	92
Owner-occupied	*Apartment*	Low	496	567	628
		Middle	49	63	57
		High	11	13	24
	Single family	Low	277	288	204
		Middle	1083	1267	1333
		High	326	411	520
		High+	79	83	106

Table 16: Departures distribution across the 13 dwelling types (Ministerie van BZK, 2017; Ministerie van Infrastructuur en Waterstaat, 2018)

Most notable in Table 16 are the higher values along the lower price ranges of each of the types. The underlined values account for around 80 percent of the total number of annual departures. This could be due to several reason which cannot be deducted from the data, but one of these reason could be the unavailability of the desired dwelling.

The reason for using this distribution of dwellings will become apparent in the next section of this chapter.

3.2 Current demand

Determining the current demand concerning the housing market of Zoetermeer was done by Versteeg et al. (2016) and as this demand was passed as the objective to achieve by the municipal council, this will be seen as the demand to realise. The first part of this section will state this demand as found by Fakton, but look at it critically as well. The second part will then supply a second way of looking at the demand, which is to analyse the residential migration chain lengths. This will be done based on data about migrations to and within Zoetermeer. The analysis will be done using Markov chain theory, which will result in multipliers or migration chains, which in turn reflect the realised household filtering in Zoetermeer.

3.2.1 Annual housing demand

The municipality of Zoetermeer has stated that it wants to better match its vision on the development of housing to the actual demand by the population of Zoetermeer. For this reason Fakton was approach to investigate how many possible consumers of newly built dwellings there are and which types of dwellings they are looking for (Versteeg et al., 2016).

Using big data the research analysed the demand of the local and regional market on the Zoetermeer housing stock. The total area taken into account, or the 'catchment area', would provide realised migrations from within that area and thus show the chance of migration for each household. This approach is similar to the approach used in this research, except that the catchment area was larger. In total a catchment area of 500,000 residents was used and a total of 32 different dwelling types were looked at. These were based on the dwelling characteristics of value, dwelling type and occupation type, as seen in Table 17. Important to note is that the value shown here is the WOZ value, which is assigned to the dwelling based on local sales and is only used by the municipality for tax purposes. The report however states that *"the WOZ value is nearly the same as the actual value [and that] the current asking prices are slightly above the WOZ-bandwidth"* (Versteeg et al., 2016, p.7 [translation by researcher]).

Rental		**Owner-occupied**	
Single family	<125	Single family	<125
	125-150		125-150
	150-175		150-175
	175-200		175-200
	200-250		200-250
	250-350		250-300
	>350		300-350
Apartment	<125		350-400
	125-150		400-600
	150-175		>600
	175-200	Apartment	<125
	200-250		125-150
	250-350		150-175
	>350		175-200
			200-250
			250-300
			300-350
			350-400
			400-600
			>600

Table 17: Division of dwelling types in report by Fakton (Versteeg, Van Eldonk, & Hagen, 2016)

The research continues to calculate movement chances, although it is not shown how, and calculates the demand based on migrations. This is done using the assumption that 10 households with each a 10 percent chance to move, will produce a migration demand of 1. This assumption however appears to only looks at the first migration after the construction of the dwelling. This means, as is also shown in the data in Table 18, that dwellings which would have a higher migration chain length are now only represented by a small demand. The possible secondary effects of these dwellings are thus not shown.

Rental		
		Effective demand
Single family	<125	29
	125-150	7
	150-175	12
	175-200	16
	200-250	60
	250-350	14
	>350	10
Apartment	<125	60
	125-150	32
	150-175	48
	175-200	22
	200-250	27
	250-350	8
	>350	12
Owner-occupied		
Single family	<125	39
	125-150	17
	150-175	18
	175-200	17
	200-250	52
	250-300	28
	300-350	14
	350-400	14
	400-600	20
	>600	10
Apartment	<125	22
	125-150	11
	150-175	20
	175-200	12
	200-250	16
	250-300	5
	300-350	4
	350-400	7
	400-600	3
	>600	3

Table 18: Effective annual dwelling demand by Fakton (Versteeg et al., 2016)

The effective annual demand is subsequently calculated, although it is again not shown how, and the results shown in Table 18 are reported as the annual demand of newly constructed dwellings. The demand is spread fairly evenly across both rental and owner-occupied dwellings, 357 to 332, as well as single family homes and apartments, 377 to 312. The more noticeable division is however found in the distribution of the dwellings among price ranges, as nearly 46 percent of demand is expected in the price range that would be classified as low, see Table 19. Out of the total demand of 690 dwellings, 315 dwellings are priced below €175,000, 222 are priced between €175,000 and €250,000, 116 are priced between €250,000 and €400,000 and the final 36 dwellings are priced at the top of the range, costing more than €400,000 (Versteeg et al., 2016). The ranges used above are similar to the ranged used by the municipality when indicating price segments, but do differ slightly, see Table 20. Respectively, the values translate to 46% for Low, 32% for Middle, 17% for High and 5% for High+.

Translating this into the categories which were used in the previous section and will be used in the following segments, results in the distribution shown in the 4th and 5th columns of Table 19. It again becomes clear that the newly constructed dwellings, as advised by Fakton, will be built in dwelling segments which are already heavily represented in the current stock. This is not necessarily bad, but as 14.3 percent of households in Zoetermeer (VNG, 2018) is living in a social dwelling which is not meant for them because they earn too much, it could be concluded that focussing on household filtering is a good addition to directly constructing what is in demand. This would increase the effectivity of the newly constructed dwelling and add overall value to what is being constructed.

			Annual demand	%	Current stock	%
Rental	Apartment	Low	140	20.3	14,626	26.6
		Middle	49	7.1	1,083	2
		High	20	2.9	159	0.3
	Single family	Low	48	7.0	4,575	8.3
		Middle	76	11.0	4,893	8.9
		High	24	3.5	270	0.5
Owner-occupied	Apartment	Low	53	7.7	5,175	9.4
		Middle	28	4.1	1,616	2.9
		High	22	3.2	1,058	1.9
	Single family	Low	74	10.7	1,052	1.9
		Middle	69	10.0	15,162	27.5
		High	56	8.1	4,622	8.4
		High+	30	4.4	768	1.4

Table 19: Effective annual dwelling demand by Fakton (Versteeg et al., 2016) and current stock divided into 13 dwelling models

3.2.2 Household filtering in Zoetermeer

In determining the demand, a different aspect which will be looked at are the secondary effects of the added supply. These effects will be investigated in terms of the realised household filtering

To determine the realised household filtering and migration within Zoetermeer, data from the BAG and BRP is combined and analysed using Markov chain theory. The former step is required to link movement of individuals, registered in the BRP, with the characteristics of their former and current dwelling, registered in the BAG. The characteristics which will be focussed on are:

Characteristic	Possible value
Ownership type	Rental or owner-occupied
Dwelling type	Apartment or Single Family
Dwelling value segment x 1,000 (WOZ)	Low (<185), Middle (185-274), High (275-499) and High+ (>500)

Table 20: Characteristics and values of housing locations of internal migrants, arrivals, departures and starters

On the right side of Table 20 the different values and thus categories into which the migrants will be distributed are shown. The occupation type was registered as being either rental or owner-occupied and thus was used as such. Ideally a third variable of social rental would have been used, but this was not registered in the database and thus the low price segment, rental housing is seen as social housing in later chapters of this report. The dwelling type variable was found to be far more specified than would be useful in the analysis. For this reason, the many values were merged into just two; single family homes and apartments, i.e. all non-stacked and all stacked are respectively grouped. The last category is based on the WOZ, which is the dwellings value used by the municipality in calculation when taxing its citizens. The ranges used were taken from ranges used when selling land positions and thus reflect what the municipality considers to be, for example, the middle segment.

For the internal migrants both the current and the former dwelling characteristics were available, which is essential to the computation of migration chains. For migrants to, hereafter 'arrivals', and from, hereafter 'departures', Zoetermeer it is only the situation within Zoetermeer which is available, so respectively the current (after moving to Zoetermeer) and previous (before moving out of Zoetermeer) housing situations. These will be used as inputs to either the Markov chain model or a later model, used to determine the realised migrations based on the development program.

Markov chain model

To determine the most relevant residential migration chains, this research looked at the past three years of migrations and assessed the lengths of the chains for each of these years. This was done for thirteen dwelling types, constructed from the characteristics describes above. These thirteen types are:

Rental	*Apartment*	Low *(Social)*
		Middle
		High
	Single family	Low *(Social)*
		Middle
		High
Owner-occupied	*Apartment*	Low
		Middle
		High
	Single family	Low
		Middle
		High
		High+

This specific separation was found to provide both sufficient homogeneity as well as limiting the number of cells containing no values. The latter is not entirely necessary, as all migrations were used. This means that a return of zero type-to-type migrations, actually means that no migrations happened in that type-to-type match, as opposed to the same situation in a research taking a only sample of the migrations. The reason for only having a 'High+' category in single family, owner-occupied dwellings was for the fact that the other segments generally had very little migration to and from this segment, which is mostly because of the fact that Zoetermeer does not have many of these dwellings in it stock.

To eliminate some of the annual fluctuations, the chains were also calculated for the entire three year period as a whole. This meant that in total 4 sets of chains were determined. As an indication of model and its results, the migration chains based on the year 2017 are shown below.

The process, as explained in '2.1.5 Markov chain theory', starts with the number of migration from type to type. The resulting matrix has to include both internal migration as well as arrivals to the local market. This latter group consists of a number of population groups, such as internal starters, i.e. people new to the housing market who choose to move within Zoetermeer, households breaking up and arrivals. This last group includes people moving to Zoetermeer from outside the city. Combined, these groups are required because they embody the group of people ending migration chains and the extent of this group thus to a degree shortens the magnitude of the detected multipliers or chains.

For 2017 the distribution looked as shown in Table 21:

				Previous dwelling														
				Rental						Owner-occupied								
				Apartment			Single family			Apartment			Single family					
				Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High	High+	Arrival	Total
Current dwelling	Rental	Apartme	Low	632	34	2	190	243	22	130	16	10	18	374	103	20	1397	3191
			Middle	51	12	0	6	26	7	17	2	6	1	33	23	8	129	321
			High	4	1	0	4	13	3	0	4	0	0	2	6	3	25	65
		Single fa	Low	223	4	0	31	47	2	34	5	0	3	68	18	0	411	846
			Middle	275	35	2	27	101	23	68	7	3	0	147	85	8	647	1428
			High	23	1	2	15	51	21	11	4	0	0	25	20	0	83	256
	Owner-occupied	Apartme	Low	130	8	2	36	60	6	79	10	8	8	188	73	8	556	1172
			Middle	18	6	0	2	28	2	5	0	8	1	33	16	2	89	210
			High	9	3	1	4	6	7	3	5	2	4	29	12	4	70	159
		Single family	Low	39	7	4	14	12	0	16	2	1	0	24	6	1	65	191
			Middle	308	45	4	97	156	12	300	23	15	23	275	54	9	1106	2427
			High	47	11	2	29	93	45	53	10	1	1	213	62	8	384	959
			High+	2	0	1	0	13	3	4	2	5	0	29	19	2	90	170
				1761	167	20	455	849	153	720	90	59	59	1440	497	73		

Table 21: Migration distribution of 2017

The next steps are to translate this into the recruitment chances, Table 22, and subsequently into the migration chains, or multiplier effect Table 23, using the unity matrix and matrix algebra. The resulting matrix shows that especially dwellings in the higher price segment of their category instigate longer migration chains, such as 2.54 for high segment, rental and single family homes. This means that for every local inhabitant moving into a dwelling of this category, the respective average number of residents of Zoetermeer will move into a different, and generally better, dwelling (Chase, 1991). This does not mean an additional 2.54, but rather an additional 1.54, as the migration to the newly constructed dwelling is included in the matrix.

Notable in the analysis is the fact that it is not the total amount of households' migrations as is usually taken, but the total number of relocated individuals which are used in the Markov model. This results is however no different in order of magnitude of the results compared to the outcomes of other migration research (H. J. Scholten, 1988; Teule, 1996). These reports also show chain lengths in the order of 1.0 to 2.5.

As a control, the model was also adjusted for household size. This was done by first calculating the total number of inhabitants in the 13 types as well as the total number of dwellings in the 13 types. This, when the former is divided by the latter, results in an average number of inhabitant per dwelling type. The average household size was then used to divide the migrations per current dwelling by (red box in Table 21) and the entire row is thus reduced by, for example, a factor of 1.8. As a result of this, the chain lengths did however not change. This is because the factor influences the entire row and thus has no effect on the recruitment chances or on subsequent chain lengths.

				Previous dwelling													
				Rental						Owner-occupied							
				Apartment			Single family			Apartment			Single family				
				Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High	High+	
Current dwelling	Rental	Apartme	Low	0.20	0.01	0.00	0.06	0.08	0.01	0.04	0.01	0.00	0.01	0.12	0.03	0.01	0.56
			Middle	0.16	0.04	0.00	0.02	0.08	0.02	0.05	0.01	0.02	0.00	0.10	0.07	0.02	0.60
			High	0.06	0.02	0.00	0.06	0.20	0.05	0.00	0.06	0.00	0.00	0.03	0.09	0.05	0.62
		Single fa	Low	0.26	0.00	0.00	0.04	0.06	0.00	0.04	0.01	0.00	0.00	0.08	0.02	0.00	0.51
			Middle	0.19	0.02	0.00	0.02	0.07	0.02	0.05	0.00	0.00	0.00	0.10	0.06	0.01	0.55
			High	0.09	0.00	0.01	0.06	0.20	0.08	0.04	0.02	0.00	0.00	0.10	0.08	0.00	0.68
	Owner-occupied	Apartme	Low	0.11	0.01	0.00	0.03	0.05	0.01	0.07	0.01	0.01	0.01	0.16	0.06	0.01	0.53
			Middle	0.09	0.03	0.00	0.01	0.13	0.01	0.02	0.00	0.04	0.00	0.16	0.08	0.01	0.58
			High	0.06	0.02	0.01	0.03	0.04	0.04	0.02	0.03	0.01	0.03	0.18	0.08	0.03	0.56
		Single family	Low	0.20	0.04	0.02	0.07	0.06	0.00	0.08	0.01	0.01	0.00	0.13	0.03	0.01	0.66
			Middle	0.13	0.02	0.00	0.04	0.06	0.00	0.12	0.01	0.01	0.01	0.11	0.02	0.00	0.54
			High	0.05	0.01	0.00	0.03	0.10	0.05	0.06	0.01	0.00	0.00	0.22	0.06	0.01	0.60
			High+	0.01	0.00	0.01	0.00	0.08	0.02	0.02	0.01	0.03	0.00	0.17	0.11	0.01	0.47

Table 22: Recruitment matrix for migrations of 2017

				Previous dwelling													Migration chain or multiplier
				Rental						Owner-occupied							
				Apartment			Single family			Apartment			Single family				
				Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High	High+	
Current dwelling	Rental	Apartme	Low	1.40	0.03	0.00	0.11	0.17	0.02	0.12	0.01	0.01	0.01	0.27	0.08	0.01	2.26
			Middle	0.36	1.06	0.00	0.07	0.18	0.04	0.14	0.02	0.03	0.01	0.28	0.13	0.03	2.35
			High	0.27	0.04	1.00	0.11	0.31	0.07	0.08	0.07	0.01	0.01	0.21	0.16	0.05	2.40
		Single fa	Low	0.46	0.02	0.00	1.09	0.14	0.02	0.11	0.01	0.01	0.01	0.22	0.07	0.01	2.15
			Middle	0.38	0.04	0.00	0.07	1.16	0.03	0.13	0.01	0.01	0.01	0.26	0.11	0.01	2.24
			High	0.33	0.03	0.01	0.12	0.32	1.11	0.14	0.03	0.01	0.01	0.29	0.15	0.01	2.54
	Owner-occupied	Apartme	Low	0.29	0.02	0.00	0.08	0.14	0.02	1.15	0.02	0.01	0.01	0.31	0.11	0.01	2.18
			Middle	0.28	0.05	0.00	0.06	0.23	0.03	0.11	1.01	0.04	0.01	0.32	0.14	0.02	2.30
			High	0.24	0.04	0.01	0.07	0.14	0.07	0.11	0.04	1.02	0.03	0.35	0.13	0.03	2.28
		Single family	Low	0.44	0.06	0.02	0.13	0.17	0.02	0.18	0.02	0.01	1.01	0.31	0.09	0.02	2.48
			Middle	0.32	0.04	0.00	0.09	0.15	0.02	0.20	0.02	0.01	0.02	1.27	0.08	0.01	2.22
			High	0.25	0.03	0.00	0.08	0.20	0.07	0.15	0.02	0.01	0.01	0.39	1.12	0.02	2.36
			High+	0.15	0.02	0.01	0.04	0.16	0.04	0.10	0.02	0.04	0.01	0.31	0.16	1.02	2.07

Table 23: Multiplier matrix for migrations of 2017

3.2.3 Markov chain outcome

The above has been done for Zoetermeer and according to the dwelling characteristics explained at the start of the previous segment. The resulting migration distribution and corresponding multiplier matrices for all years can be found in 'Appendix C – Migration distributions and multiplier matrices' on page 105.

The multipliers, or migration chain lengths, shown in the tables portray to some extend an expected pattern, but also show somewhat surprising, although useful, findings. The patterns are generally found in all Markov chain models (MCMs) that were made.

The categories of apartments and single family dwellings both show an increasing chain length as the value increases, seen in the grey cells in Table 21. This is to be expected as theory shows that the higher a dwelling is situated within the dwelling hierarchy, the longer its chain length should be (H. J. Scholten, 1988; Teule, 1996). Higher value does not directly mean higher position in this hierarchy, but as other aspects of dwelling increase in quality, the price generally increases with it, as people are willing to pay more for these added qualities, whether they are physical quality, location of the dwelling or any other characteristic which is generally seen as beneficial.

The unexpected value is found in the lower price range of the owner-occupied, single family dwellings, as this is the highest value in its category of 'owner-occupied, single family' type, which would contradict the previous statement. The unexpected value can however be explained through looking at the migrations in Table 21. The table shows that a large number of people move from a cheap, most likely social, rental dwelling, to a cheap owner-occupied dwelling. This migration is cause of the phenomena explained in '2.1.1 Household filtering' concerning the migration inhibiting effect of social rental dwellings. People are not forced to move out of these social rental dwellings and thus generally migrate out of them at a later moment compared to people living in a market rental dwelling. When they do, their household situation has generally improved so much that a large progression in the dwelling hierarchy can be made, thus causing the pattern seen above. The pattern is not found in 2016, but is again observed in 2015.

The orange cells in Table 21 show a different way of looking at the results, as these show the dwellings best built for the facilitation of migration out of a cheap, again most likely social, rental dwelling. The following four dwellings are most suitable for facilitating this migration:

- Middle segment, rental apartments
- Middle segment, rental, single family dwellings
- Low segment, owner-occupied, single family dwellings
- Middle segment, owner-occupied, single family dwellings

These are not unexpected findings as these would logically be the 'next step' in moving up the dwelling hierarchy. This means that, at least for 2017, the RMC lengths are in line with the conclusion of the previous section, which stated that the majority of departures came from the lower price segments. To explain, these dwellings thus could not only instigate migrations, the people which it would have migrated in 2017 have moved away from Zoetermeer instead. The correct construction of dwellings could thus actually help in achieving two goals of Zoetermeer; provide housing throughout the entire living cycle as well as liberating cheaper social dwellings (J. H. Scholten, 2016).

Overall the outcomes of the matrices as presented in 'Appendix C – Migration distributions and multiplier matrices' have also been compared to similar research done within the Netherlands. These first comparison was made with a national research done for larger regions within the Netherlands and this research found multiplier lengths in the order of 2.7 to 3.5 (RIGO Research & Advies BV, 2003). This is almost one full migration longer than this research, but the research is also different in three important aspects. The first is the fact that it was a research looking at larger regions, meaning provincial regions, and thus the length of a chain is naturally longer, as internal migrations can happen over far greater distances and are not broken as often, as this would require migrating to a different province. Secondly, the research was done in 2003, which had a production of new dwellings which we have been below since 2010 and are only just reaching again (CBS, 2018b). This negatively influences the ability of households to move, not even taking into account the financial ability of households to do so, as another difference is the pre vs post financial crisis difference. Lastly, this research used sampled data rather than the full database, as it only looked at the migrations reported in a national questionnaire.

Another, perhaps more similar report showed the research into RMCs of Leiden for the two years prior to 2009 (Vos, 2011). This research showed chain lengths of 1.9 and 1.8 for owner-occupied and rental dwellings respectively. Leiden thus had shorter chains than Zoetermeer has, but this is most likely due to the fact that this research included the period right after the financial crisis' crash, which made households reluctant to or even incapable of moving. Furthermore, this research again only used the migrations as registered in the WoON, which thus means that only a sample of the entire set was used. This means that differences between actual and registered migrations are likely and differences can be disproportional when extrapolated to the entire city.

The last research to be compared is also the most recent one, but also showed the most similar results. The research, done by Buys, Kromhout, Bakker, and Berkhout (2014), showed that for the two years prior to 2014, the average chain length was 2.3, opposed to 2.7 for the two years prior to 2009, both being the length at the national level. This is very similar to the lengths found for Zoetermeer, but again only a sample was used with the use of WoON.

3.3 Conclusion

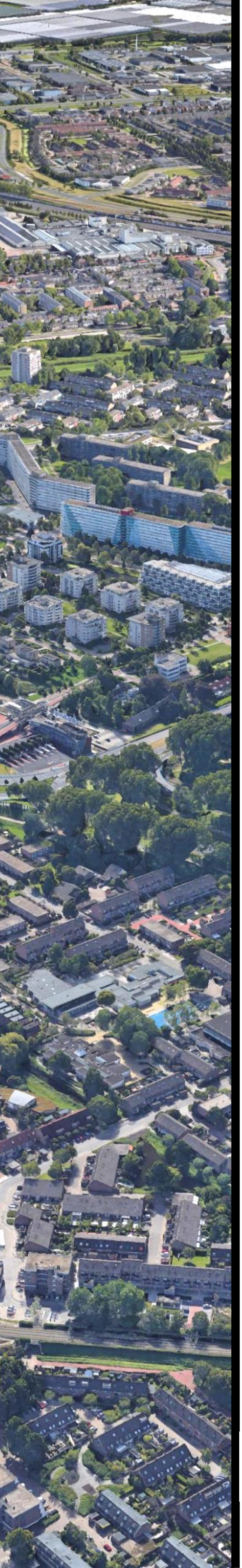
The housing stock of Zoetermeer is relatively new due to the fact that the city has seen rapid growth since the 1960s, when it was designated as the 'growth core' of Den Haag. Since then, the city has seen a growth from 5,000 dwellings to a little over 55,000 dwelling. Most of these dwellings represent have been built in a small number of different groups however. Large parts of the stock are found in the lower price ranges, but the smallest of dwellings, attractive to student, are lacking. The city does have a near fifty/fifty split in rental versus owner-occupied dwellings, but a relatively high share of social housing.

When looking at the dynamic supply, which represents the supply available for migration, the same image can be seen. The majority of people moving out of Zoetermeer, namely move out of the lowest price segments and are thus looking for a dwelling which is only available to some extent in the city, but can be found elsewhere. Furthermore, the people moving out of Zoetermeer the most are young adults, aged 25 to 34, who represent 42 percent of the migrations but only 18 percent of citizens. This could be the case because this group simply moves more, but the migrations could be captured if the right dwellings are made available.

Doing so could be done through the use of migration chains, which facilitate the migrations out of these dwellings or by adding them. Determining the chain length is done to determine which dwellings aids the process of migration the most and was done using Markov Chain theory. The results of the analysis of the period from 2015 to 2017 show that dwellings within the higher price ranges have the longest chains for overall migration. If certain migrations are desired to be facilitated, then the matrix also shows this. If, for example, residents of social housing are to be facilitated, then middle price segment dwellings, in both rental and owner-occupied as well as apartments and single family dwellings, show the most beneficial effects for doing so.

In respect to other research done in this field, comparison can best be made to research done for Leiden in 2011. This research used a different dataset, but a similar method. It showed chain lengths of 1.9 and 1.8 for owner-occupied and rental dwellings respectively. The chain lengths for Zoetermeer ranged from 1.97 to 2.63, although not for the same categories, but are significantly longer. The research of Leiden used a relatively small sample however, as it only looked at the responses of a national questionnaire and not at all migrations, as this research did. The outcomes are thus not entirely comparable, but limited research has also been done in this field.

Finally, it should be noted that the data retrieved from the databases of Zoetermeer can be retrieved from the same databases of other municipalities in the Netherlands. This thus means that the analysis could easily be executed for these municipalities.



Phase 2 Future Scenarios

Phase 2 of the DAS Framework is focussed on predicting future demand. When doing this for corporations, this process is mostly concerned with ambitions of growth, predictions of space use and possible relocations. This is significantly different for a municipality, as the municipality has no direct influence on population growth and cannot relocate. However, predictions concerning population growth have been made by the municipality (Ploeger, 2017) and at Fakton by Versteeg et al. (2016). To incorporate the use of different scenarios being used to predict different solutions, this chapter will discuss the use of different run objective sets, or ROSs, to come to different programs, which each indicate different objectives and priorities.

4.1 Future scenarios

In order to assess the future need in term of housing, an estimation concerning the future population is key, as they will occupy the added housing. In this report, the estimations will be taken from population prognoses published by the municipality of Zoetermeer, which are discussed in the first part of the section. The second part will be concerned with the specification of two opposing extremes, which will depict alternative futures in which population growth is below and above the estimate. The latter is done to show the effects of insecurities, which are inevitable in making prognoses, but these should be taken into account when designing for the future. In other words, the model and the resulting proposal both have to be flexible enough to react on possible changes in population growth.

4.1.1 Prognoses

Within the municipality of Zoetermeer, the department of Research and Statistics has for the last seven years published population prognoses and recent prognoses have shown that the city is stagnating in terms of housing stock growth and even decreasing in terms of population size (Kalisvaart, 2015; Ploeger, 2016, 2017). These prognoses are based on a number of assumptions, including the fact that only 'green' project will be executed. These projects are the projects which have a good chance of being executed and are thus fairly certain. The 2017 report also portrays a situation in which as well as the 'green', the 'orange' and 'red', i.e. less certain, projects will considered. This only increases the amount of dwellings from approximately 1,400 to 3,200, which is double the amount, but relatively small compared to the total stock of 55,477 at the start of 2017. What the publications however all show, is that the housing stock will stall at around 56,000 dwellings and population size will decrease to around 120,000 inhabitants. These are obviously largely related to one another, as a dwelling is only produced if it has a possible occupant and people only move to city which has dwellings to inhabit and the correlated stagnation is thus logical.

The initial assumption of this research was however based on a desire to grow and thus the dwelling stock and with it the population size have to be increased. This is where the problem of co-dependency arises, as any estimation concerning the population size or housing demand will be dependent upon the other estimate. This is further complicated by the fact that the type of dwellings added influence the number of inhabitants and vice versa.

The report by Ploeger (2017) calculated the population growth and housing stock increase based on this desire and has shown that the population will grow from approximately 125,000 to 156,000 and the housing stock will increase from 56,000 to 71,000 dwellings in 2037. These numbers are merely an estimation and are based upon variables, presumed to be constant, concerning the population distribution and average household size, and the assumption that demolition has been taken into account. The constant variables' values are based on the area in which the redevelopment projects are located.

The report by Versteeg et al. (2016) further detailed the demand on housing into 32 different dwelling types, shown in Table 24. This annual demand approximation is based on a broad range market analysis, which used migrations of 500,000 households to, from and within Zoetermeer and its surroundings. The table below shows the result of their research and shows the general distribution of demand. In the report that followed by Bureau073 (2017), this distribution was directly extruded to the scale of the redevelopment program, which is shown in Table 25. This assumption of direct transferability is somewhat questionable, as demand might change in coming years. The report by Fakton stated something similar, as the prognoses had a horizon of three to five years and recalibration was advised for the five to ten year period. Nonetheless, it was passed by the municipal council and will thus be used as the housing demand for Zoetermeer.

#	R_Social			R_Market			Sale			
WOZ (x1000)	S fam. h.	M fam. h.	Total	S fam. h.	M fam. h.	Total	S fam. h.	M fam. h.	Total	Total
Added until 2030	48	140	**188**	100	69	**169**	229	103	**332**	**689**
<125	29	60	**89**				39	22	**61**	150
	60%	*43%*	***47%***				*17%*	*21%*	***18%***	*22%*
125-150	7	32	**39**				17	11	**28**	67
	15%	*23%*	***21%***				*7%*	*11%*	***8%***	*10%*
150-175	12	48	**60**				18	20	**38**	98
	25%	*34%*	***32%***				*8%*	*19%*	***11%***	*14%*
175-200				16	22	**38**	17	12	**29**	67
				16%	*32%*	***22%***	*7%*	*12%*	***9%***	*10%*
200-250				60	27	**87**	52	16	**68**	155
				60%	*39%*	***51%***	*23%*	*16%*	***20%***	*22%*
250-350				14	8	**22**	42	9	**51**	73
				14%	*12%*	***13%***	*18%*	*9%*	***15%***	*11%*
350-400				10	12	**22**	14	7	**21**	43
				10%	*17%*	***13%***	*6%*	*7%*	***6%***	*6%*
400-600							20	3	**23**	23
							9%	*3%*	***7%***	*3%*
>600							10	3	**13**	13
							4%	*3%*	***4%***	*2%*
Total	48	140		100	69		229	103		
	7%	*20%*		*15%*	*10%*		*33%*	*15%*		

Table 24: Annual housing demand for the population of Zoetermeer (Versteeg et al., 2016)

#	R_Social			R_Market			Sale			
WOZ (x1000)	S fam. h.	M fam. h.	Total	S fam. h.	M fam. h.	Total	S fam. h.	M fam. h.	Total	Total
Added until 2030	700	2,000	**2,700**	1,500	1,000	**2,500**	3,300	1,500	**4,800**	**10,000**
<125	423	857	**1,280**				562	320	**882**	2,162
	60%	*43%*	***47%***				*17%*	*21%*	***18%***	*22%*
125-150	102	457	**559**				245	160	**405**	964
	15%	*23%*	***21%***				*7%*	*11%*	***8%***	*10%*
150-175	175	686	**861**				259	291	**550**	1,411
	25%	*34%*	***32%***				*8%*	*19%*	***11%***	*14%*
175-200				240	319	**559**	245	175	**420**	979
				16%	*32%*	***22%***	*7%*	*12%*	***9%***	*10%*
200-250				900	391	**1,291**	749	233	**982**	2,273
				60%	*39%*	***52%***	*23%*	*16%*	***20%***	*23%*
250-350				210	116	**326**	605	131	**736**	1,062
				14%	*12%*	***13%***	*18%*	*9%*	***15%***	*11%*
350-400				150	174	**324**	202	102	**304**	628
				10%	*17%*	***13%***	*6%*	*7%*	***6%***	*6%*
400-600							288	44	**332**	332
							9%	*3%*	***7%***	*3%*
>600							145	44	**189**	189
							4%	*3%*	***4%***	*2%*
Total	700	2,000		1,500	1,000		3,300	1,500		
	7%	*20%*		*15%*	*10%*		*33%*	*15%*		

Table 25: Total housing demand of Zoetermeer until 2030 (Bureau073, 2017)

4.1.2 Alternative scenarios

In this step of the DAS framework, it is common for corporations to assess a number of futures or scenarios and establish a number of strategies based on these futures (De Jonge et al., 2009). For a typical corporation these strategies would look at the future demand of the company concerning real estate and could be concerned with for example *"new ways of working, changed government policy, or changed strategic objectives"* (De Jonge et al., 2009, p.40). What is essential in these scenarios is that they are based on either internal or external developments in the field. This means that a part of the forces that affect the demand could have been intentionally aimed for in the future. For a municipality this is somewhat different, as it can either decide to expand or not and even then the actual expanding has to be done by third parties. This means that strategies for which actual control is possible is very limited.

For this reason, instead of establishing a number of scenarios and corresponding strategies, a number of 'run objective sets', hereafter ROSs, will be established. The difference between the two can be explained as follows. A scenarios is "a sequence of [possibly imagined] events" (Merriam-Webster, 2018). This means that based on the current situation and these events, most likely, certain conditions will change. An example of this would be that housing demand decreases and instead of 700 dwellings annually, this turns out to be only 300 dwellings annually. The input for the design of a program would thus change. In the case of a run objective set, it is not the input which will be changed, but instead the conditions on which the output is based are going to be adjusted. This is done to illustrate different viewpoints to base the program on and to show their extremes. A run thus represents going through the designing of the program once and the run objective is/are the variable(s) which are going to be optimized.

If, for example, a program were to be based solely on the desire to, i.e. has the objective to, generate as much monetary value as possible, then the most expensive dwellings would be prioritised. However, if household filtering is maximized, then the design will prioritize the dwellings with the longest RMC lengths. They can however also be combined to give a result reflecting a high number of migrations and providing the highest possible value within the constraints of the number of migrations. This process is known as goal programming.

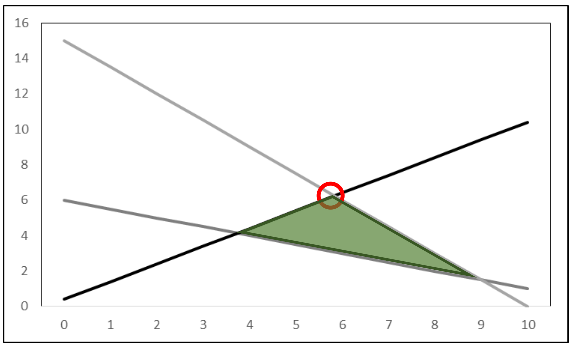


Figure 17: Solution space of three variables (Own illustration)

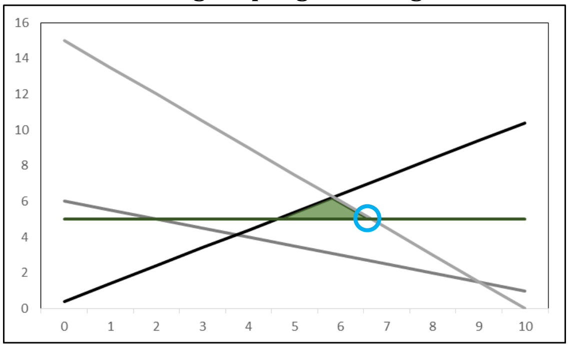


Figure 18: Solution space of three constraints plus a constraint derived from a run objective (Own illustration)

To illustrate this, Figure 17 shows the first step of developing the housing program. Now image that for the first run was done and the value 6.24, red circle, was found as the maximum value on the *y*-axis. A constraint was added to the model, setting the next run to have a minimum value of 5 for *y*, represented by the added horizontal line in Figure 18. If again maximized but now for *x*, the best solution would now show a different outcome, which represents the best outcome for both variables given the minimum of 5 for *y*, see the difference in location of the two circles.

In this case, the value of 5 for *y* was chosen somewhat arbitrarily, but in a real scenario it could represent the amount of revenue which has to be generated in billions or migrations which have to be realised in a segment in thousands, both thus setting a minimum for the *y* variable.

4.2 Run objective sets

Prior to running the model, a number of these 'Run Objective Sets', or ROSs, will be determined. Each run will have its own "environment" in which it is set, meaning that the different ROSs will or will not be taking into account certain constraints. Each ROS will also be comprised of a single or multiple variables which have to be optimized through successive runs. The order of these runs will also be stated as it influences the optimization.

The two steps of successively running the model for two different objectives is done in cases of possibly conflicting optimization runs and is done as follows. The first run will result in an optimum value, which will be lowered minimally to provide space for further optimization and a second run will be performed with a different optimization variable. For example, if the total value added after optimization is €5.23 billion, then a new constraint will be added which prohibits the total value from going lower than €5.2 or 5.1 billion. This was also explained at the end of the previous section.

The goal of every ROS is to show the impact of the changes as described in its explanation. Each ROS thus has a specific goal as to what it should describe, i.e. 'maximize the total value of developments' or 'minimize the number of dwellings constructed'. Expressing each ROSs in terms of, for example, dwelling count, facilitated migrations and total value, will make them comparable and differences will be made measurable. All ROS are believed to be achievable, although the model will also indicate whether this is the case, and have been constructed with the municipality, making them relevant to the current situation. Lastly, the programs do not contain any sense of duration or time-measurement, and thus they are not time bound.

The following segment will discuss the ROSs' aims, the reasoning behind the desire to want to have a certain ROS, their variables and order of optimizing its variables.

4.2.1 Minimal Impact

The first ROS will be aimed at setting a baseline in which only the minimization of built area will be focused on. It will thus not take into account the 'dwelling-guiding' principles such as the demand from the market or the RMC lengths. This will provide the other ROSs with a reference point and thus a measure to compare the other ROSs with.

The only constraints which will be used are those of 10,000 dwelling, which will be used as the number of dwelling to be realized, the constraints belonging to the living environments and the characteristics of the dwellings.

Dwelling count	10,000
Living environments	All 6
Dwelling types	Unconstrained
Plot area	***Minimize***

The outcome of this ROS will be a housing program, which is solely based on the living environments as stated by the municipality and thus provide Zoetermeer with a view of what a housing program would look like if designed only according to its vision on the development, whilst minimizing its impact on the existing environments.

4.2.2 According to Fakton

The next ROS which will be run is aimed at constructing a housing program with the sole purpose of supplying the demand as determined by Fakton (Versteeg et al., 2016) within the boundaries of the living environments as stated by the municipality. The allowed deviation from the stated demand will be set at a low level of 2% to provide some optimization space, but stay true to the guiding demand as stated in the report. Again the aim of 10,000 dwellings, the six living environment definitions and thirteen dwelling types will be used to construct the housing programs.

Dwelling count	10,000
Living environments	All 6
Dwelling types	Unconstrained
Market demand	Small bandwidth (±2%) on primary supply
Plot area	***Minimize***

This ROS will provide a similar picture to the previous ROS, except for the fact that the demand as found by Fakton will be influencing the distribution of dwellings. This second housing program will thus provide a distribution of dwellings as it would have been without the new input of this research. This program will be optimized by minimizing the area required to develop the program, which will make it comparable to the base line ROS.

4.2.3 Getting your Money's Worth

The third ROS is aimed at adding as much value to Zoetermeer as possible. This program will again be similar to the baseline and ROS 2, as it similarly will aim towards developing 10,000 dwellings and take into account the living environments and dwellings types. It will then maximize the total revenue of sales for the constructed program whilst staying within the constraints of the municipals visions, i.e. the living environments.

Maximizing the total value is the first step in optimization and the second step will use the outcome of the first as a new constraint. The model will be run again using this new constraint, but this time to minimize the area required for development. The result will be a program which is near to maximum added value to the city, whilst having a minimized spatial impact.

Dwelling count	10,000
Living environments	All 6
Dwelling types	Unconstrained
Total dwelling value	***Maximize (1)***
Plot area	***Minimize (2)***

The use of this model will show how the city can maximize the value being added to the city and what the requirements of such a program would be. The program will show a development based on the municipality's views, but take into account a possible desire to produce a larger portion in the more expensive housing segment, as the model will prioritize these dwellings in this ROS. The program which results will thus unlikely be one that fits the demand of Zoetermeer, as the demand for and actual selling of the dwellings is not taken into account.

An added value to this ROS could thus be the addition of the market demand with a normal bandwidth of 5% deviation up and down. Doing this would produce a program which is close to the demand of the residents of Zoetermeer.

4.2.4 The Great Migration

One of the more interesting housing programs for the municipality of Zoetermeer is the program resulting from maximum household filtering or migration. This is what the fourth ROS will provide. The ROS 'The Great Migration' will use the previously described constants, momentarily discard the finding of Fakton and look at maximizing the number of facilitated migrations, again within the boundaries of the constants. The result will be a program in which the number of migrations at maximized and spatial impact is minimized. The model will however have a constraint which forces it to have every dwelling model within the program, but no further constraint will be placed on the dwellings.

Dwelling count	10,000
Living environments	All 6
Dwelling types	All 13
Market demand	No constraints
Markov household filtering	***Maximize (1)***
Plot area	***Minimize (2)***

This program is useful to Zoetermeer as it will clearly show the positive and negative effects of constructing a program optimized for migration. It will, for example, most likely show that the number of social dwellings will be limited, as these do not facilitate a lot of migrations.

4.2.5 What the People Want

As a fifth ROS, a combination of both the market demand as determined by Fakton, ROS 2, and the facilitating of migrations, ROS 5, will be used to construct a program designed to maximize the apparent needs of the residents of Zoetermeer. Firstly, it will do so by constructing the new dwellings which Fakton stated the residents of Zoetermeer desired. This will thus supply the demand for newly constructed dwellings. Secondly, the model will maximize the number of facilitated migrations, which would increase the number of people now living in a more fitting dwelling, as it can be expected that people move to increase this fit, as explained in '2.1.1 Household filtering'. The result would be a program within which the number of facilitated migrations is maximized, whilst staying within a boundary of 5% of the demand as stated by Fakton. The program will again be minimized for area requirement, to make it comparable with the other housing programs.

Dwelling count	10,000
Living environments	All 6
Dwelling types	All 13
Market demand	Normal bandwidth (5%) on primary supply
Markov household filtering	***Maximize (1)***
Plot area	***Minimize (2)***

As Zoetermeer does not want to, and possibly cannot, deviate too much from the report by Fakton, this ROS will be especially interesting to the municipality, as it looks at both the demand and the facilitation of migrations.

4.2.6 Efficient Construction

Next, the municipality stated the desire to facilitate the market demand of Fakton as the secondary supply produced by the newly constructed primary supply. This means that the added dwellings described in the housing program would have to facilitate movements out of other dwellings and do so in line with the demand as stated by Fakton. The dwelling count in this ROS is, as opposed to the previous ROSs, not known, as it is the variable which is to be optimized and more specifically minimized. The 10,000 dwellings are however used as the goal to achieve for the number of migrations. The secondary supply has to match the demand, so the deviation allowed is set at a 5% maximum above and below the goal. Lastly, the area requirement is minimized to reduce spatial impact and make it comparable to the base line.

Dwelling count	***Minimize***
Living environments	All 6
Dwelling types	Unconstrained
Market demand	Normal bandwidth (10%) on secondary supply
Markov household filtering	10,000 migrations according to market demand
Plot area	Not adjusted for due to nature of first optimization

As stated above, this ROS will be useful to Zoetermeer as a comparison of what it could construct instead of the 10,000 dwellings as divided by Fakton. This alternative method should be more efficient, as it utilizes the existing stock and ongoing processes.

4.2.7 Maximal Urbanization

The last two ROSs requested by the municipality are concerned with extremes in terms of living environments. The first is to maximize the urbanization of Zoetermeer, which is done by applying the most urban living environment of Inner-City on all eight redevelopment areas. The program will not take into account the dwelling demand as stated by Fakton and will maximize migrations and minimize area requirement. The program will have to contain at least 10,000 dwelling.

Dwelling count	10,000
Living environments	Only Inner-City
Dwelling types	Unconstrained
Markov household filtering	***Maximize (1)***
Plot area	***Minimize (2)***

The resulting program will portray an extreme scenario, but in doing so, allow insight into the effects of programming such an extreme situation.

4.2.8 Minimal Urbanization

The last ROS focusses on the opposite of the previous ROS, i.e. minimal urbanization. This is done in the same way as the previous ROS except for the different living environment. Instead of Inner-City, the entire city will be constructed in the environment of Neighbourhood. The other aspects remain the same.

Dwelling count	10,000
Living environments	Only Neighbourhood
Dwelling types	Unconstrained
Markov household filtering	***Maximize (1)***
Plot area	***Minimize (2)***

The resulting is again an extreme scenario, although in the opposite direction, and will thus provide insight of the same fashion.

4.3 Output variables

As output for each of these ROSs, a number of variables will be presented. These will show the differences between individual ROSs and show influences of choosing to focus on one aspect as opposed to another. The following output variables were discussed to be of interest to the municipality.

A number of variables are key in most of the ROSs. These include the number of dwellings, their plot area requirement and total revenue, and the number of facilitated migrations. These are most essential variables, but are reasonably generic. For this reason, a number of supportive variables will be used as output to illustrate the type of dwellings created through the specific program. If a program is, for example, characterized by rental apartments, it is in these variables were it will become apparent.

Furthermore, for each of the individual areas, a number of specifics will be given, such as number of dwellings, plot area required within the area and the average number of layers. More information is available, but is found in the more detailed information of the model.

Dwellings	-	Av. Price	€ -
Low	-	Apartment	-
Middle	-	Single Family	-
High	-	Rental	-
High+	-	Owner-occupied	-
Migrations	-		
Low	-	Apartment	-
Middle	-	Single Family	-
High	-	Rental	-
High+	-	Owner-occupied	-
Plot Area	-		
	Dwellings	**Plot area**	**Layers**
AreaA	-	-	-
AreaB	-	-	-
AreaC	-	-	-
AreaD	-	-	-
AreaE	-	-	-
AreaF	-	-	-
AreaG	-	-	-
AreaH	-	-	-
Development			
Total value	€ -	Total GFA	-
Total costs	€ -	Total LFA	-

4.4 Conclusion

To conclude, the process of designing a program based on population prognoses is flawed, as a co-dependency exists between the two; people move to places were dwellings are available, but dwellings are added and thus available in place were people will buy them and thus move to. Furthermore, the municipality has little to no control over the actual production of dwellings, as developing parties have to be attracted to do this. For this reason this research set out to instead define Run Objective Sets, or ROSs, which encompassed the unique combinations of input which could be provided and thus portrayed a strategy for the program. Ten such ROSs were defined and they ranged from just using the bare minimum of input to intricate matches of different demands and supplies. Two more ROS resulted in the process, but both were the result of either minor adjustments or combining of different ROSs into one.

Lastly, the output variables were determined and the most important ones were determined to use as optimization variables. These optimization variables were found to be the number of dwellings, their plot area requirement and total revenue, and the number of facilitated migrations.

Phase 3 Realising the Demand

Phase 3 in the process of designing a long term accommodation strategy for Zoetermeer is concerned with the realisation of the demand and more specifically with the weighing and selecting different design solutions. This will be done differently in this research when compared to the DAS Framework, as the usual method in the DAS Framework is done through the formulation of design solutions and assessing them according to predetermined criteria.

In this research the weighing and selecting of a huge quantity of programs will be done in one step with the selection criteria being specified up front and used as design criteria. The criteria will be formulated by a number of actors, which will be defined in the first section of this chapter, while the defining of the criteria will be done in the second section. The last section of this chapter will be concerned with the design and refining of the decision-making model.

5.1 Actor definition

Ascertaining which actors should be taken into account when formulating the living environments is essential to the validity of the result of the model and to the process continuity in general. Furthermore, when defining the living environments, it is beneficial to have them meet the demands of a majority of actors who in a later stage might have to work with or support them. This is thus beneficiary to the validity of the research, but also to the use of any outcomes of the report within the municipality. This section will discuss the defining of the actors within the critical coalition and their general goals based on the most up to date policy documents.

Initially the actor definition was done in cooperation with the municipality of Zoetermeer and followed the lines of a research by Fakton, which was being conducted alongside this research and was focussed on the prioritizing of individual development projects within the city. The municipality specified eight actors within their organisation which would be interesting to interview in light of inner-city redevelopment. These disciplines are:

- Housing ('Wonen')
- Urbanism ('Stedenbouw')
- Economy ('Economie')
- Sustainability ('Duurzaamheid')
- Infrastructure ('Verkeer')
- Planning ('Planoloog')
- Social facilities ('Sociale voorzieningen')
- Real estate economy ('Vastgoedeconomie')

However, after having to reassess the use of the model due to information and time limitations, the number of actors was limited to just the essential core, as a broader view led to a scope which was too wide for this research. The second iteration of the model would only look at the distribution of dwellings and their required area and no longer take into account other spatial characteristics, such as infrastructure or greenery. This thus meant that only actors directly connected to housing were involved in designing the living environments.

In addition, the driver of development, or DoD, was asked to provide feedback on the living environments. This actor was introduced to Zoetermeer in response to the development ambition and is generally tasked with connecting the municipality's ambitions and employees with the developing companies.

Lastly, the role of the real estate economist was looked at, as the model built in this research has some overlap with models used by this department, specifically the ground exploitation, or GREX, models. This actor could have useful information for the research, so their role will also be discussed.

5.1.1 Value and influence

Both the disciplines discussed above have a number of focus points, goals and influencing powers. These will be discussed in the following part of this section. The following objectives and goals were obtained from policy documents and through short interviews.

Housing

The municipality of Zoetermeer has most recently published their ambitions on housing in 2015 and it stated that Zoetermeer is a city focused on housing. It is also a city with a green reputation due to its position between the Randstad and the Groene Hart, a large nature area situated in between a number of larger cities in the West of the Netherlands. As the city had been designated as one of the 'growth cities', "groeikernen", during the second half of the previous century, it has seen growth throughout its history, but has recently recognized that the city will never be finished, as needs change, buildings become outdated and new projects are initiated (Verburg & Van Leuveren, 2008). It is because of this ever changing environment that the department has formulated six ambitions to "cherish, further and add quality to the city" (Gemeente Zoetermeer, 2015, p.17). These six ambitions are:

- *"Sustainable construction and renovation*
- *Affordable housing for all members of society*
- *Additional housing for young starters and students*
- *Providing housing throughout the living cycle within Zoetermeer*
- *Sustaining and creating pleasant and desirable neighbourhoods*
- *Developing consumer-oriented housing."*

(Gemeente Zoetermeer, 2015, p.17 [translation by researcher])

This research is oriented towards the majority of the ambitions and specifically aims to further the third, fourth and sixth ambitions.

Driver of development

Similar to the real estate economist, the driver of development, hereafter DoD, does not have a policy-making role, but rather a policy-executing role within the municipality. The role of this actor is to actively seek to initiate the production of dwellings. The report by Versteeg et al. (2016) showed that a demand for newly constructed dwellings exists, but the supply was not being realised. As a result of this conclusion, the municipality assigned the DoD to investigate why this was the case and to attempt to change this trend. One of the conclusions of the DoD was that *"[the municipality] had little focus in terms of policy concerning the housing issue"* (Chi, 2018 [translation by researcher]) and strengthening these policy documents and solidifying the goals and ambitions of the municipality became one of the first objective of the DoD.

As part of this solidifying, two consecutive documents were established. The first was the "Housing agenda" (Chi, 2016), which stated the overall goals over the city, including the goal of 10 to 16 thousand dwellings over the next 10 to 15 years. The second document further developed these ambitions into goals for a number of plan areas (Bureau073, 2017), which has since provided the basis for this report. This actor thus has been involved in many aspects of the current challenges of Zoetermeer and also a central position in providing a solution.

Real estate economy

The real estate economy is the department within the municipality concerned with land policy, land exploitation and the economic calculations on development plans done by the municipality. This discipline, as explained at the start of this section, does not specifically define policy, but rather functions as a supporting department for the other department within the municipality.

The department of real estate economy is responsible for the financial components of any plan concerning a part of the built environment in which the municipality is involved, or as a real estate economist put it: *"Whenever a euro sign is involved [within the municipality], we are too"* (Duerink, 2018). The department does not have any specific ambitions or goals, but is tasked with assessing the financial return in terms of value created. The value does not have to be monetary, as any social problems needed investments will usually result in a different type of value being created. The department of real estate economy, whilst also checking the total expense being done by the municipality on a project, checks whether the investment return in the fashion required.

Besides the above, the real estate economist also provides a "sanity check" (Duerink, 2018) of the policy created by the other departments of the municipality. The interviewee gave the follow example:

> *"If a policy department states that the municipality would like to exclusively built apartments costing more than one million euros, then it is up to us to state that these will never all be sold. We could built ten percent of these apartments, but after that, we would need other types of dwellings to balance the project with."*
> - *Duerink (2018 [translation by researcher])*

5.2 Condition definition

Defining the boundary conditions is an important step in reaching a realistic and realisable result. This process can take a lot of time, as a number of iterations could be necessary before all parties involved agree with the definitions set. The input variables which have to be defined are the following: living environments, dwellings types, the variable which should be optimized, housing needs of the future and visions concerning the allocation of dwellings. Defining the living environments and dwelling types will be done in the following two segment of the section.

5.2.1 Living environments

Determining the definitions of the different living environments will be done in a twofold process. First, definitions for the different variations will be sought in relevant literature, both white and grey, and these will be used as a basis or example for the next step. This second step will involve group discussions with multiple actors from different disciplines from within Zoetermeer. It is these latter definitions that will be used in the final model, as these reflect the municipality's wishes, rather than literature's findings. The former step was requested by the municipality, as it could give guidance in defining their own living environments.

Literature

Within literature there are a wide variety of definitions of living environments. These are based on either differing key aspects, different goals or different views. The report written by Fakton and SpringCo for the first time defines nine living environments since the initiation of the process of urban redevelopment (Versteeg et al., 2016). These are Inner-city, Lively city neighbourhood, Calm city neighbourhood, Luxurious city neighbourhood, Neighbourhood single-family, Neighbourhood multi-family, Neighbourhood luxurious, Town and Rural. These nine environments are the taken from a report published by Stadsgewest Haaglanden and further definitions of the environments were taken from this report (Van den Berg, R., Tjong, & Klein, 2012).

The definition of these environments is based on a range of variables, including, but not limited to, the types of dwellings found in the area, dwelling density, proximity of facilities and greenery and location within the city or town. Bureau073 further specified the selection of dwellings to reflect the market of Zoetermeer and in the process cut the Town and Rural environments, as little demand was placed on these two (Bureau073, 2017). Bureau073 also renamed a number of environments into more descriptive terms and combined two into one, resulting in the following six environments:

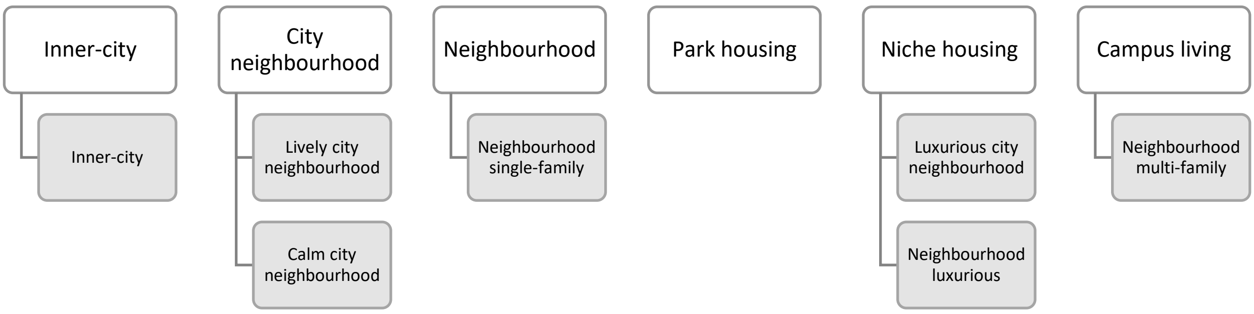


Figure 19: Narrowing of number of living environments in Bureau073 (2017)

Another report relevant to the redevelopment in Zoetermeer is the report published by the Bestuurlijk Platform Zuidvleugel. This report predates the previous report by Stadsgewest Haaglanden and was written by the same architectural firm, but shows a different and more quantitative approach (Zandbelt&vandenBerg, 2009). The report again specifies a number of living environments found within the southern part of the Randstad. These environments are specified through 17 different variables, shown in Appendix D – Living Environment section (1), which encompass characteristics such as dwelling density, primary building period, quality of greenery and public space and a number of characteristics concerning the use and users of the area. This report delves into the specifying of living environments more than the other report do, but still only moderately quantifies the details of the living environments.

The quantification of the demands concerning the living environments is however needed to use them in a mathematical model, but is also useful in the following process of redevelopment. In discussions with the driver of development, or "woningbouwaanjager", Lon Chi, it became clear that having a clear position from which to departure was desired by the municipality as well. This is due to the fact that unclear demand concerning development within an area does not only complicate the process, but increases the chance of different interpretations of the same concept, such as an undefined name for a living environment.

It is thus of benefit, not only to the research and model, but also to the municipality itself, to quantify demands concerning development. This is however only the case if the living environments are determined and endorsed by a majority of the actors within Zoetermeer, as to prevent colliding views in later stages of the process. To prevent a too broad and complex differentiation of living environments and continue upon previous approvals, the six living environments specified by the development program by Bureau073 (2017) will be used. These include Inner-city, City neighbourhood, Calm neighbourhood, Park housing, Niche housing and Campus Living.

Environment criteria

To quantify the living environments in such a manner that they are different from one another, the following criteria will be used to specify them in detail.

	Criteria	**Definition**
1	Layers	Indication of the average number of layer in an area
2	GSI	Indication of the percentage of plot area which is built upon
3	Mix of functions	Expressed in terms of percentage of non-dwelling in an area
4	Function type	Inner-city, district or neighbourhood level of facilities
5	Main dwelling type	Focus on single-family, multi-family, or a mixed
6	Average or range of dwelling price	Average price range of dwellings in an area
7	Average or range of dwelling size	Average size of dwellings in an area
8	Mix of rental and owner-occupied	Focus on rental, owner-occupied, or a mix

Table 26: Living environment criteria and exemplary values

These criteria are based on the criteria used in the report by Van den Berg, R. et al. (2012) and Zandbelt&vandenBerg (2009), as respectively the regions of Haaglanden and Zuidvleugel Randstad include the municipality of Zoetermeer and an unambiguous classification of living environments is beneficial to future discussions within the region.

The first four criteria are linked and concerned with the density and spatial characteristics of an area and will later be referred to as area characterizations. The first three have been explained in '2.1.7 Density indicators' on page 27 and the fourth will be an indication of the type of non-housing functions in an area.

Criteria 5 through 9 of the living environments will signify the types of dwellings which are desired in an area and they will in turn influence the type of resident it should attract. These four indicators have also been used to analyse household filtering and residential migration and are thus going to have to meet the future demand. These criteria are hereafter referred to as dwelling characterizations.

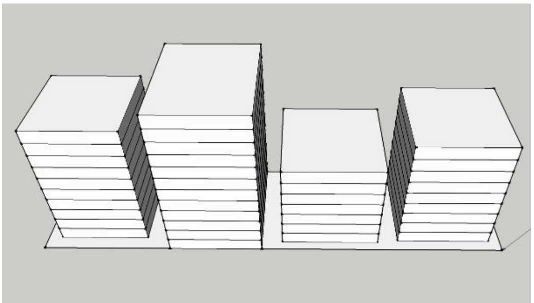
Baseline definitions for living environments

Prior to discussions with Zoetermeer, preliminary definitions of the living environments were designed to form the basis for discussion, to indicate the scale of values and for the municipality to understand the general implication of and relationship between criteria. The six living environments shown below were based on the descriptions given by Haaglanden in 2012 (Van den Berg, R. et al., 2012), but were altered based on discussions with the municipality and on a project in the city, Entrée-Afrikaweg, which was already initiated by the municipality.

Inner-city

Within the development program of Zoetermeer (Bureau073, 2017), the environment of Inner-city has been described as having a high density and a mix of functions, interventions mainly consisting of building new apartments and transforming office buildings and having a mix of appearances within the urban environment. Van den Berg, R. et al. (2012) further describes it as containing specific functions, such as theatres and cinemas, enhancing attractiveness. Due to the high density, accessibility by car is limited, but this is compensated for with public transport. Parking is done in parking garages and is paid for when used. Van den Berg further substantiates apartments being the dominant typology in this living environment. In relation to the other environments, this environment is the most densely packed environment and is characterized by apartments and rental dwellings.

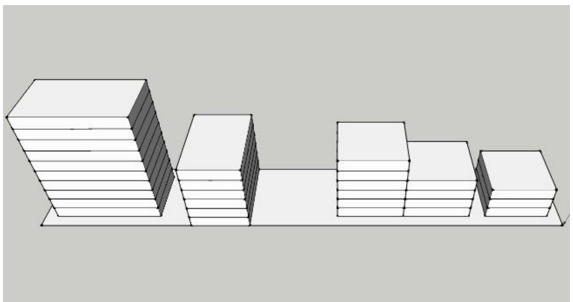
Inner-city	
Plain density	High
Layers	5 - 10
GSI	0.5 – 1.0
Function mix	15 – 25% Inner-city
Dwell. type	Apartments
Dwell. value	Mid to high
Dwell. size	Small to med.
Rent-own %	Rental



City Neighbourhood

The City Neighbourhood has many of the same roots as the Inner city, but combines these with a more spacious layout (Bureau073, 2017). It too for example has a mix of living, working and facilities, but in comparison has a more varied range of dwelling types and is meant for a broader group of households. Characteristic to this environment is the excellent public transport accessibility, but also its typical city dwellings with small or shared private outdoor space (Van den Berg, R. et al., 2012). This environment is also one which includes dwelling types which include workspace or facilities to work from home. This environment definition was based on the ongoing development of Entrée-Afrikaweg and is seen as the intermediate environment to Inner-City and Neighbourhood, respectively being the more and less urban environments.

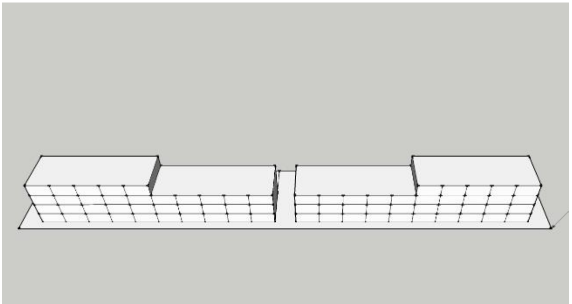
City Neighbourhood	
Plain density	Mid to high
Layers	3 – 7
GSI	0.4 – 1.0
Function mix	10 – 15% District
Dwell. type	Mixed
Dwell. value	Mid to high
Dwell. size	Small to med.
Rent-own %	Mixed



Neighbourhood

The living environment of Neighbourhood shows similarities with the previous environment, as it too aims to provide a range of households with housing, but it is, unlike the 'City' variant, primarily focussed on housing and thus provides little office or retail space. Daily facilities, like grocery stores or healthcare is found in these area. This environment does have a more specific focus group, as it provides an environment most attractive to families, which tend to look for a more quiet and withdrawn surrounding (Bureau073, 2017). This environment was seen as the least urban environment on the list and as the environment currently characterizing the city.

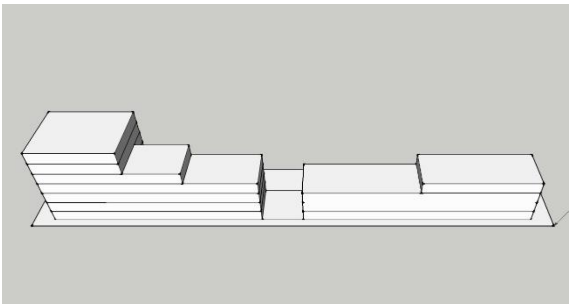
Neighbourhood	
Plain density	Low to mid
Layers	3 - 5
GSI	0.2 – 1.0
Function mix	5 – 15% Neighbourhood
Dwell. type	Mixed
Dwell. value	Mid
Dwell. size	Med to large
Rent-own %	Owner-occupied



Niche Housing

The more exclusive environment in the range is the environment of Niche Housing. These areas will not be abundant, as demand is small, but will provide housing in the higher segments of the market. The environment shares characteristics with Park Housing, as it to contains a lot of high quality greenery and is characterized by its spacious feel. In relation to the other environments it is most similar to the City Neighbourhood environment although this environment has more specific characteristics, such as providing dwelling types with integrated workspaces.

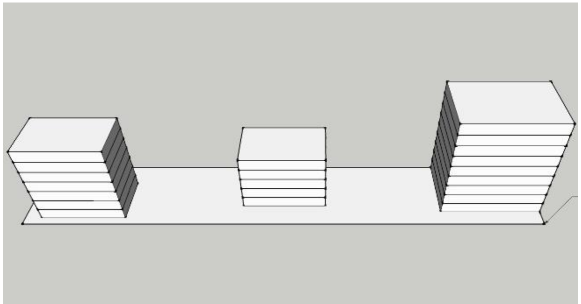
Niche Housing	
Plain density	Medium
Layers	3 - 7
GSI	0.25 – 1.0
Function mix	15 - 25% District
Dwell. type	Single family
Dwell. value	High
Dwell. size	Large
Rent-own %	Owned-occupied



Park Housing

Park Housing is an even more open and spacious version of the Neighbourhood environment. It is characterized by the large open parks and adjacent dwellings, which can use it for leisure. Dwellings are found in both the form of single family dwellings and more concentrated apartment flats (Van den Berg, R. et al., 2012). This environment is again similar to the City Neighbourhood environment, as it has similar characteristics, although Park Housing is also characterized by dwellings being located within spacious greenery.

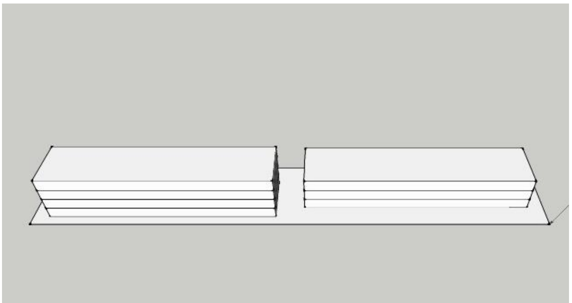
Park Housing	
Plain density	Low to med
Layers	4 – 8
GSI	0.2 – 1.0
Function mix	15 – 30% District
Dwell. type	Mixed
Dwell. value	Mid to high
Dwell. size	Med to large
Rent-own %	Mixed



Campus Living

Campus Living is an environment specifically meant for students and individuals wanting to found a start-up company. The environment will be in de vicinity of public transport hubs and business activity related to similarly nearby educational institutions (Bureau073, 2017). The dwellings found in these areas are small, but surrounded by parks, public space and third place working locations (Kojo & Nenonen, 2015). Again, it is similar to City Neighbourhood, but this time has a combination of the additions done for Park and Niche Housing, as Campus Living has both greenery as well as non-housing functions.

Campus Living	
Plain density	Med to high
Layers	3 – 6
GSI	0.3 – 1.0
Function mix	20 – 30% Neighbourhood
Dwell. type	Apartment
Dwell. value	Low
Dwell. size	Small
Rent-own %	Rental



The classifications used above are however still abstract in the sense that they do not convey objective categories of characteristics. For this reason, the abstract definitions are translated below into more concrete classifications of their respective characteristic.

The first characteristic of dwelling density or plain density is further defined using the definitions specified in the report by Bureau073 (2017). The report uses the same three abstract categories and links these with distinct ranges of <30, 30-40 and 40-60 for respectively low, middle and high densities. The other density variables of Layers and GSI are based on the overall descriptions of the areas and range respectively from 3 to 10 and 0.2 to 1.0. The last variable concerning the density it the specification of other functions in terms of a percentage of non-dwelling functions within an area.

The criteria concerning the dwellings are related to the categories used in the Markov chain analyses. The living environments will be classified to be either apartment or single family home oriented, which means that an orientation towards either corresponds to a majority of more than sixty percent, i.e. either a 60-40 or 40-60 ratio of apartments to single family homes. The gap in between will be defined as mixed use, but has a slightly broader range of between 35 and 65% of either type.

The second dwelling criteria defines the average property value, ranging from low (<€150,000), to middle (€175,001-274,000) to high (>€275,000). The dwelling size is the third criteria and is divided into small, medium and large, which correspond to dwellings of sizes which will be defined more specifically in the model, as precise value can be entered. The last criteria of ownership versus rental has the same structure as the criteria of dwelling type and thus ranges from mostly rental (>60% rental), to mostly owner-occupied (>60% owned) to mixed (between 35-65% of either).

The last four criteria are concerned with the spatial characteristics of the living environments. The first three criteria are public space, green/water and infrastructural requirements and these will be specified in terms of a ratio to housing area or as a percentage of the entire area. However, due to their nature in requiring specific insight into spatial design, these criteria could not be further defined by the researcher. The last criteria of parking requirements could be further specified as they are specified in municipal policy (Gemeente Zoetermeer, 2012). It ranges from which is linked to the type of dwelling that is realised.

For a complete overview of all criteria and the specific values, see 'Appendix D – Living Environment' section (3).

5.2.2 Dwelling types and other built functions

The model which is the aim of this research, will provide the municipality with an indication of dwelling numbers based on previously expressed requirements and demand concerning the housing stock of Zoetermeer and specific area development that have been planned. To do this, the model will need a number of input variables, such as the definitions of living environments, housing stock aims or demands and the characteristics of the dwellings which are to be distributed among the areas. The latter will be done in this segment and will involve the defining of fifteen different dwelling typologies.

To define the dwelling typologies, the characteristics used to analyse household filtering will be used and matched with a demand specified by Bureau073 (2017). It detailed counts of dwellings to be constructed by 2030 and did so using a total of 32 different types of dwellings. These were split amongst three variables, shown below in Table 27:

Characteristic	Values
Ownership	Rental-social, rental-market or owner-occupied
Dwelling value (x1000)	<125-175, 175-250, 250-400, >400
Dwelling type	Single family dwelling or multi-family dwelling (apartment/flat)

Table 27: Dwelling characteristics of housing demand as specified by Bureau073 (2017)

The division above was however seen as too specific to be used in redevelopment planning, as it would make the problem unnecessarily specified and complicated at the same time. For this reason, the number of dwellings was reduced to fifteen types by merging multiple types into one. This resulted in the following typological differentiation.

Name	Ownership	Dwelling type	Dwelling value (x1000)
SAP070	Rental-social	Apartment	<125 – 175
RAP080	Rental-market	Apartment	175 – 250
RAP130	Rental-market	Apartment	250 – 400
SSF070	Rental-social	Single family dwelling	<125 – 175
RSF100	Rental-market	Single family dwelling	175 – 250
RSF140	Rental-market	Single family dwelling	250 – 400
OAP065	Owner-occupied	Apartment	<125 – 175
OAP090	Owner-occupied	Apartment	175 – 250
OAP120	Owner-occupied	Apartment	250 – 400
OSF065	Owner-occupied	Single family dwelling	<125 – 175
OSF090	Owner-occupied	Single family dwelling	175 – 250
OSF125	Owner-occupied	Single family dwelling	250 – 400
OSF200	Owner-occupied	Single family dwelling	400 – >600

Table 28: Reduced number of dwelling archetypes and corresponding characteristics

To these characteristics seven more categories were added; the indoor, built and plot area, building cost per m^2, value per m^2, land price and parking requirement. This was done to specify the type of dwelling that should be aimed for. The specific models are however target dwellings and can be interpreted as the average dwelling for a bandwidth around the archetype. It was as well for this reason that the number of types was reduced and the bandwidth of each was increased. The first five characteristics were determined in collaboration with the valuation department of the municipality of Zoetermeer due to their close relation with each other and the other criteria and in the process the “Bouwkostenkompas” was used as an indicator of cost (IGG Bouweconomie, 2018). The last characteristic was taken from policy documents expressing requirements on parking (Gemeente Zoetermeer, 2012).

Naming the different models was done to easily identify the differences between them. The first letter in the name indicates ownership type; S for social, R for rental and O for owner-occupied. The second two letter indicate type of dwelling; SF for single family dwelling and AP for apartment. The last three numbers indicate the lettable floor area of the dwelling in m^2. The complete overview of the fifteen dwelling models can be found below in Table 29.

Name	Cost/m^2 (euro)	Cost/unit (euro)	Res. ground value (euro)	GFA (m^2)	LFA (m^2)	Value/m^2 (euro)	Value/unit (euro)	Built area	Plot area	Type	Rental-Owned	P. norm
SAP070	900	95,625	54,375	85	60	2,500	150,000	90	90	Ap	R	1.2
RAP080	1,100	137,500	74,500	100	80	2,650	212,500	100	100	Ap	R	1.3
RAP130	1,200	240,000	104,500	160	130	2,650	344,500	160	160	Ap	R	1.6
SSF070	850	106,250	68,750	100	70	2,500	175,000	40	110	SF	R	1.3
RSF100	950	142,500	122,500	120	100	2,650	265,000	50	150	SF	R	1.6
RSF140	1,050	210,000	161,000	160	140	2,650	371,000	70	250	SF	R	1.8
OAP065	1,050	105,000	67,250	80	65	2,650	172,250	80	80	Ap	O	1.2
OAP090	1,050	131,250	107,250	100	90	2,650	238,500	100	100	Ap	O	1.3
OAP120	1,100	199,375	118,625	145	120	2,650	318,000	145	145	Ap	O	1.6
OSF065	1,000	93,750	78,500	75	65	2,650	172,250	40	120	SF	O	1.6
OSF090	1,000	156,250	82,250	125	90	2,650	238,500	50	200	SF	O	1.7
OSF125	1,000	212,500	118,750	170	125	2,650	331,250	60	250	SF	O	1.8
OSF200	1,100	357,500	172,500	260	200	2,650	530,000	90	400	SF	O	1.9

Table 29: Dwelling characteristics and values

Alongside dwellings, a number of other functions will be realised to some extend in a number of areas. These include for example retail and leisure functions, public facilities such as schools and parking facilities. Each of these functions has its own cost attached to it, which are shown below in Table 30 and Table 31.

Other functions	Cost/m^2	Land price	Value/m^2
Retail - City centre	€ 800	€ 1.200	
Retail - District centre	€ 750	€ 600	
Retail - Neighbourhood centre	€ 700	€ 400	
Horeca - City centre	€ 800	€ 1.100	
Horeca - District centre	€ 750	€ 550	
Horeca - Neighbourhood centre	€ 700	€ 400	
Sociale facilities	€ 1.400	€ 190	

Table 30: Costs and values of 'Other functions'

Parking			Parkeren		
Housing			**Retail**		
Area	15	m^2	For every	100	m^2
Cost/m^2			Parking req.	4	p.p.
Street	70	€	Area	15	m^2
Underground	800	€	Cost/m^2		
Value/m^2			Street	70	€
Street	90	€	Underground	800	€
Underground	900	€	Value/m^2		
			Street	90	€
			Underground	900	€
			Average depth/height	3	floors

Table 31: Costs and values of parking

Lastly some additional percentual values were needed to calculate the actual prices paid and received by different parties. These included a percentage for additional costs and a percentage for the taxes paid over the price of the dwelling, thus differentiating the price paid by the future owner and the income of the developer.

5.3 Decision making model

In order to provide the municipality with the next step in the detailing of the development program, this research has developed an LP model. The basics of the type of model have been described in previous chapters, but this section will delve into the model that was designed for the municipality of Zoetermeer. The first part of this section will explain the goal of the model and explain the desired outcome. The second part of this section on the structure of the model will delve into the general order of operations, calculations and relations and the third part will provide the input to the model, including a concise input descriptions of data previously discussed such as the dwelling type and living environment definitions. The next part will be most extensive, as it will concern the workings of the model. The final part discusses the outcome of the model.

5.3.1 Model goal

The following model was designed to provide the next step in a development program that is currently used by the municipality of Zoetermeer. The current version is at the level of a vision document and thus does not provide much detail or insight into realisation criteria. This research has set out to provide this and while clarity has been provided through the defining of migration chains, living environments and dwelling types, the detailing of realisation criteria has not yet been done. This is what the LP model will provide and its goal thus is to specify the redevelopment program and do this according to general and specific demands and criteria. In terms of a concrete outcome this means that the model has to distribute dwellings and area characteristics across eight redevelopment locations in such a manner that these are aligned with area specific demands as well as with city-wide demands concerning overall housing need. The model will optimize the distribution according to a number of possible output variables, which have been discussed at the end of the previous chapter.

The model described above was initially designed specifically for Zoetermeer, but is structured in such a way that the inputs are completely customizable to fit any city looking to (re)develop and has to scalable without much difficulty. This is achieved due to the fact that all expressions of demand are ultimately linked to relatively simple characteristics of an area, which means that an indication of need is expressed per hectare, per inhabitant or per household.

5.3.2 Model basics and structure

The LP model which will be explained below was built in Microsoft Excel, and using a plugin called What'sBest. This plugin provides the capability to use *"a highly developed solver capable of performing linear and nonlinear optimization on the most difficult of problems"* (LINDO Systems, 2017, p.1). This means that the model can find a solution similar to the existing 'goal-seek' function within Excel, but instead of looking for a specific solution through changing one variable, it can find the optimal solution through changing a large amount of variables. The model furthermore provides the capability to constrain any value which is encountered during the process of optimization. An input, intermediate or output variable can thus be constrained to have a minimum value, a maximum value or a value equal to any value. These two functions allow for intricate model building, which is why it was used to construct the model for Zoetermeer.

An LP model can, amongst others, solve both linear and non-linear problems. The difference between the former and the latter is the fact that in the former all terms within the equations are of the first order, meaning that the expression does not contain, for example, a variable which is taken to the any power other than one, a term is divided by a variable or variables are multiplied by each other. In terms of results, this means that for every constant increase of a variable, the outcome increases by a constant amount.

The model is structured along three different levels, which each handle a level of detail and processing of information. The following illustration shows the division of information, processes and relationships between the different modules of the model:

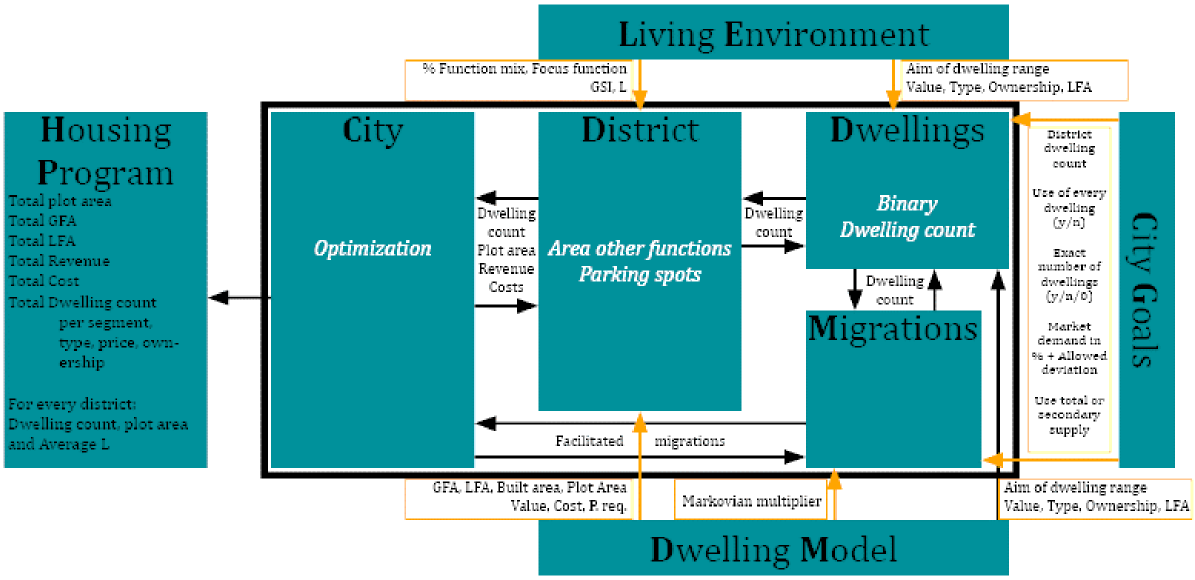


Figure 20: Structural representation of mathematical DMM (Own illustration)

The first level in this hierarchy addresses the actual distribution of the dwellings across an area. This is done centralized for all districts and takes into account a number of district characteristics. The process at this level, at its core, has to only be compatible with itself. Without the other levels, this level would essentially distribute values randomly based on variables entered. In reality these variables are determined by the District and City levels positioned above it and Markov model alongside it.

The level above thus provides the first level of internal control. The control is done at district level and this level thus includes 8 sections; one for each area assigned for redevelopment. Within the section its relevant information is combined and checked according to district specific demands. This means that dwelling characteristics are checked according to demands placed on housing within the area. This is done for each of the districts separately and thus provides the first view of a realistic distribution on an area level. It however does not yet include the demands set on a city-wide level or checks for optimization, as this check occurs at the City level. For this, the last level is required.

The upper most level concerns the entire city, or at least all relevant parts of it. For Zoetermeer this includes all redevelopment districts, but it could theoretically include many more. This last level of control connects all separate parts of model to each other and in the process optimizes the program on a city-wide level. The requirements which are optimized are discussed in section '4.2 Run objective sets' and '4.3 Output variables'.

The above is a simplification of the actual model in the sense that the distribution is not as clear-cut. This is due to the fact that there are several instances in which a value is assigned to a variable based on criteria originating from all three levels. This is illustrated by the different arrows going in both directions, representing the multi-directional nature of the model. If a value is entered at a lower level, but does not fit within the constraints at a different level, then this will be 'noticed' by the model and the value will be changed. A typical run of can perform several thousands to millions of 'tries', which each represent an attempt at finding the optimal solution.

5.3.3 Model input

In order to determine the best distribution of dwellings, it is important to first indicate the boundary criteria of and for the model. These thus include not only the previously determined living environments and dwellings characteristics, which can be used to control the system with, but also includes the boundaries within which the model has to find a solution, which are out of the control of the user and originate from external environments or other systems. In linear programming language these are respectively called the control and input variables (Van Loon et al., 2012). The former could be represented by chess pieces and the latter would be the chess board.

As many of the input has been described in previous parts of the report, the following segment will reiterate the most important information on them and indicate how they are named in the next segment on the mathematics of the model. A full list of all variables and short descriptions on each variable can be found in Appendix E.

An example of the input are the general direction of the program as stated in the current redevelopment plan by Bureau073 (2017). The following general distribution was taken and the last two columns were added to it.

Plan area	**Dwelling count**	**Living environment**	**Area**	**Dwelling variation**
Binnenstad	1400-2000	Inner-City	25	3-6
Entrée-Afrikaweg	2200-3500	City Neighbourhood	37.5	4-7
Bedrijventerrein	2000-3000	Neighbourhood	133.6	5-8
Dwarstocht	300-400	Neighbourhood	9.1	2-4
Groene stadsas	1100-2000	Park Housing	43	4-7
Dutch innovation park	800-1200	Campus Living	27.6	3-6
Rokkeveen A12 as	800-1500	Niche Housing	58.5	5-8
Solitary locations	1400-2400	City Neighbourhood	24	2-5
	$min\_dwc\_d_k$ & $max\_dwc\_d_k$			$min\_n\_dwc\_d_k$ & $max\_n\_dwc\_d_k$

Table 32: Area characteristics for all eight plan areas designated for redevelopment (Bureau073, 2017)

The mentioned living environments have been described in previous sections of the report, but the characteristics and variables attached to each environment are found below in Table 33. The table shows how the variables will be named in the following segment, as it will go into explaining the mathematical workings of the model.

	Criteria	**Mathematical representation**
1	Layers	min_f_d & max_f_d
2	GSI	min_gsi_d & max_gsi_d
3	Mix of functions	$min\_p\_non\_d$ & $max\_p\_non\_d$
4	Function type	Indication of scale for which the non-housing function is meant
5	Main dwelling type	Focus dwelling type, which is translated into $min\_p\_t\_d$ & $max\_p\_t\_d$
6	Average or range of dwelling price	min_r_d & max_r_d
7	Average or range of dwelling size	min_lfa_d & max_lfa_d
8	Mix of rental and owner-occupied	Focus ownership type, which is translated into $min\_p\_w\_d$ & $max\_p\_w\_d$

Table 33: Characteristics of living environments and their mathematical representation

Alongside it, a distribution of housing demand was published, see Table 34. This demand estimation was used as the demand that had to be fulfilled by the dwellings to be constructed, whether it be directly or indirectly. The table also shows the characteristics of the dwellings that were initially known. This input is one of the control inputs and the municipality will use these to control which types of dwellings are constructed within the proposed plan.

#	R_Social			R_Market			Sale			
Value (x1000)	S fam. h.	M fam. h.	Total	S fam. h.	M fam. h.	Total	S fam. h.	M fam. h.	Total	Total
Added until 2030	700	2,000	**2,700**	1,500	1,000	**2,500**	3,300	1,500	**4,800**	**10,000**
<125	423	857	**1,280**				562	320	**882**	2,162
	60%	*43%*	***47%***				*17%*	*21%*	***18%***	***22%***
125-150	102	457	**559**				245	160	**405**	964
	15%	*23%*	***21%***				*7%*	*11%*	***8%***	***10%***
150-175	175	686	**861**				259	291	**550**	1,411
	25%	*34%*	***32%***				*8%*	*19%*	***11%***	***14%***
175-200				240	319	**559**	245	175	**420**	979
				16%	*32%*	***22%***	*7%*	*12%*	***9%***	***10%***
200-250				900	391	**1,291**	749	233	**982**	2,273
				60%	*39%*	***52%***	*23%*	*16%*	***20%***	***23%***
250-350				210	116	**326**	605	131	**736**	1,062
				14%	*12%*	***13%***	*18%*	*9%*	***15%***	***11%***
350-400				150	174	**324**	202	102	**304**	628
				10%	*17%*	***13%***	*6%*	*7%*	***6%***	***6%***
400-600							288	44	**332**	332
							9%	*3%*	***7%***	***3%***
>600							145	44	**189**	189
							4%	*3%*	***4%***	***2%***

Table 34: Housing demand until 2030 in absolute numbers and percentual distribution (Bureau073, 2017)

The number of different categories in this table was however reduced and dwelling characteristics were added to provide a better view of what a certain dwelling could look like. In total nine characteristics were thus defined and used as input variables. These have been discussed in the '5.2.2 Dwelling types and other built functions' section of this chapter on page 64 and are found in Table 29.

Alongside these control variables linked to the dwellings, the Markov chain outcome was also used as an input to the model. This included not just the total chain length of every dwelling type, but consisted of the entire type-to-type multiplier matrix, as shown in Figure 36. The matrix shows the multipliers for the period 2015 to 2017 in total, which was used to negate some of the fluctuation seen in some of the individual years. Nonetheless this is only a representation of the migrations for a short period of time and thus does not represent the most accurate version of the matrix, however, as was explained in Chapter 1, this was due to time and data limitations.

2015 - 2017				**Previous dwelling**												
				Rental						**Owner-occupied**						
				Apartment			**Single family**			**Apartment**			**Single family**			
				Low	**Middle**	**High**	**Low**	**Middle**	**High**	**Low**	**Middle**	**High**	**Low**	**Middle**	**High**	**High+**
Current dwelling	**Rental**	**Apartme**	**Low**	1.41	0.02	0.00	0.14	0.13	0.01	0.12	0.01	0.00	0.05	0.24	0.06	0.01
			Middle	0.33	1.05	0.00	0.09	0.13	0.02	0.12	0.01	0.02	0.05	0.30	0.11	0.02
			High	0.32	0.03	1.02	0.13	0.20	0.06	0.09	0.05	0.00	0.03	0.27	0.13	0.03
		Single fa	**Low**	0.44	0.02	0.00	1.12	0.10	0.01	0.13	0.01	0.00	0.04	0.20	0.05	0.01
			Middle	0.37	0.03	0.00	0.11	1.14	0.02	0.14	0.01	0.00	0.04	0.23	0.08	0.01
			High	0.32	0.03	0.00	0.12	0.21	1.05	0.12	0.03	0.00	0.06	0.32	0.12	0.02
	Owner-occupied	**Apartme**	**Low**	0.30	0.02	0.00	0.10	0.11	0.01	1.14	0.01	0.01	0.05	0.30	0.08	0.01
			Middle	0.28	0.07	0.00	0.08	0.14	0.02	0.15	1.02	0.02	0.05	0.37	0.13	0.02
			High	0.22	0.03	0.01	0.07	0.11	0.04	0.10	0.03	1.02	0.05	0.35	0.16	0.04
		Single family	**Low**	0.35	0.03	0.00	0.12	0.12	0.01	0.19	0.01	0.00	1.05	0.25	0.06	0.01
			Middle	0.33	0.03	0.00	0.11	0.12	0.01	0.20	0.02	0.01	0.05	1.23	0.06	0.01
			High	0.26	0.03	0.00	0.09	0.14	0.03	0.18	0.02	0.01	0.06	0.38	1.10	0.02
			High+	0.20	0.01	0.00	0.07	0.11	0.02	0.09	0.03	0.01	0.05	0.33	0.14	1.01

Table 35: Type-to-type multiplier (M) matrix of 2015 – 2017

A fifth input variable is the variable of the living environments. These have been discussed at the start of the second section of this chapter and will be used as the area defining input. Currently six have been defined, these are the environments of Inner city, City Neighbourhood, Neighbourhood, Park Housing, Niche Housing and Campus Living. The exact values of these variables can be found 'Appendix D – Living Environment' section (4) on page 115.

The current number of living environments is limited to six, but as the model was built with the aim to model larger developments as well, the total number definitions can be increased up to nine. This thus means that three are currently empty and unused.

Lastly, an input concerning the goals of each ROS have to be entered. These input determine factors such as the desire to construct each dwelling type at least once, having a precise dwelling count or a range and where to take into account market demand. These will be referred to as ROS settings and in total five such inputs are required. They are:

Bandwidth of the market demand	- Narrow - Normal *Each bandwidth will also be given a value, i.e. "Narrow" = 2%*	- Broader - Free -> no constraint
Take market demand into account	- In primary supply - In secondary supply	- In both primary and secondary supply - Do not take into account market demand
Exact goal for the total program	- Yes - No -> bandwidth of dwellings or migrations	- 0 -> minimum of 0 dwellings or migrations
Use all dwelling types	- Yes	- No
Taking into account migrations	- Total migrations or supply	- Only secondary migration or supply

5.3.4 Mathematics of the model

The following segment of this chapter will be discussing the mathematics used in the model. The first part will explain the mathematics behind the optimization target, i.e. the variables of the model which will be maximized or minimized. The second part will discuss all the constraints, their relationships to other variables and constants and their results. These constraints have been numbered from one to fifteen and all explain one specific constraint. Most constraints have both a first and second part, being numbered .1 and .2, which describe the minimum and maximum value of the variables being constraint respectively.

The first part will, as stated, discuss the variables which are going to be mini- and maximized. These are the variables which will be used to optimize the outcome of the model for a specific purpose. The formulas below represent the four variables for which will be optimized in the ROSs explained earlier. These are, in order of appearance, the minimization of the plot area required, the maximization of the number of facilitated migrations, the maximization of the total value and the total dwelling count.

The first formula describes the summation of the individual plot area requirements per district. This variables will be minimized at some point in every ROS to make them comparable. The minimization of this variable is also done to minimize the impact that a program will have of the built environment or greenery in an area. The next formula maximizes the migrations of a program. This maximization is done at a city level and thus does not look at individual areas. The third formula describes the process used to determine the total revenue of the proposed program. Lastly, the variable of the total dwelling count can be minimized using the last formula.

$$\text{MIN! } \sum s\_dwc_i * N_{dwc_i} \qquad \textit{(Plot area)}$$

OR

$$\text{MAX! } \sum m\_dwc_i * N\_dwc_i \qquad \textit{(Facilitated migrations)}$$

OR

$$\text{MAX! } \sum r\_dwc_i * N\_dwc_i + A\_non_w * r\_non_w + N\_prk_y * r\_prk_y \qquad \textit{(Revenue)}$$

OR

$$\text{MIN! } \sum N\_dwc_i \qquad \textit{(Dwelling count)}$$

The optimization above will be done according to constraints which inhibit the number of possible solutions to the problem. The first set of constraints, numbered 1.1 to 2.2, addresses the number of different areas in which a dwelling model is to be constructed, 1.1 and 1.2, and the number of dwelling models which have to be constructed within an area, 2.1 and 2.2. Both are related to the binary adjustable assigning these occurrences.

The former, in general, checks whether the number of occurrences of a dwelling model is unrestrained, i.e. ranging from 0 to 8, has a minimum of 1 or is equal to 0. These options are controlled by two different inputs. The first is whether a model type is defined, which, if not the case, results in the count having to be equal to 0. The second is an input stating the desire to use all dwelling models at least once or not, resulting in a respective minimum of either 1 or 0.

The second set of formulas is controlled by the decision-maker's desire to have a minimum and maximum amount of different dwelling models which is an input of the district characteristics. This could be the case in view of having a certain mix of dwelling types.

SUB:

$$\forall_k \sum B\_dwc_{i,k} \geq min\_dst\_dwc_i \quad (1.1)$$

$$\forall_k \sum B\_dwc_{i,k} \leq max\_dst\_dwc_i \quad (1.2)$$

$$\forall_i \sum B\_d_{k,i} \geq min\_n\_dwc\_d_k \quad (2.1)$$

$$\forall_i \sum B\_d_{k,i} \leq max\_n\_dwc\_d_k \quad (2.2)$$

The next set of formulas checks whether the adjustable of the number of constructed dwellings of type i in district k matches the minimum and maximum values which are allowed based on the input. The minimum and maximum are based on the respective number of dwellings desired in the district, $min\_dwc\_d_k$ and $max\_dwc\_d_k$, which is multiplied by inverse of the number of dwellings models desired in a district. The minima and maxima are however reversed, so the minimum amount of dwellings is multiplied by the inverse of the maximum number of dwelling models and inversely. This is done, because those produce the highest and lower possible numbers allowed of a certain model. The last variable in the formula is the previously discussed binary adjustable and thus controls whether the constraint is assigned.

$$N\_dwc_{i,k} \geq min\_dwc\_d_k * \frac{1}{max\_n\_dwc\_d_k} * B\_dwc_{i,k} \quad (3.1)$$

$$N\_dwc_{i,k} \leq max\_dwc\_d_k * \frac{1}{min\_n\_dwc\_d_k} * B\_dwc_{i,k} \quad (3.2)$$

The next constraint controls the minimum and maximum values of the total number of dwellings constructed of a certain model compared to the total supply. These minima and maxima are defined by two inputs. The first is the actual demand, which in this report came from Fakton. The second controls whether this demand is used in the primary or secondary supply. If the former is chosen, the stated supply plus or minus a certain value is used. When the latter is chosen, then this constraint is made ineffective by setting its percentual range at 0 to 100 percent.

$$N\_dwc_i \geq min\_p\_dwc_i * \sum N\_dwc_i \quad (4.1)$$

$$N\_dwc_i \leq max\_p\_dwc_i * \sum N\_dwc_i \quad (4.2)$$

The fifth set of constraints check the total dwelling count for both individual districts (5.1 and 5.2) as well as for the entire city (5.3 and 5.4). These constraints are based on the inputs as defined per area and for the city as a whole. Controlling these is however again done with a secondary input as well, as the minimum input can be taken as a bandwidth or be reduces to 0 to allow the possibility of constructing less dwellings than the minimum. This can be done for both the individual districts as well as for the entire city. The latter also has a third option, which is to have the constraint be set so the total number has to equal a certain goal.

$$N\_dwc\_d_k \geq min\_dwc\_d_k \quad (5.1)$$

$$N\_dwc\_d_k \leq max\_dwc\_d_k \quad (5.2)$$

$$\sum N\_dwc\_d_k \geq \sum min\_dwc\_d_k \quad (5.3)$$

$$\sum N\_dwc\_d_k \leq \sum max\_dwc\_d_k \quad (5.4)$$

The following four duos of constraints each control for criteria linked to districts, which have to be met by the total of the dwellings constructed in them. They are, in order of appearance, dwelling value, dwelling size (LFA), dwelling type and ownership type of the dwelling. Each of these are checked for all of the districts separately and respective to the requirements based on the living environment assigned to the district. For the first four constraints, these control whether the total value of all dwelling in a district is between a minimum and a maximum value multiplied by the number of dwellings in that district, essentially checking whether the average value if between this minimum and maximum.

$$\forall_k \sum_i (r\_dwc_i * N\_dwc_{i,k}) \geq min\_r\_d_k * \sum N\_dwc_{i,k} \quad (6.1)$$

$$\forall_k \sum_i (r\_dwc_i * N\_dwc_{i,k}) \leq min\_r\_d_k * \sum N\_dwc_{i,k} \quad (6.2)$$

$$\forall_k \sum_i (lfa\_dwc_i * N\_dwc_{i,k}) \geq min\_lfa\_d_k * \sum N\_dwc_{i,k} \quad (7.1)$$

$$\forall_k \sum_i (lfa\_dwc_i * N\_dwc_{i,k}) \leq min\_lfa\_d_k * \sum N\_dwc_{i,k} \quad (7.2)$$

The last four constraints control for non-numerical criteria and thus requires a small translation of the criteria into numerical criteria. This is done by translating the two verbal options into binary values. For the dwelling type, this means that apartments and single family homes are respectively translated into a 1 and a 0. For ownership, the same is done for rental and owner-occupied. The model thus always considers the requirement from one perspective, which means that a focus on, for example, single family dwellings results in a requirement of 0 to 40 percent apartments, and not 100 to 60 percent single family.

$$\forall_k \sum_i (t\_dwc_i * N\_dwc_{i,k}) \geq min\_p\_t\_d_k * \sum N\_dwc_{i,k} \quad (8.1)$$

$$\forall_k \sum_i (t\_dwc_i * N\_dwc_{i,k}) \leq max\_p\_t\_d_k * \sum N\_dwc_{i,k} \quad (8.2)$$

where $t\_dwc_i \in \{0,1\}$

in which 0 = single family dwelling, 1 = apartment

$$\forall_k \sum_i (own\_dwc_i * N\_dwc_{i,k}) \geq min\_p\_w\_d_k * \sum N\_dwc_{i,k} \quad (9.1)$$

$$\forall_k \sum_i (own\_dwc_i * N\_dwc_{i,k}) \leq max\_p\_w\_d_k * \sum N\_dwc_{i,k} \quad (9.2)$$

where $own\_dwc_i \in \{0, 1\}$

in which 0 = owner-occupied, 1 = rental

The tenth constraint is similar to the fourth, expect that it checks for match of the secondary supply with the stated demand. This is however only in the case if stated that the secondary supply has to match this demand. In that case, the migrations have to match the stated supply plus or minus a certain value. If not, then this constraint is 'freed', similar to the fourth constraint.

$$\forall_j \sum_i (m\_dwc_{i,j}) \geq min\_p\_dwc_i * \sum (m\_dwc_i * N\_dwc_i) \quad (10.1)$$

$$\forall_j \sum_i (m\_dwc_{i,j}) \leq max\_p\_dwc_i * \sum (m\_dwc_i * N\_dwc_i) \quad (10.2)$$

This next constraint is, like to the previous one, similar to a previous constraint, as it checks the total number of migrations and possible restriction which can be placed upon it. The only constraint possible is that of requiring an exact number of migrations, which is the case in ROS 6. In all other ROSs, the constraint is set essentially unconstrained in that is has to be between 0 and 10 times the total number of constructed dwellings. This factor does not represent any specific value, but was merely used to allow the variable to be virtually unconstrained.

$$\sum(m\_dwc_i * N\_dwc_i) \geq min\_m \quad (11.1)$$

$$\sum(m\_dwc_i * N\_dwc_i) \leq max\_m \quad (11.2)$$

The following constraints check whether the total number of dwellings constructed in each of the districts match with the amount of Layers and GSI desired in the respective district based on the assigned living environment. To do this, the formulas of calculating the L's and GSI's have to be altered slightly, due to the severely limiting effect of dividing by an adjustable. This makes the model into a non-linear model and decreases the speed at which a solution can be found. For this reason the formula $gfa/built\ area \geq minimum\ L$ was changed to $gfa \geq minimum\ L * built\ area$. The same was done for the GSI, which was altered into $built\ area \geq minimum\ GSI * plot\ area$.

$$\forall_k \sum_i(gfa\_dwc_i * N\_dwc_{i,k}) \geq min\_f\_d_k * \sum_i(a\_dwc_i * N\_dwc_{i,k}) \quad (12.1)$$

$$\forall_k \sum_i(gfa\_dwc_i * N\_dwc_{i,k}) \leq max\_f\_d_k * \sum_i(a\_dwc_i * N\_dwc_{i,k}) \quad (12.2)$$

$$\forall_k \sum_i(a\_dwc_i * N\_dwc_{i,k}) \geq min\_gsi\_d_k * \sum_i(s\_dwc_i * N\_dwc_{i,k}) \quad (13.1)$$

$$\forall_k \sum_i(a\_dwc_i * N\_dwc_{i,k}) \leq max\_gsi\_d_k * \sum_i(s\_dwc_i * N\_dwc_{i,k}) \quad (13.2)$$

The second to last constraint focusses on the adjustable variable of non-housing functions and checks whether the variable has a value within the range stated in the living environment assigned to the district. It compares the LFA of non-housing functions to the LFA of housing functions and takes a form factor into account in the former. In the latter, it simply computing the total LFA using the individually stated LFA's the dwelling models.

$$\forall_k \sum_i(p\_gfa\_lfa * A\_non_{w,k}) \geq min\_p\_non\_d_k * \sum_i(lfa\_dwc_i * N\_dwc_{i,k}) \quad (14.1)$$

$$\forall_k \sum_i(p\_gfa\_lfa * A\_non_{w,k}) \leq max\_p\_non\_d_k * \sum_i(lfa\_dwc_i * N\_dwc_{i,k}) \quad (14.2)$$

The last constraint controls the adjustable variables of the parking places. Combined with the sum of all single family dwellings, which are expected to have at least one parking spot on their plot, these have to equal the total number of parking places required based on the dwellings and LFA non-housing function constructed.

$$\forall_k \forall_{|own\_dwc_i=0} \sum_i(own\_dwc_i * A\_non_{w,k}) + N\_prk_{y,k} = \sum_i(n\_prk\_non_y * (A\_non_{w,k}/ lfa\_prk\_non_y) + \sum_i(n\_prk\_dwc_i * N\_dwc_{i,k}) \quad (15)$$

where $own\_dwc_i \in \{0,1\}$

The above are all constraints and mini- and maximization formulas which have been used to construct the model. The full list can also be found in 'Appendix F – Model mathematics' in a more convenient manner.

5.3.5 Model outcome

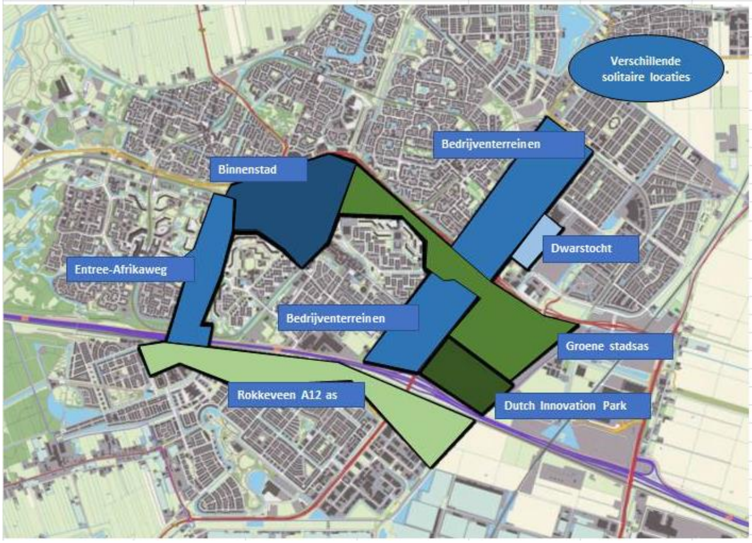
The outcome of each run of the model is based on the ROSs determined at the end of the previous chapter. These determined the runs objective and input constraints. For each of the runs a specific set of output variables was produced and all sets will be discussed in the following segment. The complete outcomes of all ROSs can be found in 'Appendix G – Model outcome'.

The following ROS outcomes all have two expressions of outcome; a map and a number of output variables. The output variables will be discussed for each ROS and the most interesting outcomes will be highlighted. The map requires a legend, which can be found in Figure 21

Figure 21: Colour coding of living environments in ROS outcome maps (Own illustration)

Minimal Impact

The first ROS which was run, the ROS Minimal Impact, provided the baseline for the other sets. Its goal was to not take into account any input concerning the housing demand or migration chains and only take into account views of the municipality on the living environments. It would then find the program which minimized spatial impact whilst staying within the boundaries of these plan area criteria and constructing 10,000 dwellings. The result is the following program:



Dwellings	10.000	Av. Price	€ 205.796
Low	5.606	Apartment	7.340
Middle	3.950	Single Family	2.660
High	444	Social	3.500
High+	-	Rental	600
		Owner-occupied	5.900

Migrations	22.319	Apartment	12.780
Low	11.852	Single Family	9.539
Middle	8.644	Social	7.892
High	1.667	Rental	2.379
High+	155	Owner-occupied	12.047

Plot area (ha)	38,47	Dwel. models	6

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.500	1	10
Entree-Afrikaweg	2.500	12	4
Bedrijventerreinen	2.250	11	4
Dwarstocht	-	-	-
Groene stadsas	1.500	7	5
Dutch Innovation F	900	1	6
Rokkeveen A12 as	-	-	-
Solitaire locaties	1.350	6	4

Development			
Total value	€ 2.228.684.204	Total GFA	1.074.882
Total costs	€ 1.308.900.363	Total LFA	877.123
		Total GFA Other F	109.635

Figure 22: Results of ROS Minimal Impact (Own illustration)

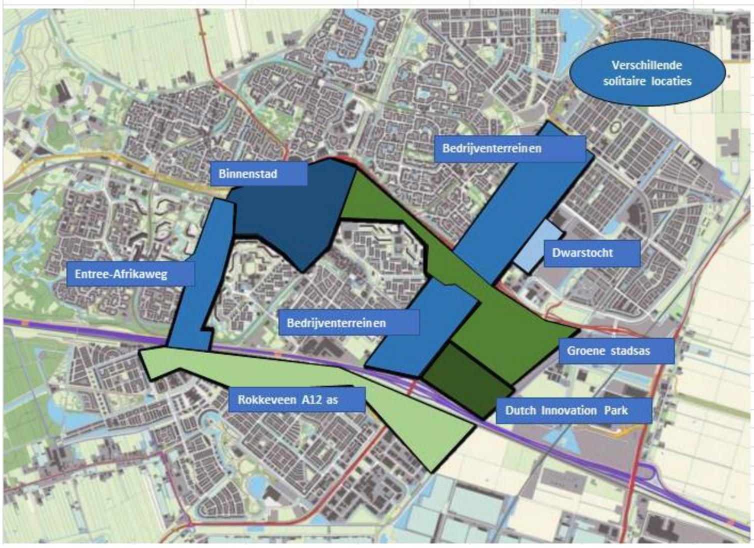
The program shows that, whilst staying within the required conditions of the living environments assigned to the plan areas, the minimal amount of area required to develop 10,000 dwellings is 38.47 hectares. Only six different dwellings types are however constructed and further investigation shows the following dwelling types and their counts:

- SAP060 -> 840
- RAP080 -> 600
- SSF070 -> 2660
- OAP065 -> 2106
- OAP090 -> 3350
- OAP120 -> 444

It thus shows that a majority are apartments with 73 percent and that the program contains a 35 percent share of social rental, 6 percent share of market rental and 59 percent share of owner-occupied. Furthermore, the dwellings are mostly constructed in the lower and middle segment, meaning below 175,000 and up to 250,000 respectively. When looking at the migrations facilitated, the same picture arises, as the majority of migrations are again facilitated in the lower price ranges. It could be argued that the latter is a good result, as these people move up along the dwelling ladder. This statement is not untrue, however it should be noted that the long term effect of adding these dwellings could be below optimal as it can also be argued that these dwellings will not increase the possible length of any future chains, whereas the middle to high price segment could.

According to Fakton

The next ROS investigated the effects of taking into account the market demand as stated by Fakton. It was identical to Minimal impact, except for the fact that the newly constructed dwellings had to be within a 2 percent range above or below the stated demand. Again, the only variable which was optimized for was the plot area used and this resulted in the following program:



Dwellings	10.000	Av. Price	€ 240.808
Low	4.737	Apartment	5.700
Middle	3.252	Single Family	4.300
High	1.778	Social	2.900
High+	233	Rental	2.500
		Owner-occupied	4.600

Migrations	22.218	Apartment	11.084
Low	11.117	Single Family	11.134
Middle	7.755	Social	7.403
High	2.955	Rental	4.318
High+	391	Owner-occupied	10.497

Plot area (ha)	83,83	Dwel. models	13

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.500	2	10
Entree-Afrikaweg	1.750	12	3
Bedrijventerreinen	1.580	11	3
Dwarstocht	200	3	3
Groene stadsas	1.500	12	5
Dutch Innovation F	808	8	4
Rokkeveen A12 as	1.125	24	3
Solitaire locaties	1.537	12	3

Development			
Total value	€ 2.502.452.419	Total GFA	1.238.184
Total costs	€ 1.532.735.539	Total LFA	985.358
		Total GFA Other F	131.389

Figure 23: Results of ROS According to Fakton (Own illustration)

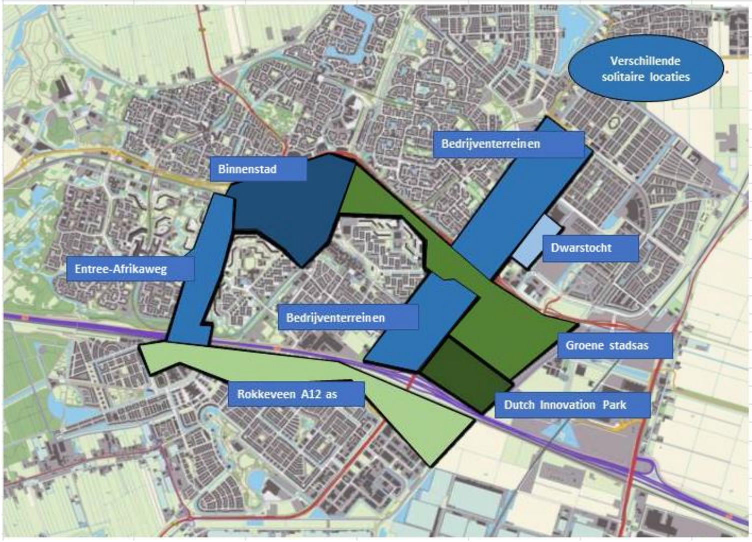
The first, albeit unsurprising, outcome is that the construction program is far more spread out, both across dwelling models as well as across dwelling categories. Were the baseline had a strong bias for less expensive dwellings, apartments and a mix of social and owner-occupied dwellings, the current program is more evenly distributed. This is unsurprising as this was how Fakton roughly distributed the dwellings. What is more interesting is the fact that this program facilitates more migrations and does so across all characteristics of the dwellings. It has a more even spread of migrations and also migrates a number of households out of the most expensive dwellings in the city, which was not the case at all in Minimal Impact.

The only major downside of this program is the fact that the required plot area is more than twice than that of the baseline program; 83.8 compared to 38.5. This is still not problematic, as it would take up no more than 57 percent of every plan area's total area, with the majority using 20 to 40 percent.

Getting Your Money's Worth

The next ROS involved the development of a program which maximized the value of the newly constructed real estate and thus added the most value to Zoetermeer. The previous baseline was again used as the foundation, but the market demand was not taken into account. Instead, the program was optimized in two steps, first maximizing the total value of the developments, which found the value of €3,895,000,471 as the maximum total value. This was constraint at €3,850,000,000 to give the model some solution space to work within, after which the model was again run with the objective to minimize the required plot area. The outcome in Figure 24 resulted.

What should be noted when looking at the results however, is fact that the model constructed all parking spots underground or within buildings, as these can be monetized more profitably and the model only looked at profits and did not take into consideration the hassle of such underground construction or the possibility of even doing so.



Dwellings	10.000	Av. Price	€ 324.714
Low	1.676	Apartment	7.110
Middle	1.629	Single Family	2.890
High	5.988	Social	630
High+	707	Rental	5.520
		Owner-occupied	3.850

Migrations	22.739	Apartment	12.085
Low	7.355	Single Family	10.654
Middle	6.642	Social	4.780
High	7.767	Rental	7.852
High+	975	Owner-occupied	10.107

Plot area (ha)	70,31	Dwel. models	9

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.500	2	10
Entree-Afrikaweg	1.887	11	5
Bedrijventerreinen	2.250	13	5
Dwarstocht	-	-	-
Groene stadsas	1.500	13	5
Dutch Innovation P	900	2	6
Rokkeveen A12 as	922	23	3
Solitaire locaties	1.041	6	4

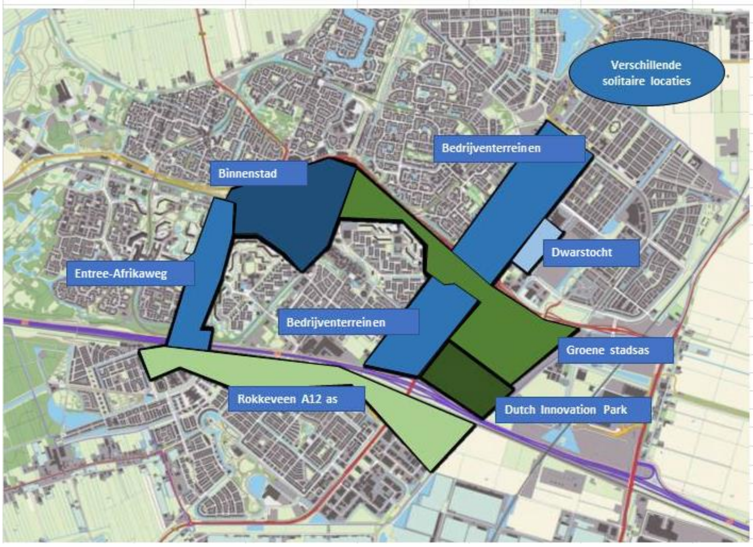
Development			
Total value	€ 3.850.000.000	Total GFA	1.747.673
Total costs	€ 2.597.249.486	Total LFA	1.452.450
		Total GFA Other F	953.012

Figure 24: Results of ROS Getting Your Money's Worth (Own illustration)

An expected result of this optimization is the overrepresentation of expensive and very expensive dwellings, which constitute 67 percent of all planned dwellings, and a near absence of social housing with only 6 percent. This is however not compensated by the facilitated migrations, as only 19 percent of migrations happen in social dwellings. Another expected result is the high total value of €3,850,000,000, which is a factor 1.7 higher than the baseline's value. However, the cost of the program rise as well, resulting in only a small amount of added profit and when calculated as euro per m^2 plot area, the result is actually worse than in the baseline; €1,782 compared to €2,425, which is a vast difference. This is however mostly due to the fact that the latter requires a lot less plot area, but still develops 10,000 dwellings upon that area.

The Great Migration

The following ROS explores the program in the context of specifically the facilitated migrations and attempts to maximize the number of them within the proposed program. It does not take into account the market demand and aims to develop 10,000 dwellings with all dwelling models being within the program at least once. The result is shown in Figure 25.



Dwellings	10.000	Av. Price	€ 294.469
Low	1.065	Apartment	7.090
Middle	4.345	Single Family	2.910
High	4.465	Social	271
High+	125	Rental	4.752
		Owner-occupied	4.977

Migrations	23.350	Apartment	12.374
Low	6.968	Single Family	10.976
Middle	9.849	Social	4.397
High	6.174	Rental	7.227
High+	359	Owner-occupied	11.726

Plot area (ha)	72,68	Dwel. models	13

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.500	2	10
Entree-Afrikaweg	2.310	18	4
Bedrijventerreinen	1.502	11	4
Dwarstocht	250	3	3
Groene stadsas	1.500	13	4
Dutch Innovation P	900	2	6
Rokkeveen A12 as	750	14	3
Solitaire locaties	1.288	10	4

Development			
Total value	€ 3.145.594.324	Total GFA	1.431.564
Total costs	€ 1.905.324.201	Total LFA	1.224.364
		Total GFA Other F	159.425

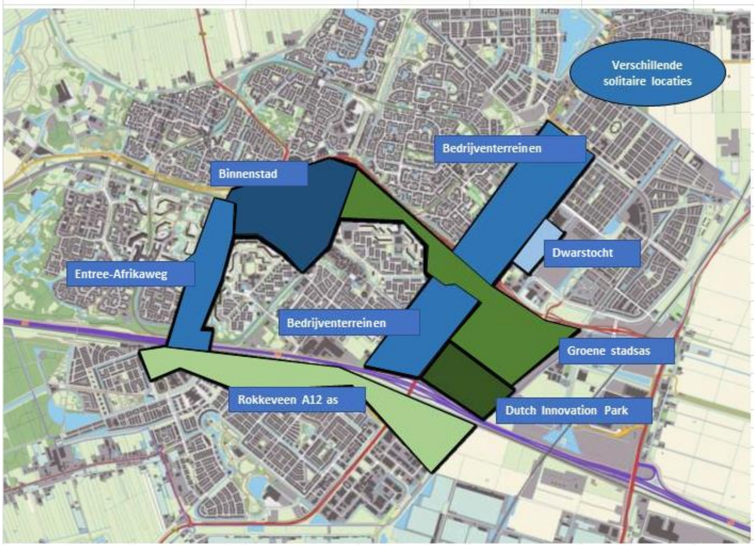
Figure 25: Results of ROS The Great Migration (Own illustration)

As is evident from the tables on the right side and expected, this program does quite well in terms of migrations. It facilitated 23,428 migrations before and 23350 migrations after plot area minimization, which both represent the primary and secondary supply combined (for explanations on these concepts see ‘2.1.5 Markov chain’). What the program however also does, is provide a majority of dwellings in two different price ranges; middle and high price segments, i.e. €175,000 to €250,000 and €250,000 to €500,000. The lower segment is barely provided for as a mere 1,065 dwellings are planned in this segment. This is somewhat compensated by the facilitation of migrations as in both the low and middle price segments a secondary supply of respectively 5,904 and 5,558 dwellings is facilitated.

The Great Migration still achieves second place in terms of the value per m^2 plot area out of ROS 2 through 6, with a value of €1,473 and only the value-driven ROS being higher. This is interesting as the model at no point during the optimization maximized for this variable ‘actively’. However, as was stated earlier in the report, more valuable dwellings tend to have longer migration chains, so the result is logical. The reasons for excluding ROS 7 and 8 in this was due to their unrealistic characteristic of assigning only one living environment to all plan areas and not the prescribed ones.

What the People Want

The fifth ROS seeks to combine the market demand with the maximization of the facilitated migrations. It does so by restricting the newly constructed dwellings to a bandwidth of 5 percent above or below the market demand as stated by Fakton (Versteeg et al., 2016) and then finding the maximum number of migrations which can be facilitated. The result of the first optimization step was that a total of 22,666 migrations could be facilitated. The migrations were then constrained at a minimum of 22,550 and the model was run again to minimize the required plan area. The result was the following program:



Dwellings	10.000	Av. Price	€ 258.214
Low	3.776	Apartment	6.739
Middle	3.252	Single Family	3.261
High	2.872	Social	2.700
High+	100	Rental	3.500
		Owner-occupied	3.800

Migrations	22.550	Apartment	12.053
Low	10.021	Single Family	10.497
Middle	8.024	Social	7.145
High	4.215	Rental	5.502
High+	290	Owner-occupied	9.903

Plot area (ha)	73,09	Dwel. models	13

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.500	1,92	10
Entree-Afrikaweg	1.963	13,08	4
Bedrijventerreinen	2.090	13,81	4
Dwarstocht	200	3,42	3
Groene stadsas	1.500	12,64	5
Dutch Innovation F	738	7,54	4
Rokkeveen A12 as	750	12,94	3
Solitaire locaties	1.260	7,73	4

Development			
Total value	€ 2.643.901.218	Total GFA	1.279.198
Total costs	€ 1.615.824.246	Total LFA	1.037.683
		Total GFA Other F	135.903

Figure 26: Results of ROS What the People Want (Own illustration)

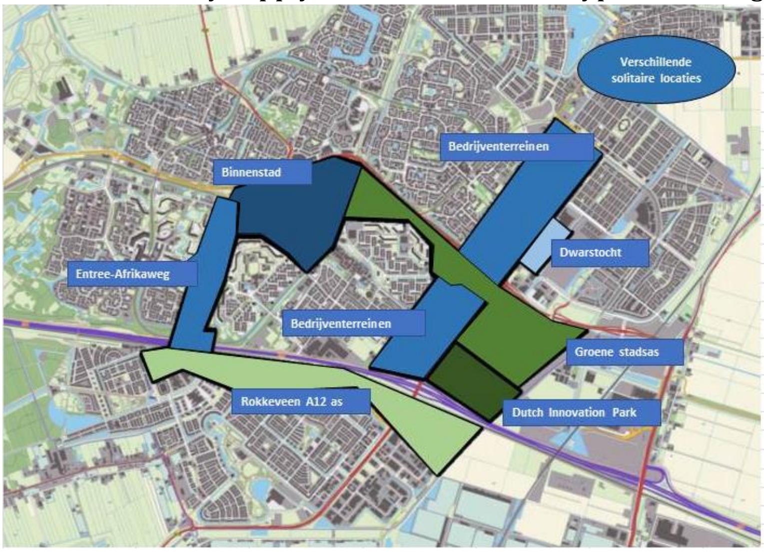
The primary supply as shown in this program closely resembles that of the second ROS According to Fakton, although it is also evident that optimization for migration occurred, as more expensive dwellings are realised. However, what is also shown is that a total of 7,145 households currently living in a social dwelling are migrated and of these, approximately 3,000 households move out of social housing and into market rental or owner-occupied dwellings. Another interesting aspect of this program is the 35 percent market rental dwellings, whilst also having a normal spread of the two other types. This program is only program showing such a distribution.

Efficient Construction

The next ROS investigated the idea of constructing the primary which would provide the secondary supply which would match the market demand. This meant that instead of the planned 10,000 dwellings a possibly smaller plan could be developed, which would still supply the demand with the required dwellings.

The outcome of this program, when using the Markov multipliers of 2015 – 2017, returned “Infeasible” in every run, even when constraints had been loosened. The ROS thus proved to be insolvable and for that reason the Markov multipliers of only 2017 were used, albeit to only show the possibility of the model of working with the other variables. Normally the input should not be changed, as this would be considered scientific cherry-picking and instead the inputs in terms of aims of the municipality would have been altered. An example could be tweaking or loosening the living environment definitions to see what a feasible solution would look like. The following program represents the results which was found without this process and based on the multipliers of 2017, and can thus not be compared to the other programs directly, as the migration chains were used as one of the constraints.

The ROS was minimized for the amount of dwellings constructed and resulted in the program shown in Figure 27 on the next page. The first notable outcome of this program is the fact that, through efficient construction, the amount of dwellings can be reduced to 7,015 dwellings, meaning the annual supply drops from 700 to approximately 470 dwellings on a 15 years planning. Another interesting aspect is the fact that not a single social dwelling is constructed, which suggests that through efficient construction alone, enough dwellings could theoretically be ‘liberated’ to fully supply the demand for this type of housing.



Dwellings	7.015	Av. Price	€ 254.996
Low	3.827	Apartment	3.095
Middle	942	Single Family	3.920
High	2.222	Social	-
High+	24	Rental	2.601
		Owner-occupied	4.414

Migrations	10.000	Apartment	4.404
Low	4.469	Single Family	5.596
Middle	4.028	Social	3.404
High	1.305	Rental	2.158
High+	198	Owner-occupied	4.438

Plot area (ha)	54,50	Dwel. models	6

	Dwellings	Plot area (ha)	Layers
Binnenstad	-	-	-
Entree-Afrikaweg	1.388	12	3
Bedrijventerreinen	2.051	16	3
Dwarstocht	300	3	3
Groene stadsas	1.500	11	4
Dutch Innovation P	782	5	3
Rokkeveen A12 as	43	1	3
Solitaire locaties	952	8	3

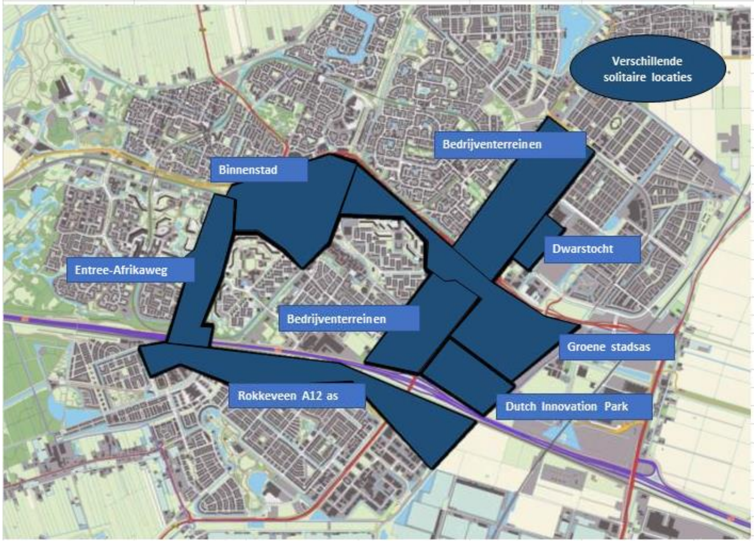
Development			
Total value	€ 1.779.806.845	Total GFA	815.762
Total costs	€ 1.088.549.985	Total LFA	687.548
		Total GFA Other F	81.216

Figure 27: Results of ROS Efficient Construction (Own illustration)

As can be expected, this program also requires less plot area compared to the other proposals. Were the others would generally need between 70 and 90 hectares, this plan only requires 54.5 hectares. This is a second benefit of the program, as it would not only require less development, but it would also do so within a less space, thus requiring less acquisition of space and, as a result, less capital investments.

Maximal Urbanization

The following two programs were designed as explorative studies of extreme programs. This ROS first addresses a situation in which the entire city is constructed according to the living environment Inner-City, thus maximizing the urbanity of the plan areas. The optimization occurred on the facilitated migrations first and afterwards a second run was done to minimize the required area of the program. Both the maximization as well as the minimization of urbanisation achieved slightly more than 23,100 migrations, respectively 23,529 and 23,218, so the facilitated number of migrations was constrained to be at least 24,000 in both. This was done in order to make them even more comparable and see the effects of the different living environments.



Dwellings	10.000	Av. Price	€ 241.972
Low	-	Apartment	10.000
Middle	8.862	Single Family	-
High	1.138	Social	-
High+	-	Rental	6.000
		Owner-occupied	4.000

Migrations	23.100	Apartment	15.323
Low	5.791	Single Family	7.777
Middle	14.277	Social	4.018
High	2.800	Rental	8.264
High+	232	Owner-occupied	10.818

Plot area (ha)	10,68	Dwel. models	3

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.250	1	10
Entree-Afrikaweg	1.458	1	10
Bedrijventerreinen	2.250	3	10
Dwarstocht	300	0	10
Groene stadsas	1.500	2	10
Dutch Innovation P	900	1	10
Rokkeveen A12 as	1.125	1	10
Solitaire locaties	1.217	1	10

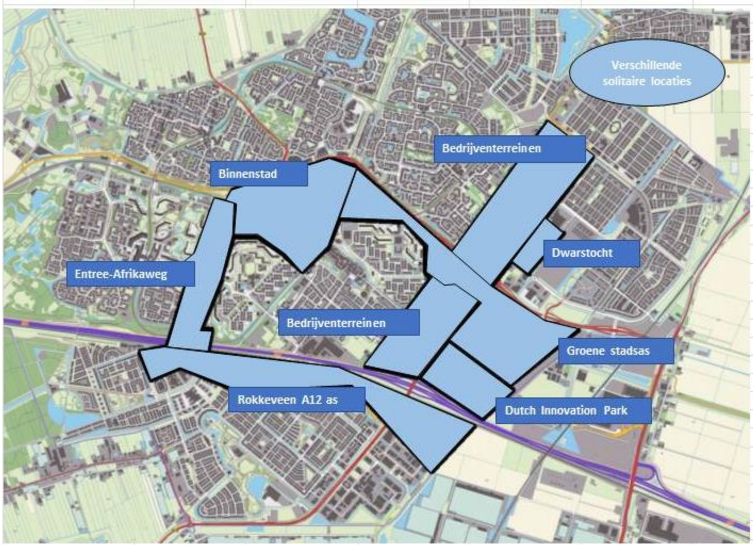
Development			
Total value	€ 2.671.616.136	Total GFA	1.240.351
Total costs	€ 1.648.499.232	Total LFA	1.055.203
		Total GFA Other f	172.044

Figure 28: Results of ROS Maximal Urbanization (Own illustration)

The most interesting result of this program is the fact the number of different dwelling models is only 3, which is the lowest of all programs. Furthermore, it only plans for apartments to be in the program and the majority of the dwellings is found within the middle price segment. This is combined with a migration distribution which is similarly focussed on apartments and the middle price segment. The program thus shows the undesirable nature of constructing only according to the Inner-City living environment.

Minimal Urbanization

The last ROS probed the outcome of a program which involved the opposite of the previous ROS; achieve minimal urbanization. The program would, like the previous one, again not take into account the market demand and only focus on maximizing the number of facilitated migrations, whilst minimizing the required plot area. It did this in a program which only had the living environment of Neighbourhood and had to consist of 10,000 dwellings.



Dwellings	10.000	Av. Price	€ 280.000
Low	2.930	Apartment	4.000
Middle	2.267	Single Family	6.000
High	4.803	Social	-
High+	-	Rental	2.709
		Owner-occupied	7.291

Migrations	23.100	Apartment	9.380
Low	9.129	Single Family	13.720
Middle	7.527	Social	4.136
High	6.249	Rental	4.935
High+	196	Owner-occupied	14.029

Plot area (ha)	121,99	Dwel. models	5

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.500	17	3
Entree-Afrikaweg	2.188	30	3
Bedrijventerreinen	2.047	28	3
Dwarstocht	300	3	3
Groene stadsas	1.500	17	3
Dutch Innovation P	-	-	-
Rokkeveen A12 as	880	10	3
Solitaire locaties	1.586	18	3

Development			
Total value	€ 2.872.863.102	Total GFA	1.294.142
Total costs	€ 1.701.488.019	Total LFA	1.071.770
		Total GFA Other f	58.248

Figure 29: Results of Minimal Urbanization (Own illustration)

This last ROS provides a number of interesting aspects. The first is the enormous amount of plot area required to construct all 10,000 dwellings when doing so in the living environment Neighbourhood. Further exploration unveils that a number of plan areas would have up to 80 percent of their total area taken by buildings, which is impossible seeing as infrastructure and greenery are also needed in these areas. Another interesting aspect is the fact that only 5 dwelling models are constructed in the program and the complete absence of social housing.

5.4 Overall findings

This last section of this chapter will provide a number of concluding observations on all ROSs and compare them in more detail. This will show a number of important finding which can be taken into account when designing an actual housing program, which will be done in the next chapter.

Table 36 shows an overview of all key outcomes of each ROS. The first section of the table show the primary supply, or newly constructed dwellings, of each program. A clear difference can be seen when comparing ROS 1 through 4; the first two 'favour' cheaper dwellings, whilst the latter two 'favour' the more expensive dwellings. This is because of the different objectives. The former aimed to just minimize plot area, whilst the latter two aimed to maximize value and maximize migrations. This split in resemblances is however not found in the distributions of type and ownership, as all four have a majority of apartments and ROS 1 has a split ownership, ROS 2 had a spread distribution and ROS 3 and 4 have a small portion of social housing. A number of trends

Variable	ROS 1	ROS 2	ROS 3	ROS 4	ROS 5	ROS 6	ROS 7	ROS 7b	ROS 8	ROS 9
Primary supply	**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**7,015**	**10,000**	**10,000**	**10,000**	**10,000**
Low	5,606	4,737	1,676	1,065	3,776	3,827	-	923	2,930	1,754
Middle	3,950	3,252	1,629	4,345	3,252	942	8,862	6,480	2,267	4,386
High	444	1,778	5,988	4,465	2,872	2,222	1,138	2,597	4,803	3,822
High+	-	233	707	125	100	24	-	-	-	40
Apartment	7,340	5,700	7,110	7,090	6,739	3,095	10,000	10,000	4,000	7,104
Single family dwelling	2,660	4,300	2,890	2,910	3,261	3,920	-	-	6,000	2,898
Social	3,500	2,900	630	271	2,700	-	-	923	-	362
Rental	600	2,500	5,520	4,752	3,500	2,601	6,000	5,997	2,709	5,424
Owner-occupied	5,900	4,600	3,850	4,977	3,800	4,414	4,000	3,080	7,291	4,216
Secondary supply	**12,319**	**12,218**	**12,739**	**13,350**	**12,550**	**10,000**	**13,100**	**13,100**	**13,100**	**13,000**
Low	6,246	6,380	5,679	5,903	6,245	4,469	5,791	5,877	6,199	5,960
Middle	4,694	4,503	5,013	5,504	4,772	4,028	5,415	5,311	5,260	5,194
High	1,223	1,177	1,779	1,709	1,343	1,305	1,662	1,673	1,446	1,610
High+	155	158	268	234	190	198	232	239	196	234
Apartment	5,440	5,384	4,975	5,284	5,314	4,404	5,323	5,300	5,380	5,248
Single family dwelling	6,879	6,834	7,764	8,066	7,236	5,596	7,777	7,800	7,720	7,750
Social	4,392	4,503	4,150	4,126	4,445	3,404	4,018	4,213	4,136	4,174
Rental	1,779	1,818	2,332	2,475	2,002	2,158	2,264	2,344	2,226	2,273
Owner-occupied	6,147	5,897	6,257	6,749	6,103	4,438	6,818	6,543	6,738	6,551
Dwelling models	6	13	9	13	13	6	3	5	5	13
Plot area	38.5	83.8	70.3	72.7	73.1	54.5	10.7	11.5	122.0	64.3
Average value	206,000	241,000	325,000	294,000	258,000	255,000	242,000	251,000	280,000	273,000
Value	2,229 mln	2,502 mln	3,850 mln	3,146 mln	2,644 mln	1,780 mln	2,672 mln	2,345 mln	2,873 mln	3,047 mln
Cost	1,309 mln	1,533 mln	2,597 mln	1,905 mln	1,616 mln	1,089 mln	1,648 mln	1,771 mln	1,701 mln	1,906 mln
Profit	920 mln	969 mln	1,253 mln	1,241 mln	1,028 mln	691 mln	1,024 mln	574 mln	1,172 mln	1,141 mln
Profit per m² plot area	2,391	1,155.9	1,782.1	1,707.5	1,406.5	1,267.9	9,588.0	5,013.1	960.7	1,775.3

Table 36: Overview of all ten ROS outcomes (Own illustration)

can however be distinguished. Firstly, to minimize the required plot area, a 'preference' towards small, apartments is found in all ROSs. Secondly, to maximize both value and migrations, more expensive dwellings are being constructed, which is further substantiated by the almost equally high profit per m^2 plot area. The fifth ROS further confirms these assumptions, as it combined ROS 2 and 4 into one and achieved the beneficial results of both ROSs; a spread of dwelling price, type and ownership, whilst having relatively high profit per m^2 plot area and an average amount of secondary supply.

When analysing the secondary supply more closely, the balancing effects of constructing more expensive and non-social dwellings becomes more apparent. ROS 1 through 5 all have similar distributions of the secondary supply, but the ROSs optimized for migrations, ROS 4 and 5, tends to have programs which perform better in facilitating migrations throughout all segments and ownership types, instead of having a focus on one or two categories. These programs do also seem to facilitate migrations out of single family homes in distributions proportional to the overall stock of Zoetermeer.

The third set of variables concern the number of dwelling models, the required plot area, the average value and the value and cost of the overall construction. These variables provide two more resulting variables, namely the profit, which is found by subtracting the costs from the value, and the profit per m^2 plot area, which is found by dividing the profits by the required plot area. It should be noted that these profits still include 21 percent in taxes on the value of the dwellings, so these should be taken out. This percentage was not taken out in the model, as it would have conflicted with the aims of achieving a certain average price of the dwellings, which is the price the household has to pay, thus including the taxes.

An interesting first conclusion found in these latter variables is the fact that in terms of required plot area and profit per m^2 plot area, the program based on Fakton's market demand performs the worst. This is also the case when looking at the migrations, as this program has the lowest amount of facilitated migrations as well. It is however likely caused by the optimization that occurred in the program; the minimization of required plot area attempts to reduce plot area and thus tends to 'favour' small and cheap dwellings over large and expensive dwellings. This is given more foundation when looking at ROS 5, which as stated before performed well on a number of important aspects including the migrations and average dwelling price. The only difference between ROS 2 and 5 is the fact that migrations where optimized for and the model was given some 'breathing space' to do so, thus showing the influence of taking the secondary supply into account.

Another conclusion taken from these ROSs, is the fact that once migrations are taken into account the average dwelling prices also seem to rise, again showing the pull this optimization has on the dwellings which are built.

ROS 6 has not yet been discussed, as this ROS looked at the program not from the primary supply, but aimed at facilitation specific numbers, or rather percentages, of migrations. These percentages had to match with the demand as stated by Fakton, but instead of using the 2015 to 2017 Markovian multipliers, the 2017 multipliers were used to show the workings of the model. The resulting program portrays a different answer to supplying the demand, as instead of adding the dwellings which are in demand, the dwellings which promote the availability of this demand in the secondary supply area added, thus taking a more indirect approach. Without the construction of social rental dwellings, 3,400 are still made available. Similarly, 2,100 middle segment dwellings become vacant as the result of migrations whilst only 950 are added to the stock. This programs furthermore shows that this is possible in only a portion of the space with is required for the other programs. A connotation to these findings should however be taken into account, as these migrations are purely theoretical and can thus change. However, they could do so negatively as well as positively, meaning that as migration chains change, they could do so in a manner that increases the effects of certain dwelling models, while decreasing the effects of others. This is why, to maintain the best possible effects of the program, these chains should be monitored annually as dwellings are added to the stock, because these will likely alter the migration patterns and with it the multipliers.

Finally, the last two ROSs show a number of effects of their respective focusses. Firstly, the divide is found in terms of primary supply categories. ROS 7 programs more apartments, middle segment dwellings and rentals, whilst ROS 8 is dominated by single-family dwellings and owner-occupied dwellings, but has a more even spread in terms of price. Inversely, the migrations show a near identical picture, showing the same number of facilitated migrations in all three characteristics. Lastly, the effects focusses are shown again in the required plot area, which influences the profit per m^2 plot area. ROS 7 requires only 10 hectares, whilst ROS 8 needs 122 to construct all 10,000 dwellings. This difference is cause by the fact that the latter primarily aims to construct single-family dwellings, which require more plot area. All discussed effects are logically expected in environments aimed at maximal and minimal urbanization respectively. They do however show how certain outcomes can be influenced with the use of the environment definition.

5.5 Conclusion

In conclusion to this second to last chapter, a number of remarks could be made. The first is the fact that in this specific model only a small number of actors were taken into account, due to the limited scope of the model. This does however not mean that the model will not produce a useful output, as it still designs the entire housing program and enables the municipality to provide input to have an influence on the proposed program. This was done with the use of two main inputs and a number of smaller inputs.

The first large input was that of the living environments, which determined the area characterizations. Nine different environments could be defined and they included the characteristics of GSI and L for density, the mix and type of functions to determine non-housing functions and the four dwelling characterizations of type, price as paid by the buyer, size in LFA and ownership type. The combination of these eight characteristics were used to provide the model with boundaries within which it had to design a housing program. The latter four were also used as defining characteristics of the dwellings which were the second set of input and the area characteristics thus had to be met by the average dwelling characteristics of a district's total program. Along with the size type, price, size and ownership type, the dwelling models were also defined through the supply of building costs, a GFA, built area and plot area matching to the LFA and a parking requirement matching the dwelling's characteristics. These two major parts of input were taken from previously established documentation and added upon through discussions with the municipality of Zoetermeer.

The smaller input used in the model included a total aim of dwellings, as well as an indication of the distribution among plan areas. It was furthermore established whether the model had to take into account certain aspects, such as market demand or migrations, at all and if so, were to use which information. Finally, percentual values for the additional costs and taxes were established.

After having defined the inputs, the model could now use them to design a housing program. The model tasked with doing this was designed specifically for Zoetermeer, but is also constructed in such a way that it could be cleared of any data specific to the city and another city's information could be supplied. The model type that was used is a decision making model. This type of model knows three types; verbal, graphical and formal. The latter, also known as a mathematical, was used due to the complexity of the problem and amount of input needed to design a housing program. Furthermore, the current method of designing a housing program uses graphical decision-making, i.e. designing on paper and assessing every iteration until all criteria are satisfied, and the mathematical model would ideally shorter the time required to find the best design. The type of mathematical model used is a Linear Programming, or LP, model, and it uses boundary criteria to find the best possible solution to a problem.

The outcome of the model was a set of variables detailing the program which was proposed. These included dwelling count specified into the fifteen available dwelling models, the required plot area, the total added monetary value and the number of facilitated migrations to mention the four most important variables. The entire model was run for ten different Run Objective Set, or ROSs. These were essentially the unique combinations of input which could be provided and thus portrayed a strategy for the program. The outcomes of the model showed the strength as well as the flexibility of the model and resulted in ten more or less fitting solutions to the problem. They also showed a number of correlations between objectives of programs, such as the comparable effects of maximizing migration and adding as much monetary value as possible.

Phase 4 Realising the Supply

This last phase will describe the proposal for the redevelopment plan for Zoetermeer. It will describe the best solution for Zoetermeer when looking at the problems it is facing and when taking its goals and desires into account. This phase, and therefore this chapter, will be rather short, as the actual realization cannot be described because the construction of the dwellings is out of the control of the municipality and will take time beyond the scope of this report.

6.1 The proposed program

This last chapter will provide the outcome of the model which seems to be the best solution in view of the problems Zoetermeer is facing and the desires it has stated in terms of its housing program. These aims were stated by Bureau073 (2017) as being:

- **1) Growth of the number of inhabitants** and 2) the economy
- **3) Inner-city redevelopment 4) with a long term view**
- **5) Quality of housing** and 6) public space
- **7) Accommodating the entire living cycle 8) within the city**

From these points, all bold points were taken into account in some manner in the developments of the program in this research. The other points were not, as they are concerned with aspects of the program not directly linked to the construction of dwellings.

To address points 4, 5 and 7, the city's residential migration chains were analysed and Fakton's market demand was used and both were used in the programming of the development plans. Points 3 and 8 were not directly taken into account, as they concern the placement of the developments, but they were addressed through the calculation, and more specifically the minimization, of the required plot area. The point on the growth of the number of inhabitants is taken into account again through the usage of the demand as stated by Fakton, which in turn took into account the growth of the city's population.

Besides these ambitions, the municipality had also stated that it wanted to get a better sense of which product segments should be added, which target groups will be aimed for and in which living environments the dwellings will be added. These aspects were addressed and used as input to the model and were thus also taken into account. The next section will discuss the most appropriate ROS outcome to these aims and the last section will aim to combine the most beneficial results of all ROSs into one ROS.

6.2 The Best Findings

In the following section of this chapter, a number of ROS outcomes will be addressed as answers to the questions the municipality of Zoetermeer is currently asking.

6.2.1 Best unaltered outcome

When taking into account the criteria mentioned above, the ROS which approximates these the most is ROS 5, or What the People Want. This ROS is within a small range of the market demand as stated by Fakton (Versteeg et al., 2016) and is optimized for the facilitation of migrations. The migrations are quite evenly spread as well, with the focus of the distribution in the price segments being on the low and middle segments. Beside this, the program facilitates the secondary supply of 4,445 social dwellings, which account for a little over a third of the total secondary supply. The total number of migrations however is not as high as it is in some of the other ROSs.

Next to facilitating migrations and achieving a dwelling distribution within 5 percent of Fakton stated demand, the program also performs well on other important factors. Firstly, it requires an average amount of plot area, 73 hectare, and in general requires less than 35 percent of any plan area's total area. Furthermore, it constructs all 13 available dwelling models, thus providing both a good mix, as well as movement space for the developing parties. Lastly, it achieves a profit per m^2 plot area of €1,406.5, which is average, but far below other ROS's values of around €1,750.

Overall, ROS 5 thus performs the best, but still not optimal. Most of the previous points were also made at the end of the previous chapter and many of them have exceptions as to why ROS 5 is not entirely optimal. In general it does however perform better than ROSs 1 and 2, which could be considered as the baseline and current housing program respectively.

6.2.2 Best combined outcome

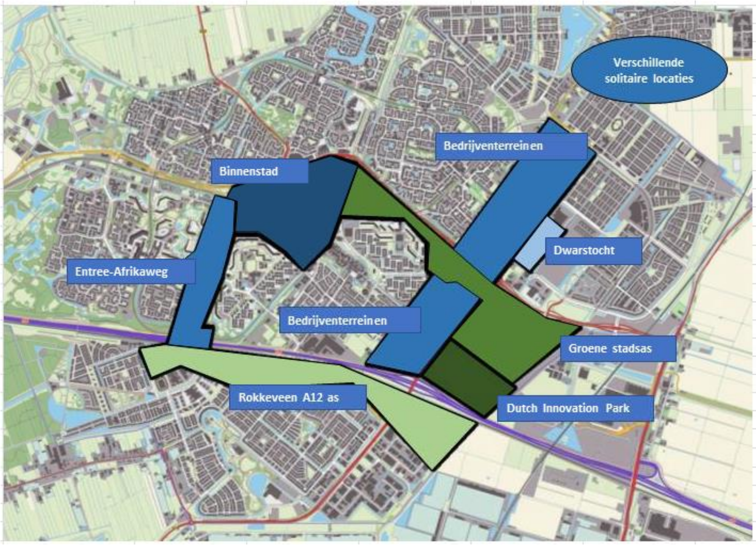
This last segment of the chapter will aim to combine and achieve the best results seen in the individual ROSs and do so within a new a ninth ROS resulting in a ninth housing program. This last ROS, called Best of All ROSs, was achieved through combining ROS 2, 4, 5 and 6 and aimed to reconcile the Fakton demand with the migrations, whilst constructing 10,000 dwellings in 13 dwelling models and doing so on as little plot area as possible.

What this meant, was that instead of using only the secondary supply, like in ROS 6, this ROS would aim to align the total supply to the market demand in terms of percentages. It was given a five percent margin of bandwidth within which the migrations had to be, but the primary supply was not constrained. The only limitations the primary supply had was the fact that all dwelling models had to be in the program and a total of 10,000 dwellings had to added to the housing stock. This all had to achieve the maximum number of migrations and do so in as little plot area as possible. To put this into the format used in Chapter 4:

Dwelling count	10,000
Living environments	All 6
Dwelling types	All 13
Market demand	Normal bandwidth (5%) on secondary supply
Markov household filtering	***Maximize (1)***
Plot area	***Minimize (2)***

The result, seen in Figure 30 was a program which outperformed all viable alternatives. Firstly, it constructed 10,000 dwellings in mostly the middle and high price segments and of rental and owner-occupied ownership. Especially the rental, middle and high segment dwellings are dwelling type not found a lot in Zoetermeer. Social dwellings, or dwelling in the lowest price segment of the rental ownership type, are however constructed very little, but 32 percent of the total secondary supply relocates this group, constituting to a total of 4,174 households.

Also, whilst the program mostly adds middle and high priced dwellings, the majority of the secondary supply is found in the low and middle segments, with a total of 11,154 out of the total secondary supply of 13,000 being in this category.



Dwellings	10.000	Av. Price	€	273.312
Low	1.754	Apartment		7.104
Middle	4.386	Single Family		2.898
High	3.822	Social		362
High+	40	Rental		5.424
		Owner-occupied		4.216

Migrations	23.000	Apartment	12.352
Low	7.714	Single Family	10.648
Middle	9.580	Social	4.536
High	5.432	Rental	7.697
High+	274	Owner-occupied	10.767

Plot area (ha)	64,27	Dwel. models	13

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	1.500	2,02	10
Entree-Afrikaweg	1.850	12,52	4
Bedrijventerreinen	1.500	10,15	4
Dwarstocht	200	2,98	3
Groene stadsas	1.500	11,07	5
Dutch Innovation P	900	1,45	6
Rokkeveen A12 as	750	10,62	3
Solitaire locaties	1.800	13,47	4

Development			
Total value	€ 3.046.630.543	Total GFA	1.376.681
Total costs	€ 1.906.042.446	Total LFA	1.164.442
		Total GFA Other F	406.815

Figure 30: Results of ROS Best of All ROSs (Own illustration)

This ROS further outperforms the other ROSs in terms of average dwelling price, which is approximately €273,000, and also in terms of profit per m^2 plot area, which is €1,775 per m^2. This number is again including taxes, so a substantial portion should be deducted from it, however this is the case with the other ROSs as well. The dwelling value is fourth out of all ten ROSs and the profit per m^2 plot area is second, only a little behind ROS 3. Lastly, the ROS also requires relatively little plot area; only 64.3 hectares is required in total, with no more than 33 percent of the total area of a plan area being required for redevelopment.

To conclude, the reasons for this ROS performing better have been explained and the most important requirements have been shown to meet the requirements of the municipality. This ROS has the best combined performance across all variables.

6.2.3 Surprisingly fitting

A ROS that was surprisingly fitting to the goals of Zoetermeer, was the Maximal Urbanization ROS. It aimed to construct a program in which all plan areas were assigned the living environment of Inner-City and thus had to achieve programming 10,000 dwellings within their constraints. The result was a program characterized by middle segment rental dwellings and exclusively consisting of apartments. Furthermore, not a single social dwelling is constructed. The entire program used only a limited amount of plot area; with the footprint of only 10.7 it is by far the smallest program in term of area requirement.

This is all however contrasted by a program which does facilitate the migration of a varied group of households, as low price segment dwellings, single family homes and social dwellings are made available through the migration of their occupants. Also, the program facilitates the migrations of a total of 23,100 households, which is amongst the highest of all ROSs. The program furthermore performs in a desirable fashion in terms of the average value of the added real estate and the limited impact it has on its surroundings in terms of how much plot area will be required. All these conditions reverberated well with the municipality's program manager of housing, Jeroen Scholten, who explained that the outcome actually reflected a desire to increase the value of Zoetermeer and construct dwelling types not found a lot in the city to attract a new kind of inhabitant.

The only downside of the model is the fact that it did not really facilitate the migration of households currently residing in social rental dwellings. This was due to the reason that the migrations just had to be maximized and no further care was taken in how they had to be distributed. This resulted in a little over 17 percent of all facilitated migrations resulting in an empty social dwelling. Whilst this percentage is low, it does translate to 4,018 dwellings, which is well above the goal of 2,700 for the 10,000 dwelling program as defined by Bureau073 (2017). Furthermore, with the addition of condition of the secondary supply meeting the demand as stated by Fakton, the program can be adjusted to migrate 5,136 (22%) households, whilst still achieving all previously established goals, such as an even higher average dwelling price, a small required plot area of only 11,5 hectares and the same migration count.

Conclusion

The last part of this report will conclude to answer the main research and sub-questions. Each of the following parts will thus answer one of the questions. The main research question which was posed at the beginning of this research was:

To what extend do different dwellings types aid in household filtering in Zoetermeer and how can they be constructed within Zoetermeer in light of its redevelopment plans?

To answer this question however, the associated sub-questions will first have to be answered, as each focussed on one aspect of the main research.

The first sub-questions addressed the demand which the market was placing on the dwelling stock of Zoetermeer. The question aimed to establish a goal in terms of numbers of dwellings which had to be provided. The answer to this question was found relatively easily, as Fakton had already determined this market demand. This demand was specified as being for newly constructed dwellings, but, with the other aims of this report in mind, it would be used to reflect the need for housing in general. The outcome of the report showed an annual demand of 690 dwellings and this demand was distributed among 32 different dwelling models. These models were specified in terms of ownership (social, rental, owner-occupied), dwelling type (single family dwelling, apartment) and the value of the dwelling. This differentiation was however seen by the municipality as too detailed and thus the number of dwelling models was reduced to 13 models and the corresponding demands were summed. The differentiation into 13 models would later also be used to determine the migrations chains.

The annual demand of 690 was translated to a 15-year plan which resulted in the aim of building 10,000 dwellings. The translation of the annual demand to a housing program, done by Bureau073, is somewhat questionable, as it was linearly scaled to 10,000 dwellings and took into account no variation due to changing demand. Nonetheless, the program was passed by the municipal council and was thus used as the required demand to supply dwellings for.

The second sub-question provided a baseline for the housing program and a better understanding of the situation into which the program had to fit, or which problems had to be addressed. The resulting analysis showed that Zoetermeer had a slightly higher percentage of rental dwellings, when compared to the entirety of the Netherlands, and a low average price when compared to its region and surrounding cities. The latter was further characterized by the majority, 75%, of the dwellings having a WOZ value, which is used for taxing purposes by the municipality and represents a relatively accurate value of the dwelling, of between €100,000 and €250,000.

The third sub-question was focussed on one of the main pillars of this research and addressed household filtering and the facilitation of migration within the city. The data used for this was taken from two different data sets, the BRP and BAG, which were linked. From this linked database, the different counts of migrations for type-to-type matches of dwellings, being the current and previous dwelling, were extracted. What was extracted was a 13 by 13 matrix containing these migration counts. This data was then analysed using Markov chain theory, which assumes, and attempts to show, the relationship between two states of the same object. In this case the presumed relationship was a relationship between the current and previous dwelling of a household. The results, as presented in 'Appendix C – Migration distributions and multiplier matrices', showed a number of interesting results.

The first is the fact that, more expensive dwellings seemed to facilitate more migrations than middle and low price segment dwellings did. This is in line with theory found in literature, which found similar relationships between the placement of a dwelling among the dwelling hierarchy and the number of migrations it facilitated. These higher values of migrations were found across dwelling and ownership types as well as across different years for which the data was available. The difference between the different dwelling types was not as stark as seen in some other research, but did range from 1.97 to 2.63 in average chain lengths in the most extreme case. Generally, it ranged from 2.0 to 2.5 and only minor differences were found between the best and second best facilitators of migrations.

The few dwelling models which were found to have the longest chains were however different from the models Fakton suggested to construct, which shows that the different view of the subject of providing housing could conflict with or add another dimension to the presented solution.

Another result of the residential migration chain analysis was the fact that, to facilitate the migration of residents of social rental dwellings, a number of dwelling models aided the most in doing so. The dwelling models which were found to facilitate this the best, mainly middle segment rental dwellings and lower segment owner-occupied dwellings, could be seen as solutions to two problems. On the one hand, Zoetermeer has the ambition to add more value to its housing stock which does not include social dwellings, but on the other hand it want to supply the most vulnerable in its city with housing as well. Building the aforementioned dwellings achieves both, as social dwellings are made available, but the average value of the dwelling is somewhat higher.

The following four sub-questions provided input to the second part of the research and the first questions addressed the model type which was to be used in the research. The outcome of a brief introduction to a number of model types was that the formal, or mathematical, model would suit the problem at hand the best. This is due to the fact that a formal model is capable of solving complex problems, involving a lot of actors and many variables in a relatively short period of time. The choice of using a formal model was founded even more as this type of model is relatively new in the field of urban planning and in the development of housing programs and is still rarely used by municipalities or private parties. This thus provided scientific incentive to test its appropriateness to solving the problem Zoetermeer was facing.

The next two steps involved the defining of the majority of the input variables of for the model, as little had been established in terms of their specific nature. The first was the definition of the living environments assigned to the different plan areas, which would describe the desired area characteristics. Before the start of this research, the municipality had defined them no further than the definitions of environments by Haaglanden. These however addressed only the general sense of the environment and failed to provide specific values for variables such as dwelling density or amount of non-housing function. This would however be a necessity if any mathematical model was to compute a housing program using it. With the use of the basic descriptions, through discussions with the municipality and using a number of reference project provided by Zoetermeer, the living environments were however specified. This was done using 8 variables, which focussed on aspects like the area characteristics, dwelling characteristics and the assigning of functions other than housing. Most important in this classification was the previously established definition of the environment City Neighbourhood and the relationships between different environments. The table on the next page shows these variables and the value for each of the used living environments.

	Inner-City	City Neighb.	Neighbour -hood	Niche Housing	Park Housing	Campus Living
Layers	5 – 10	3 – 7	3 – 5	3 – 7	4 – 10	3 – 6
GSI	0.5 – 1.0	0.4 – 1.0	0.2 – 1.0	0.25 – 1.0	0.2 – 1.0	0.3 – 1.0
Mix of functions	15 – 25%	10 – 15%	5 – 15%	15 – 25%	10 – 20%	20 – 30%
Function type	Inner-city	District	Neighbourhood	District	District	Neighbourhood
Dwelling type	Apartment	Mixed	Single family dwelling	Single family dwelling	Mixed	Apartment
Dwelling price	€180,000 to 300,000	€200,000 to 300,000	€180,000 to 280,000	€300,000 to 500,000	€230,000 to 350,000	€120,000 to 250,000
Dwelling size	70 – 120 m^2	80 – 130 m^2	90 – 140 m^2	120 – 200 m^2	70 – 150 m^2	50 – 100 m^2
Ownership	Rental	Mixed	Owner-occupied	Owner-occupied	Mixed	Rental

The second of the two steps provided the dwellings which would be used to design the housing programs. These would be constructed using the previously discussed 13 dwelling models, which were based on three variables. The first was whether the dwelling was a social, rental or owner-occupied dwelling, the second addressed whether it was an apartment or single family dwelling and the last addressed the value of the dwelling. Based on the value and a value per m^2, the floor area expressed in LFA was deduced. Besides these four variables, a GFA, the cost of construction of one square metre and a parking requirement was also specified for each dwelling model. The thirteen resulting dwelling models are however not the specific dwelling which has to be constructed, but should be viewed as the archetype for a range of dwellings which are above and below it in price. Constructing 100 rental apartments of €200,000 thus does not actually mean 100 of these exact dwellings need to be built, but it means 100 dwellings in the range from €150,000 to €249,000 need to be constructed and preferable have an average price close to €200,000. The ranges for which the "averages" are representative are: Low (<175), Middle (175-249), High (250-399) and High+ (>400). The following table shows all different dwelling models which were used.

Name	**Cost/m^2 (euro)**	**Cost/unit (euro)**	**Res. ground value (euro)**	**GFA (m^2)**	**LFA (m^2)**	**Value/m^2 (euro)**	**Value/unit (euro)**	**Built area**	**Plot area**	**Type**	**Rental-Owned**	**P. norm**
SAP070	900	95,625	54,375	85	60	2,500	150,000	90	90	Ap	R	1.2
RAP080	1,100	137,500	74,500	100	80	2,650	212,500	100	100	Ap	R	1.3
RAP130	1,200	240,000	104,500	160	130	2,650	344,500	160	160	Ap	R	1.6
SSF070	850	106,250	68,750	100	70	2,500	175,000	40	110	SF	R	1.3
RSF100	950	142,500	122,500	120	100	2,650	265,000	50	150	SF	R	1.6
RSF140	1,050	210,000	161,000	160	140	2,650	371,000	70	250	SF	R	1.8
OAP065	1,050	105,000	67,250	80	65	2,650	172,250	80	80	Ap	O	1.2
OAP090	1,050	131,250	107,250	100	90	2,650	238,500	100	100	Ap	O	1.3
OAP120	1,100	199,375	118,625	145	120	2,650	318,000	145	145	Ap	O	1.6
OSF065	1,000	93,750	78,500	75	65	2,650	172,250	40	120	SF	O	1.6
OSF090	1,000	156,250	82,250	125	90	2,650	238,500	50	200	SF	O	1.7
OSF125	1,000	212,500	118,750	170	125	2,650	331,250	60	250	SF	O	1.8
OSF200	1,100	357,500	172,500	260	200	2,650	530,000	90	400	SF	O	1.9

Lastly, the variables which will be optimized for were determined. These are of great influence as they pull the outcome of the model towards their optimal. An example is the optimization for maximum value of the total development, which is logically going to attempt to produce as many expensive dwellings as is allowed within the constraints of the model. To further specify these optimization variables as well as a number of constraints it had to abide by, a number of Run Objective Sets, or ROSs, were formulated. Each of these had an aim to illustrate in the program it produced, such as maximizing migration counts, minimizing required newly constructed dwellings or maximal urbanization.

In general, the four variables for which was optimized were plot area, dwelling count, overall value and migration count, which were used individually or in pairs. The latter would be done with the use of goal programming. This is the process of first running the model based optimizing on one variable and then use the outcome of the variable as a new constraint. After adding the new constraint, the model would be run again, but instead it would now be run to optimize a different variable, resulting in the optimal outcome with the other variable's lower or upper bound constraint not being crossed.

Based on the desires of Zoetermeer and all of the above, the ten different programs were assessed, with each showing a different aspect or having a different aim in the program. Out of these ten programs, ROS 5 showed to have the best direct fit to the ambitions of Zoetermeer, as it achieved a relatively high count of migrations but stayed true to the demand as stated by Fakton. Furthermore it achieved a 2,700 social dwellings which is directly in line with

This is why ROS 7 provided a surprisingly interesting result, as it achieve many migrations on very little plots area, constructed only rental and owner-occupied apartments in the middle and high price segments, but still facilitated many migrations in low price segments as well as social dwellings. Furthermore, with the addition of some further constraints, the number of social rental dwellings made available as a result of migrations could be increased from 4,018 to 5,136. The reason for this outcome to be surprisingly interesting is due to the fact that it was initially seen as an extreme which would not likely be considered, as it revolved around the intense urbanization of Zoetermeer, which meant that all areas were to be programmed according to the living environment Inner-City.

Combining ROSs 2, 4, 5 and 6 into a new ROS 9 and also resulted in a program which showed promise as it achieved a good count of migration across a number of dwelling and ownership types. It did so while constructing dwellings which were not present in the city a lot and even though the number of social dwelling constructed was low, a large portion of the migrations were facilitated in this segment of the stock. This program returned to using the assigned living environments as proposed by Bureau073, which resulted in it using much more space than the previous ROS; 64 hectares compared to only 10 of ROS 7.

All these programs are however the first or second iterations and could be optimized more in discussions with the municipality, the developing parties and other actors.

This research thus showed that combining the two principles is possible and that the results can potentially produce the desired outcome, i.e. a useful housing program. Doing so is however strongly reliant on the input but can in the process take accommodate the specific ambition of the municipality. Furthermore, both the model for the analysis of the migration chains as well as the model tasked with designing the housing programs can be used by any party desiring to use either individually or in synchronicity. This is due to the structure of both models, which are set up in such a manner, that any data can be cleared and new data for the model can be entered to suit the new situation, location, municipality or actor.

Discussion

When looking at the results of this report, a number of remarks should be taken into account. These remarks address the shortcomings of the research and will be discussed in this short chapter. The following part of this chapter will first assess any of the imperfections of the analysis of the residential migrations chains and the last part will do it for the process of designing the housing program.

The analysis of the RMCs was done using the Markov chain theory and included the collection of data from a combination of the BAG and BRP. The most important difference from normal RMC research is the fact that instead of households' migrations, this research looked at individuals' migrations. It was however shown that correcting for it had no effect. The second notation which should be made in light of this method is the fact that the data could not show whether the entire household or just a part of it had migrated and thus whether the dwelling actually became available. This was due to the combination of movements and household size, as the former was registered throughout the year, while the latter was registered once a year. This combination made it difficult to determine whether the entire household moved and it would also require other databases on aspects affecting the household size, such as birth and death.

Another flaw in the data, which could not be resolved was the fact that internal starters, for example young adults moving out of their parents' home, were included in the internal migrations instead of arrivals group. This means that some effects of the internal migration are actually the result of internal starters. Furthermore, the arrivals group included people moving into a home which was already occupied and thus "contaminated" the group in a similar way.

Lastly, neither the Markov chain nor the LP model, took into account the departing migrants. This should have been done, as the departing households leave behind a dwelling, which is going to compete with the newly constructed dwelling, as well as instigate its own migration chain. This groups wasn't taken into account however, as it provided challenges similar to the arrivals group.

In terms of the outcome of the Markov Chain models, it should be noted that the length of the migration chains differed quite a bit from year to year. In general the order of hierarchy did not, as chain length decreased along with price segment and the combination of all three analysed years showed a less volatile outcome. Finally, on first sight the difference between different dwelling models might seem small, but when translating it into hundreds or thousands of dwellings, which is the scale of development, then the difference becomes less insignificant. As an example, 2.2 or 2.3 migration results in an added 10 migrations on the scale of 100 newly constructed dwellings or 100 on the scale of 1000.

In terms of defects of the decision-making model the list is a little shorter, but not less significant. One of the most important flaws of the decision-making model and its inputs is the fact that it was not used extensively and in a process of adjustment. In the usual process of using a model such as this one, the core actors come together to discuss the problems seen in the proposed program on the spot and alter the input to adjust it until all actors agree with the end result. Due to limitations of time and busy schedules, this was not done. The current programs thus represent the first iterations and thus show undesirable features, but this could and would be resolved in the process described above.

Secondly, the input which was provided was largely based on vaguely descriptive documents and made slightly more reliable through a small number of discussions with the actors involved. This however still means that the descriptions are most likely far from definitive and improvement can still be made in the exact definitions. This would again require further discussions.

Finally, the outcome of the research has shown that a mismatch possibly exists between the desired outcome and what it is called. The municipality states the supply of newly constructed dwellings as supplying the demand, but does not take into account the secondary effect of these dwellings. One of the actors said that the goals could perhaps be reframed and stated in terms of *available* dwelling supply instead of *newly constructed* dwelling supply.

Recommendations

The results discussed above show that the approach works, but also show that the input is of great importance and can be hard to define. Especially the development of clear living environment definitions proved difficult, as the municipality had not approached the problem from the quantitative point of view and was actually moving away from it and instead focussing on the qualitative side. To really provide the municipality with a clear housing program, the process of refining the definitions, establishing clearer goals and discussing the outcomes amongst different actors would be essential. This would traditionally be a process of complete design iterations, but the model can adjust to new input very quickly, which makes it very useful in a pressure-cooker setting. At the end of this session, a number of iterations on a chosen starting point could have been done and a number of flaws could be resolved.

Another aspect of the research which could improve over time is the understanding of the migration chains in Zoetermeer. Currently, only 3 years and their cumulative could be used to compute the migrations with, but this can be extended over the next couple of years as the data in collected annually. This should not only be done to better understand the migrations, but also to update the program based on the newest data on migrations. The longer the period is for which data is available, the less likely it is that certain spikes in the data affect the outcome drastically. Moreover, when looking at the past three years, the coming three years can really only be predicted and they would still be flawed. When the past ten years have been analysed, the predictions which can be made could be extended to more than three years and when looking at long term housing programs this is obviously desirable.

Final reflection

This research had as its aim to provide answers to two different questions the municipality of Zoetermeer was asking; how do we advance residential migration or household filtering and what is the housing program for the coming 10 to 15 years going to look like? These questions were being asked because of a local interest and a regional demand respectively. To provide the answers, the migration data was first analysed and based upon it and a number of other inputs a number of housing programs were designed using a decision-making model which was developed. Both questions were thus being answered with the use of one housing program.

User value

The use of the model which was designed is strongly dependant on the process of defining the input, which consisted of the living environments, the dwelling models and a number of city-wide variables. The two are thus almost part of the same iterative process and should be used as such. This likely makes the process too complicated to any given employee of the municipality, which however is hard to prevent, as the approach is also relatively new in the field of urban planning and the development of housing programs specifically.

The outcome of the model seemed to be useful at first sight and the municipality's program manager of housing responded positively to the speed at which a new program could be calculated. This provides potential for implementation of this model as well as its outcome. The outcomes would not be directly applicable, but by optimization the program through a number of iterations, the outcome could come very close to what is desired as a housing program by Zoetermeer, without the need to place design decisions in the hand of others of spend longer periods of time on making these iterations.

Social Value

In terms of social value the model has potentially provided the municipality with a step forward in terms of its housing program and did so with the aspect of migration in mind. It should however be kept in mind that the results will not likely be implemented directly, as the municipality is an organisation which is greatly intertwined with politics and the implementation of any program is thus also greatly dependant on the support it gets from the political environment. Moreover, this report was written during the municipal election of a new municipal council and thus might have been finished shortly after it would have been most useful, i.e. during the formation of a new coalition. Nonetheless it will provide the municipality with new information and view on how it could solve, or attempt to solve, the problems it is facing.

In terms of overall societal value, the results of the research are expected to be rather easily transferable to other municipalities or developments, as the model was built with just that in mind. Both the model for the calculation of migrations chains as well as the decision-making model can be cleared of any data and be filled with any input desired. If any other town or city would like to use the model to construct their housing program, it could do so provided they have the capability to provide the input. Only very little alteration would be required and these would mostly be quality of output alterations, such as the map of Zoetermeer being replaced by the map of the current location. Other than these little alteration, the model is completely set up to facilitate any number of desired dwellings, distribution of dwellings, 15 adjustable dwelling models and 9 adjustable living environments, the model is adjustable to aim at almost any optimization and has the flexibility to facilitate additional input if required, although the latter would naturally require some adjusting to the model.

Scientific Value

In view of the Master track Management in the Built Environment, the research linked quite closely to a number of aspects which have been discussed in the two years of curriculum. Firstly, it aims to solve large scale urban redevelopment problems, which have been central in many parts of the track. Secondly, it applies a decision-making model, which was learned of from a course, in practice and proves that, within a reasonably short period of time, quite decent outcomes can already be achieved. Lastly, knowledge on a number of aspects such as multi-actor decision-making and financial land exploitations had to be applied to the development of the model and the process in general to combine the many inputs and facilitate the actors' aims and goals.

This research also combined housing market analysis with operational research. The housing market analysis was done in the form of researching the residential migration chains that are present in Zoetermeer. This was done using the proven method of Markov Chain Theory, but even though it was proven to show these outcome over twenty years ago, the analysis of migration chains has since barely happened by municipalities and the scientific field in general, or very little was written about it at least. Application of the theory did happen in other fields or research, such as migration of animals, but this research showed that it could also be applied to residential migration using pre-existing data.

In the process of collection this data, some hurdles had to be overcome however. The first was that the two databases in which the information was stored had only been digitalized between 2011 and 2014 and contained useable data for only very few years. Had the database been more precise, concise and structured, than the results concerning migration chains could have been more detailed as well. Nonetheless, the most recent years showed this useable structure and one can thus be hopeful that this kind of analysis can be done in the future as well.

The analysis of the data provided another hurdle however. As is discussed in this report, the Markov Chain Theory requires a number of criteria to be met by the data. Two of these are homogeneity of migration chances and stability of migration patterns. The former provides the research with a contradiction, as extensive diversification of dwelling models results in too little cell coverage. This in turn results in skewed migration chances and distorts the findings from reality. The latter is not likely to be met either, as the patterns are likely to change, not only through time, but through the sheer fact of the interventions which are planned based upon them. Adding dwelling which were previously non-existent in the stock will shift and alter the chains. It was for this reason that the recommendations said to continue analysing the migration patterns throughout the coming years.

The usage of the two databases, the BAG and BRP, was new as far as literature showed. Previously the same mathematical theory was applied to samples found in a national questionnaire, the WoON and the WBO, but using *all actual* migrations registered within a municipality was new.

A weak point of the methodology was the fact it required quite a lot of input which was previously not specified and thus needed to be defined in the process as well. This resulted in the definition of living environments using vague verbal descriptions. Additionally one discussion was held with a number of actors, but a number of actors had to cancel shortly before the meeting and only one such discussion could be held due to time constraints. For this reason, the living environments are not as specifically defined as they could or should be to truly show use the input of Zoetermeer. Similarly, the dwelling models had to be defined based on general characteristics provided by the Fakton report and the archetypes were thus not truly representative of the dwelling models desired by Zoetermeer. The two input were discussed with Zoetermeer however and seen as sufficiently accurate to use for this research.

Ethical issues and dilemmas

Two ethical dilemmas were encountered during this research. The first was that the data which was required to analyse migration chains was private and could not be shared by the municipality. This meant that the municipality had to process the data into matrices which could not be traced back to the individual and provide these to the research. This turned out to be fairly easy, as the department of Research and Statistics within the municipality was very willing to aid in this research and provided multiple iterations of these matrices. The resulting matrices could be put into the Markov Chain model by the researcher and privacy would be maintained as the matrices contained only three characteristics of any dwelling; value range, ownership type and dwelling type.

The second dilemma was encountered in the development of the model. The first version of the model used the input of a number of different variables, but this proved to be too difficult to retrieve and use as input. What resulted was a model which used values for variables which were likely all off by an unknown degree and thus would provide an output which would not be useful, if any outcome could even be found. To resolve this issue, the model was made more detailed, but this meant that a great number of actors and their input were no longer being used or considered in the model. This was however accepted, as the model would likewise also not provide directions in terms of their fields. In short, no input concerning a topic was met with no output on that same topic. Still, the exclusion of certain actors was based on the initial aim of this research to provide a housing program and thus disciplines such as infrastructure, public space, greenery and the like were not taken into account, which is strange as they too influence a living environment.

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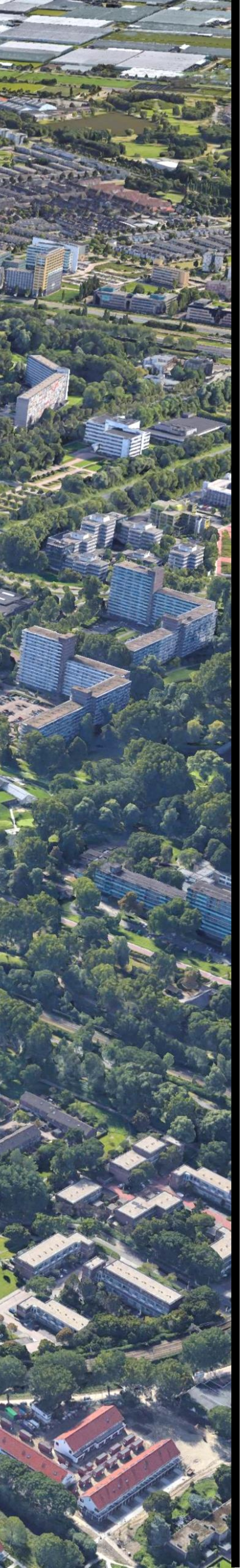


Appendices

Appendix A – BRP and BAG

List of variables contained within the BRP and BAG. The databases are managed by the municipality of Zoetermeer, and was received from Elianne van Dam on the 8th of January 2018:

(1) – Variables registered in the BRP

Variabelen in het bestand BRP van vertrekkers (ongeveer gelijk voor bestand vestigers/binnenverhuizers)

BSN-nummer persoon
Sleutelveld
Mutatiejaar
Mutatiemaand
Mutatiedag
Jaar ingang geldigheid
Maand ingang geldigheid
Dag ingang geldigheid
Geboortejaar persoon
Geboortemaand persoon
Geboortedag persoon
Geboorteplaats persoon
Geboorteland persoon
Geslacht persoon
Rijkskode nationaliteit
Burgerlijke staat persoon
Geboorteland ouder1
Geboorteland ouder2
Originele Nationaliteit 1
Nationaliteit 2 persoon
Nationaliteit 3 persoon
Jaar inschrijving
Maand inschrijving
Dag inschrijving
Jaar aanvang adreshouding
Maand aanvang adreshouding
Dag aanvang adreshouding
Straat-code
Huisnummer
Huisletter
Huisnummertoevoeging
Aanduiding bij huisnummer
Postcode
Land van emigratie
Jaar emigratie
Maand emigratie
Dag emigratie
Land van immigratie
Jaar immigratie
Maand immigratie
Dag immigratie
Gemeente uitschrijving
Jaar uitschrijving
Maand uitschrijving
Dag uitschrijving
A-nummer persoon
A-nummer ouder1
A-nummer ouder2
AON-nummer (BAG)
INA-nummer (BAG)
Leeftijd
Leeftijd in groepen
Leeftijd in groepen
Straatnaam
Buurt
Wijk
Subbuurt (oude codering)
Wijk-Buurt-Subbuurt
X-coördinaat
Y-coördinaat
herkomst (CBS def)
Herkomst persoon
herkomst in groepen(CBS def)
herkomst in groepen(CBS def)
Provincie van bestemming
Bestemming *(bij bestand vestigers is dit herkomst en bij binnenverhuizers is er een bestemming en herkomst)*

(2) – Variables registered in the BAG

Variables within BAG database

Bestandsopbouw van het microdatabestand

Onderstaand volgt een overzicht van alle variabelen in het microdatabestand.

Nr.	Variabele en label	Formaat
1	Soortrinadres	A1
	Soort identificatiecode rinadres	
2	Rinadres	A9
	Identificatiecode rinadres	
3	GEMcode	A4
	Gemeentecode op 1 januari bestandjaar	
4	Pc4	A4
	Postcode 4 cijfers	
5	VBOvoorraad	A1
	Verblijfsobject geteld in voorraad	
6	VBOvoorraadtype	A1
	Verblijfsobject oorspronkelijk gebruiksdoel volgens de BAG	
7	VBOtypeinliggend	A1
	Verblijfsobject type inliggend(een- of meergezins)	
8	Inliggend	F3
	Aantal verblijfsobjecten in het pand waarin het verblijfsobject ligt	
9	Meerfunctie	A2
	Meerfunctie verblijfsobject	
10	Oppervlakte	F6
	Gebruiksoppervlakte van het verblijfsobject	
11	Bouwjaar	A4
	Bouwjaar van het pand (PND) waarin het verblijfsobject ligt	
12	Bouwjaarklasse	A1
	Bouwjaarklasse van het pand (PND) waarin het verblijfsobject ligt	
13	Bew1jan2013	A1
	Aanduiding of er personen staan ingeschreven volgens de GBA op 1 januari bestandjaar	
14	WoningtypeKadaster	A1
	Woningtypering bron Kadaster	
15	PERCCODE2013	A1
	Perceelcode, Aanduiding van de aard van het perceel, toegekend door PostNL	
16	Gebruikscode2013	A2
	WOZ-gebruikscode	
17	WOZwaarde2013	F11
	WOZ-waarde 2013,waardepeildatum 1-1-2012, euro	
18	Eigenaar2013	A1
	Code eigenaar/gebruiker afkomstig WOZ	
19	Aardeigendom2013	A1
	Aanduiding eigendom van woonruimte door Kadaster	
20	Eigendom2013	A1
	Aanduiding eigen/huur woning	
21	Verhuurder2013	A1
	Aanduiding van de soort verhuurder	
22	IdCorp2013	A5
	Identificatienummer Toegelaten instelling volkshuisvesting of gemeentelijk woningbedrijf	

(CBS, 2014)

Appendix B – Characteristics of Zoetermeer

Number	Neighbourhood
010	Dorp
020	Stadscentrum
030	Palenstein
040	Driemanspolder
100	Meerzicht-West
110	Meerzicht-Oost
200	Buytenwegh
210	De Leyens
300	Seghwaert-Zuidwest
310	Seghwaert-Noordoost
400	Noordhove-West
410	Noordhove-Oost
500	Rokkeveen-West
510	Rokkeveen-Oost
600	Oosterheem-Zuidwest
610	Oosterheem-Noordoost
800	Rokkehage
810	Lansinghage
820	Zoeterhage
830	Hoornerhage
920	Balijbos
930	Westerpark-EO
940	Buitengebied-West
950	Meerpolder
960	Scheidingszone
970	Van Tuyllpark

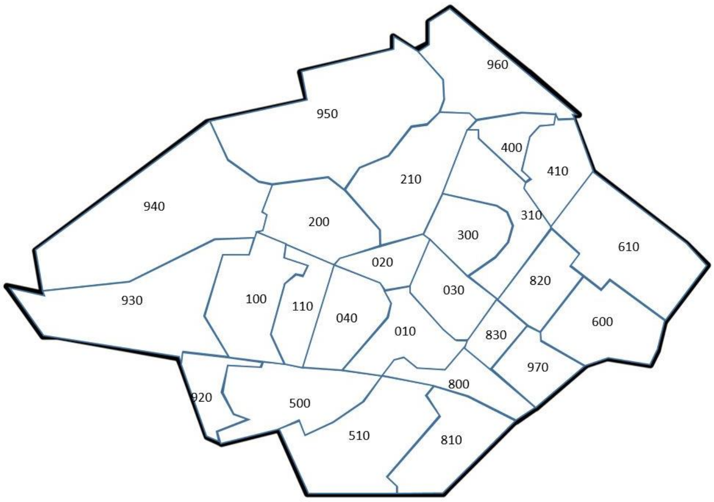


Figure 32: Neighbourhood codes of Zoetermeer (Own illustration)

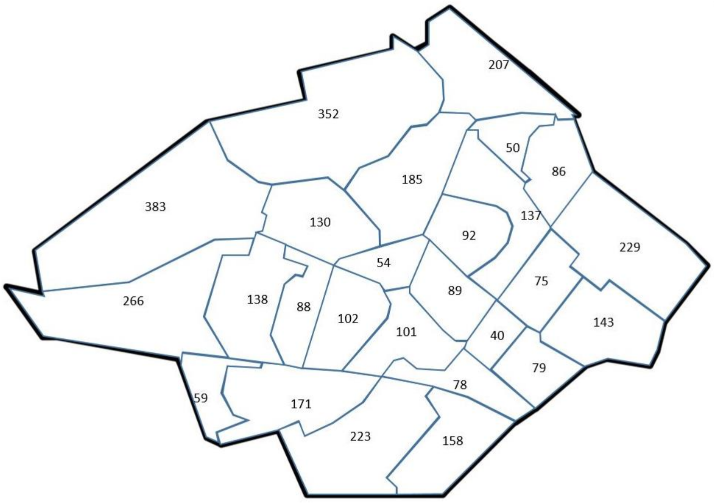


Figure 31: Total area of the neighbourhoods expressed in hectares (Own illustration)

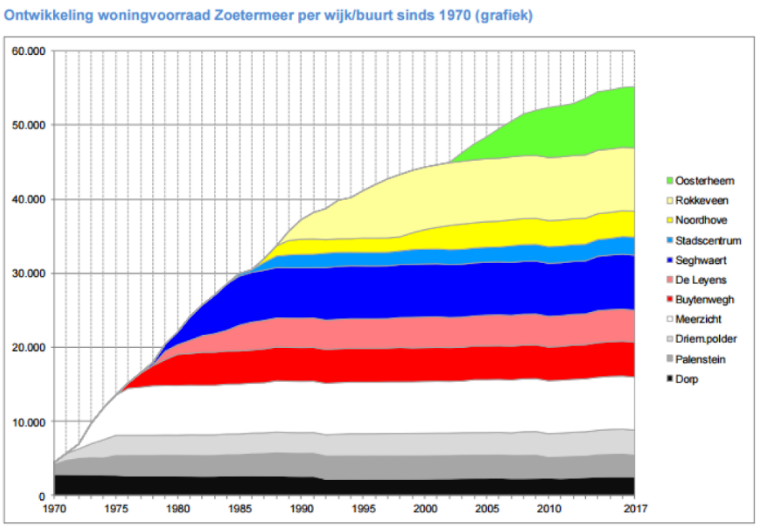


Figure 33: Growth of Zoetermeer from 1970 to 2017 (Bureau073, 2017)

Appendix C – Migration distributions and multiplier matrices

2015

Migrations

Binnenverhuizers 2015				Vorige woning														
				Huur						Koop								
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen					
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	Vestigers	Total
Huidige woning	Huur	Meergez	Goedkoop	747	38	1	268	183	21	122	22	5	101	361	74	8	1594	3545
			Middel	58	16	0	16	23	5	5	0	8	17	78	22	1	164	413
			Duur	8	0	2	1	2	3	0	1	0	0	5	4	0	20	46
		Eengezin	Goedkoop	316	16	0	89	48	7	74	1	0	21	109	14	2	605	1302
			Middel	199	13	0	69	80	10	88	6	0	17	104	19	9	530	1144
			Duur	29	3	0	6	13	0	3	4	0	14	38	13	3	91	217
	Koop	Meergez	Goedkoop	129	22	1	59	48	5	56	5	1	38	187	34	1	474	1060
			Middel	13	11	0	1	4	1	10	2	0	3	25	7	4	52	133
			Duur	1	0	0	0	2	0	0	0	1	0	7	8	2	10	31
		Eengezinswo	Goedkoop	58	0	0	25	24	1	35	0	0	6	39	7	3	163	361
			Middel	276	24	4	84	69	4	209	11	1	46	136	42	12	845	1763
			Duur	47	14	0	14	20	1	46	0	0	14	119	23	11	220	529
			Duur+	11	0	0	2	4	3	0	0	0	5	23	14	0	57	119
				1892	157	8	634	520	61	648	52	16	282	1231	281	56		

Recruitment table

Binnenverhuizers 2015				Vorige woning													
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	0.21	0.01	0.00	0.08	0.05	0.01	0.03	0.01	0.00	0.03	0.10	0.02	0.00	0.55
			Middel	0.14	0.04	0.00	0.04	0.06	0.01	0.01	0.00	0.02	0.04	0.19	0.05	0.00	0.60
			Duur	0.17	0.00	0.04	0.02	0.04	0.07	0.00	0.02	0.00	0.00	0.11	0.09	0.00	0.57
		Eengezin	Goedkoop	0.24	0.01	0.00	0.07	0.04	0.01	0.06	0.00	0.00	0.02	0.08	0.01	0.00	0.54
			Middel	0.17	0.01	0.00	0.06	0.07	0.01	0.08	0.01	0.00	0.01	0.09	0.02	0.01	0.54
			Duur	0.13	0.01	0.00	0.03	0.06	0.00	0.01	0.02	0.00	0.06	0.18	0.06	0.01	0.58
	Koop	Meergez	Goedkoop	0.12	0.02	0.00	0.06	0.05	0.00	0.05	0.00	0.00	0.04	0.18	0.03	0.00	0.55
			Middel	0.10	0.08	0.00	0.01	0.03	0.01	0.08	0.02	0.00	0.02	0.19	0.05	0.03	0.61
			Duur	0.03	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.03	0.00	0.23	0.26	0.06	0.68
		Eengezinswo	Goedkoop	0.16	0.00	0.00	0.07	0.07	0.00	0.10	0.00	0.00	0.02	0.11	0.02	0.01	0.55
			Middel	0.16	0.01	0.00	0.05	0.04	0.00	0.12	0.01	0.00	0.03	0.08	0.02	0.01	0.52
			Duur	0.09	0.03	0.00	0.03	0.04	0.00	0.09	0.00	0.00	0.03	0.22	0.04	0.02	0.58
			Duur+	0.09	0.00	0.00	0.02	0.03	0.03	0.00	0.00	0.00	0.04	0.19	0.12	0.00	0.52

Multiplier matrix

Binnenverhuizers 2015				Vorige woning													Verhuisketen
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	1.43	0.03	0.00	0.15	0.11	0.01	0.11	0.01	0.00	0.06	0.24	0.05	0.01	2.21
			Middel	0.37	1.06	0.00	0.11	0.12	0.02	0.10	0.01	0.02	0.08	0.34	0.09	0.01	2.33
			Duur	0.39	0.02	1.05	0.09	0.10	0.07	0.08	0.03	0.00	0.03	0.26	0.12	0.01	2.26
		Eengezin	Goedkoop	0.46	0.03	0.00	1.14	0.09	0.01	0.13	0.01	0.00	0.05	0.21	0.04	0.01	2.18
			Middel	0.38	0.03	0.00	0.13	1.13	0.02	0.15	0.01	0.00	0.05	0.22	0.05	0.01	2.18
			Duur	0.35	0.03	0.00	0.10	0.12	1.01	0.10	0.02	0.00	0.10	0.32	0.09	0.02	2.28
	Koop	Meergez	Goedkoop	0.33	0.04	0.00	0.13	0.10	0.01	1.14	0.01	0.00	0.07	0.31	0.06	0.01	2.21
			Middel	0.32	0.10	0.00	0.08	0.09	0.02	0.17	1.02	0.00	0.06	0.35	0.09	0.04	2.35
			Duur	0.25	0.02	0.00	0.07	0.13	0.01	0.11	0.01	1.03	0.04	0.43	0.31	0.08	2.50
		Eengezinswo	Goedkoop	0.37	0.02	0.00	0.14	0.12	0.01	0.18	0.01	0.00	1.05	0.24	0.05	0.01	2.20
			Middel	0.35	0.03	0.00	0.12	0.09	0.01	0.19	0.01	0.00	0.06	1.21	0.05	0.01	2.15
			Duur	0.30	0.05	0.00	0.10	0.10	0.01	0.18	0.01	0.00	0.06	0.37	1.08	0.03	2.28
			Duur+	0.28	0.02	0.00	0.08	0.09	0.03	0.09	0.01	0.00	0.07	0.33	0.15	1.01	2.15

2016

Migrations

Binnenverhuizers 2016				Vorige woning														
				Huur						Koop								
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen					
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	Vestigers	Total
Huidige woning	Huur	Meergez	Goedkoop	723	27	0	268	175	8	121	17	3	102	357	78	17	1612	3508
			Middel	22	7	0	10	12	0	6	3	0	7	34	21	6	134	262
			Duur	1	0	0	3	0	0	0	0	0	0	6	0	0	3	13
		Eengezin	Goedkoop	334	13	0	90	54	1	85	3	3	38	83	29	4	718	1455
			Middel	172	11	0	83	72	6	80	7	0	28	88	45	2	528	1122
			Duur	5	2	0	7	8	3	1	4	0	2	27	5	6	37	107
	Koop	Meergez	Goedkoop	165	2	1	44	56	2	81	6	1	53	197	54	7	648	1317
			Middel	8	6	0	5	0	0	11	4	1	6	39	15	0	46	141
			Duur	0	0	0	0	0	0	0	0	0	0	7	6	2	19	34
		Eengezinswo	Goedkoop	80	6	0	25	23	0	77	5	0	26	63	10	0	296	611
			Middel	334	15	0	118	109	6	308	16	6	93	171	60	10	1113	2359
			Duur	49	9	0	15	31	9	74	10	4	50	171	31	6	286	745
			Duur+	5	0	0	5	7	1	1	6	0	5	36	11	1	88	166
				1898	98	1	673	547	36	845	81	18	410	1279	365	61		

Recruitment table

Binnenverhuizers 2016				Vorige woning													
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	0.21	0.01	0.00	0.08	0.05	0.00	0.03	0.00	0.00	0.03	0.10	0.02	0.00	0.54
			Middel	0.08	0.03	0.00	0.04	0.05	0.00	0.02	0.01	0.00	0.03	0.13	0.08	0.02	0.49
			Duur	0.08	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.77
		Eengezin	Goedkoop	0.23	0.01	0.00	0.06	0.04	0.00	0.06	0.00	0.00	0.03	0.06	0.02	0.00	0.51
			Middel	0.15	0.01	0.00	0.07	0.06	0.01	0.07	0.01	0.00	0.02	0.08	0.04	0.00	0.53
			Duur	0.05	0.02	0.00	0.07	0.07	0.03	0.01	0.04	0.00	0.02	0.25	0.05	0.06	0.65
	Koop	Meergez	Goedkoop	0.13	0.00	0.00	0.03	0.04	0.00	0.06	0.00	0.00	0.04	0.15	0.04	0.01	0.51
			Middel	0.06	0.04	0.00	0.04	0.00	0.00	0.08	0.03	0.01	0.04	0.28	0.11	0.00	0.67
			Duur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.18	0.06	0.44
		Eengezinswo	Goedkoop	0.13	0.01	0.00	0.04	0.04	0.00	0.13	0.01	0.00	0.04	0.10	0.02	0.00	0.52
			Middel	0.14	0.01	0.00	0.05	0.05	0.00	0.13	0.01	0.00	0.04	0.07	0.03	0.00	0.53
			Duur	0.07	0.01	0.00	0.02	0.04	0.01	0.10	0.01	0.01	0.07	0.23	0.04	0.01	0.62
			Duur+	0.03	0.00	0.00	0.03	0.04	0.01	0.01	0.04	0.00	0.03	0.22	0.07	0.01	0.47

Multiplier matrix

Binnenverhuizers 2016				Vorige woning													Verhuisketen
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	1.40	0.02	0.00	0.14	0.10	0.01	0.12	0.01	0.00	0.07	0.22	0.06	0.01	2.16
			Middel	0.24	1.04	0.00	0.09	0.09	0.00	0.10	0.02	0.00	0.07	0.25	0.12	0.03	2.05
			Duur	0.35	0.01	1.00	0.32	0.07	0.00	0.14	0.01	0.00	0.06	0.61	0.04	0.01	2.63
		Eengezin	Goedkoop	0.41	0.02	0.00	1.13	0.09	0.00	0.13	0.01	0.00	0.06	0.17	0.05	0.01	2.08
			Middel	0.34	0.02	0.00	0.14	1.12	0.01	0.15	0.01	0.00	0.06	0.20	0.07	0.01	2.13
			Duur	0.25	0.03	0.00	0.14	0.14	1.03	0.12	0.05	0.00	0.07	0.41	0.10	0.06	2.41
	Koop	Meergez	Goedkoop	0.30	0.01	0.00	0.09	0.09	0.00	1.15	0.01	0.00	0.08	0.27	0.07	0.01	2.09
			Middel	0.26	0.06	0.00	0.11	0.06	0.00	0.20	1.04	0.01	0.10	0.45	0.16	0.01	2.45
			Duur	0.12	0.01	0.00	0.04	0.04	0.00	0.09	0.01	1.00	0.04	0.33	0.21	0.06	1.97
		Eengezinswo	Goedkoop	0.30	0.02	0.00	0.10	0.09	0.00	0.21	0.02	0.00	1.08	0.22	0.05	0.01	2.10
			Middel	0.32	0.01	0.00	0.11	0.10	0.01	0.21	0.01	0.00	0.08	1.20	0.06	0.01	2.13
			Duur	0.26	0.02	0.00	0.09	0.10	0.02	0.21	0.02	0.01	0.12	0.38	1.08	0.02	2.32
			Duur+	0.18	0.01	0.00	0.08	0.09	0.01	0.10	0.04	0.00	0.07	0.33	0.10	1.01	2.02

2017

Migrations

Binnenverhuizers 2017				Vorige woning														
				Huur						Koop								
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen					
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	Vestigers	Total
Huidige woning	Huur	Meergez	Goedkoop	632	34	2	190	243	22	130	16	10	18	374	103	20	1397	3191
			Middel	51	12	0	6	26	7	17	2	6	1	33	23	8	129	321
			Duur	4	1	0	4	13	3	0	4	0	0	2	6	3	25	65
		Eengezin	Goedkoop	223	4	0	31	47	2	34	5	0	3	68	18	0	411	846
			Middel	275	35	2	27	101	23	68	7	3	0	147	85	8	647	1428
			Duur	23	1	2	15	51	21	11	4	0	0	25	20	0	83	256
	Koop	Meergez	Goedkoop	130	8	2	36	60	6	79	10	8	8	188	73	8	556	1172
			Middel	18	6	0	2	28	2	5	0	8	1	33	16	2	89	210
			Duur	9	3	1	4	6	7	3	5	2	4	29	12	4	70	159
		Eengezinswo	Goedkoop	39	7	4	14	12	0	16	2	1	0	24	6	1	65	191
			Middel	308	45	4	97	156	12	300	23	15	23	275	54	9	1106	2427
			Duur	47	11	2	29	93	45	53	10	1	1	213	62	8	384	959
			Duur+	2	0	1	0	13	3	4	2	5	0	29	19	2	90	170
				1761	167	20	455	849	153	720	90	59	59	1440	497	73		

Recruitment table

Binnenverhuizers 2017				Vorige woning													
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	0.20	0.01	0.00	0.06	0.08	0.01	0.04	0.01	0.00	0.01	0.12	0.03	0.01	0.56
			Middel	0.16	0.04	0.00	0.02	0.08	0.02	0.05	0.01	0.02	0.00	0.10	0.07	0.02	0.60
			Duur	0.06	0.02	0.00	0.06	0.20	0.05	0.00	0.06	0.00	0.00	0.03	0.09	0.05	0.62
		Eengezin	Goedkoop	0.26	0.00	0.00	0.04	0.06	0.00	0.04	0.01	0.00	0.00	0.08	0.02	0.00	0.51
			Middel	0.19	0.02	0.00	0.02	0.07	0.02	0.05	0.00	0.00	0.00	0.10	0.06	0.01	0.55
			Duur	0.09	0.00	0.01	0.06	0.20	0.08	0.04	0.02	0.00	0.00	0.10	0.08	0.00	0.68
	Koop	Meergez	Goedkoop	0.11	0.01	0.00	0.03	0.05	0.01	0.07	0.01	0.01	0.01	0.16	0.06	0.01	0.53
			Middel	0.09	0.03	0.00	0.01	0.13	0.01	0.02	0.00	0.04	0.00	0.16	0.08	0.01	0.58
			Duur	0.06	0.02	0.01	0.03	0.04	0.04	0.02	0.03	0.01	0.03	0.18	0.08	0.03	0.56
		Eengezinswo	Goedkoop	0.20	0.04	0.02	0.07	0.06	0.00	0.08	0.01	0.01	0.00	0.13	0.03	0.01	0.66
			Middel	0.13	0.02	0.00	0.04	0.06	0.00	0.12	0.01	0.01	0.01	0.11	0.02	0.00	0.54
			Duur	0.05	0.01	0.00	0.03	0.10	0.05	0.06	0.01	0.00	0.00	0.22	0.06	0.01	0.60
			Duur+	0.01	0.00	0.01	0.00	0.08	0.02	0.02	0.01	0.03	0.00	0.17	0.11	0.01	0.47

Multiplier matrix

Binnenverhuizers 2017				Vorige woning													Verhuisketen
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	1.40	0.03	0.00	0.11	0.17	0.02	0.12	0.01	0.01	0.01	0.27	0.08	0.01	2.26
			Middel	0.36	1.06	0.00	0.07	0.18	0.04	0.14	0.02	0.03	0.01	0.28	0.13	0.03	2.35
			Duur	0.27	0.04	1.00	0.11	0.31	0.07	0.08	0.07	0.01	0.01	0.21	0.16	0.05	2.40
		Eengezin	Goedkoop	0.46	0.02	0.00	1.09	0.14	0.02	0.11	0.01	0.01	0.01	0.22	0.07	0.01	2.15
			Middel	0.38	0.04	0.00	0.07	1.16	0.03	0.13	0.01	0.01	0.01	0.26	0.11	0.01	2.24
			Duur	0.33	0.03	0.01	0.12	0.32	1.11	0.14	0.03	0.01	0.01	0.29	0.15	0.01	2.54
	Koop	Meergez	Goedkoop	0.29	0.02	0.00	0.08	0.14	0.02	1.15	0.02	0.01	0.01	0.31	0.11	0.01	2.18
			Middel	0.28	0.05	0.00	0.06	0.23	0.03	0.11	1.01	0.04	0.01	0.32	0.14	0.02	2.30
			Duur	0.24	0.04	0.01	0.07	0.14	0.07	0.11	0.04	1.02	0.03	0.35	0.13	0.03	2.28
		Eengezinswo	Goedkoop	0.44	0.06	0.02	0.13	0.17	0.02	0.18	0.02	0.01	1.01	0.31	0.09	0.02	2.48
			Middel	0.32	0.04	0.00	0.09	0.15	0.02	0.20	0.02	0.01	0.02	1.27	0.08	0.01	2.22
			Duur	0.25	0.03	0.00	0.08	0.20	0.07	0.15	0.02	0.01	0.01	0.39	1.12	0.02	2.36
			Duur+	0.15	0.02	0.01	0.04	0.16	0.04	0.10	0.02	0.04	0.01	0.31	0.16	1.02	2.07

2015 – 2017

Migrations

Binnenverhuizers 2015 - 2017				Vorige woning														
				Huur						Koop								
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen					
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	Starters	Total
Huidige woning	Huur	Meergez	Goedkoop	2102	99	3	726	601	51	373	55	18	221	1092	255	45	4603	10244
			Middel	131	35	0	32	61	12	28	5	14	25	145	66	15	427	996
			Duur	13	1	2	8	15	6	0	5	0	0	13	10	3	48	124
		Eengezin	Goedkoop	873	33	0	210	149	10	193	9	3	62	260	61	6	1734	3603
			Middel	646	59	2	179	253	39	236	20	3	45	339	149	19	1705	3694
			Duur	57	6	2	28	72	24	15	12	0	16	90	38	9	211	580
	Koop	Meergez	Goedkoop	424	32	4	139	164	13	216	21	10	99	572	161	16	1678	3549
			Middel	39	23	0	8	32	3	26	6	9	10	97	38	6	187	484
			Duur	10	3	1	4	8	7	3	5	3	4	43	26	8	99	224
		Eengezinswo	Goedkoop	177	13	4	64	59	1	128	7	1	32	126	23	4	524	1163
			Middel	918	84	8	299	334	22	817	50	22	162	582	156	31	3064	6549
			Duur	143	34	2	58	144	55	173	20	5	65	503	116	25	890	2233
			Duur+	18	0	1	7	24	7	5	8	5	10	88	44	3	235	455
				5551	422	29	1762	1916	250	2213	223	93	751	3950	1143	190		

Recruitment table

Binnenverhuizers 2015 - 2017				Vorige woning													
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	0.21	0.01	0.00	0.07	0.06	0.00	0.04	0.01	0.00	0.02	0.11	0.02	0.00	0.55
			Middel	0.13	0.04	0.00	0.03	0.06	0.01	0.03	0.01	0.01	0.03	0.15	0.07	0.02	0.57
			Duur	0.10	0.01	0.02	0.06	0.12	0.05	0.00	0.04	0.00	0.00	0.10	0.08	0.02	0.61
		Eengezin	Goedkoop	0.24	0.01	0.00	0.06	0.04	0.00	0.05	0.00	0.00	0.02	0.07	0.02	0.00	0.52
			Middel	0.17	0.02	0.00	0.05	0.07	0.01	0.06	0.01	0.00	0.01	0.09	0.04	0.01	0.54
			Duur	0.10	0.01	0.00	0.05	0.12	0.04	0.03	0.02	0.00	0.03	0.16	0.07	0.02	0.64
	Koop	Meergez	Goedkoop	0.12	0.01	0.00	0.04	0.05	0.00	0.06	0.01	0.00	0.03	0.16	0.05	0.00	0.53
			Middel	0.08	0.05	0.00	0.02	0.07	0.01	0.05	0.01	0.02	0.02	0.20	0.08	0.01	0.61
			Duur	0.04	0.01	0.00	0.02	0.04	0.03	0.01	0.02	0.01	0.02	0.19	0.12	0.04	0.56
		Eengezinswo	Goedkoop	0.15	0.01	0.00	0.06	0.05	0.00	0.11	0.01	0.00	0.03	0.11	0.02	0.00	0.55
			Middel	0.14	0.01	0.00	0.05	0.05	0.00	0.12	0.01	0.00	0.02	0.09	0.02	0.00	0.53
			Duur	0.06	0.02	0.00	0.03	0.06	0.02	0.08	0.01	0.00	0.03	0.23	0.05	0.01	0.60
			Duur+	0.04	0.00	0.00	0.02	0.05	0.02	0.01	0.02	0.01	0.02	0.19	0.10	0.01	0.48

Multiplier matrix

Binnenverhuizers 2015 - 2017				Vorige woning													Verhuisketen
				Huur						Koop							
				Meergezinswoning			Eengezinswoningen			Meergezinswoning			Eengezinswoningen				
				Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Goedkoop	Middel	Duur	Duur+	
Huidige woning	Huur	Meergez	Goedkoop	1.41	0.02	0.00	0.14	0.13	0.01	0.12	0.01	0.00	0.05	0.24	0.06	0.01	2.21
			Middel	0.33	1.05	0.00	0.09	0.13	0.02	0.12	0.01	0.02	0.05	0.30	0.11	0.02	2.26
			Duur	0.32	0.03	1.02	0.13	0.20	0.06	0.09	0.05	0.00	0.03	0.27	0.13	0.03	2.37
		Eengezin	Goedkoop	0.44	0.02	0.00	1.12	0.10	0.01	0.13	0.01	0.00	0.04	0.20	0.05	0.01	2.14
			Middel	0.37	0.03	0.00	0.11	1.14	0.02	0.14	0.01	0.00	0.04	0.23	0.08	0.01	2.18
			Duur	0.32	0.03	0.00	0.12	0.21	1.05	0.12	0.03	0.00	0.06	0.32	0.12	0.02	2.41
	Koop	Meergez	Goedkoop	0.30	0.02	0.00	0.10	0.11	0.01	1.14	0.01	0.01	0.05	0.30	0.08	0.01	2.16
			Middel	0.28	0.07	0.00	0.08	0.14	0.02	0.15	1.02	0.02	0.05	0.37	0.13	0.02	2.35
			Duur	0.22	0.03	0.01	0.07	0.11	0.04	0.10	0.03	1.02	0.05	0.35	0.16	0.04	2.24
		Eengezinswo	Goedkoop	0.35	0.03	0.00	0.12	0.12	0.01	0.19	0.01	0.00	1.05	0.25	0.06	0.01	2.20
			Middel	0.33	0.03	0.00	0.11	0.12	0.01	0.20	0.02	0.01	0.05	1.23	0.06	0.01	2.16
			Duur	0.26	0.03	0.00	0.09	0.14	0.03	0.18	0.02	0.01	0.06	0.38	1.10	0.02	2.32
			Duur+	0.20	0.01	0.00	0.07	0.11	0.02	0.09	0.03	0.01	0.05	0.33	0.14	1.01	2.07

Appendix D – Living Environment

(1) – Living environment as described for the Randstad

Living environment matrix southern Randstad

	ABF kenmerken	**variabelen**				
1	grootte van de stad	grote stad	stad	kleine stad	dorp	
2	voorzieningen	bijzondere	centrum	dagelijkse	geen	
3	mate van menging	wonen tussen winkels en werken	wonen met geclusterd werken en winkels	voornamelijk wonen	alleen wonen	
4a	dichtheid woongeb. in won./ha.	> 60	40-60	20-40	< 20	
4b	dichtheid totaal won./ha.	> 30	10-30	3-10	< 3	
5a	persentage vooroorlogs	> 60%	30-60	2030	< 20	
5b	dominante bouwperiode	< 1940	1940-1970	1970-1990	>1990	gemengd
	Aanvullende kwalitatieve kenmerken					
6	nabijheid recreatief of open landschap	omgeven door	op loopafstand	op fietsafstand		
7	kwaliteit openbare ruimte	hoog	gemiddeld	laag		
8	kwaliteit van het groen	volwassen	veel	divers		
		jong	weinig	monotoon		
9	woningtypologie	vrijstaand	eengezins geschakeld	portiek-appartement	hoogbouw-appartement	
10	spreidingstoestand	verspreid weinig openbaar	verspreid veel openbaar	compact weinig openbaar	compact veel openbaar	
11	stedenbouwkundige bouwsteen	erf/kavel	blok	stempel	buurt	divers
12	ruimtelijke identiteitsdragers	veel	weinig			
		namelijk...				
13	bewoners en bezoekers (bestemming)	veel bezoekers, weinig bewoners	bewoners en bezoekers	vooral bewoners, weinig bezoekers		
14	programma in de wijk	wonen	winkels	kantoren		
		cultuur	recreatie	bedrijven		
15	parkeren met name	op eigen kavel	op straat	gemeenschappelijk straat	gemeenschappelijk gebouwd	
	gebaseerd op	enkele voorbeeldwijken				

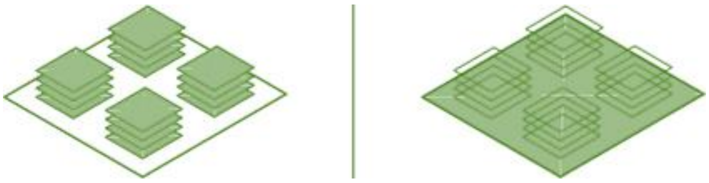
(Zandbelt&vandenBerg, 2009)

(2) - FSI, GSI, OSR and L formulas

Floor Space Index (FSI)

The FSI expresses the built intensity of an area and is a representation of the coverage of an area by the building within it.

$FSI = gross\ floor\ area/plan\ area$



Ground Space Index (GSI)

GSI, or compactness, is the ratio between the amount of square metres of dwelling built and amount of square metres in the area within which it is built and is calculated as follows:

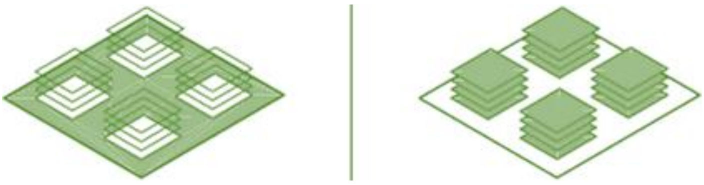
$GSI = built\ area/plan\ area$

This ratio is expressed in m^2 per m^2.

Open Space Ratio (OSR)

The Open Space Ratio is an expression of the amount of outdoor space a dwelling has and signifies the square metres of outdoor a dwelling has for every indoor square metre. An OSR of 2 thus translates to a dwelling of 50 m^2 having a total outdoor area of 100 m^2, being both or either private and/or public. The unit of OSR is m^2 per m^2.

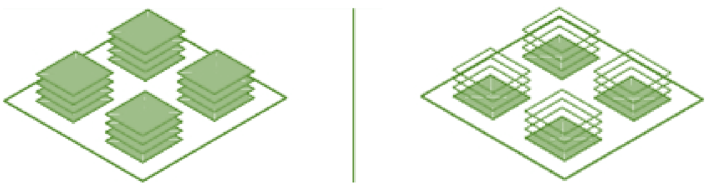
$OSR = (plan\ area - built\ area)/gross\ floor\ area$ or $OSR = (1 - GSI)/FSI$



Layers (L)

Layers represents the average number of layers found within an area.

$L = gross\ floor\ area/built\ area$ or $L = FSI/GSI$



(3) – Calculated FSI's, GSI's, L's and OSR's

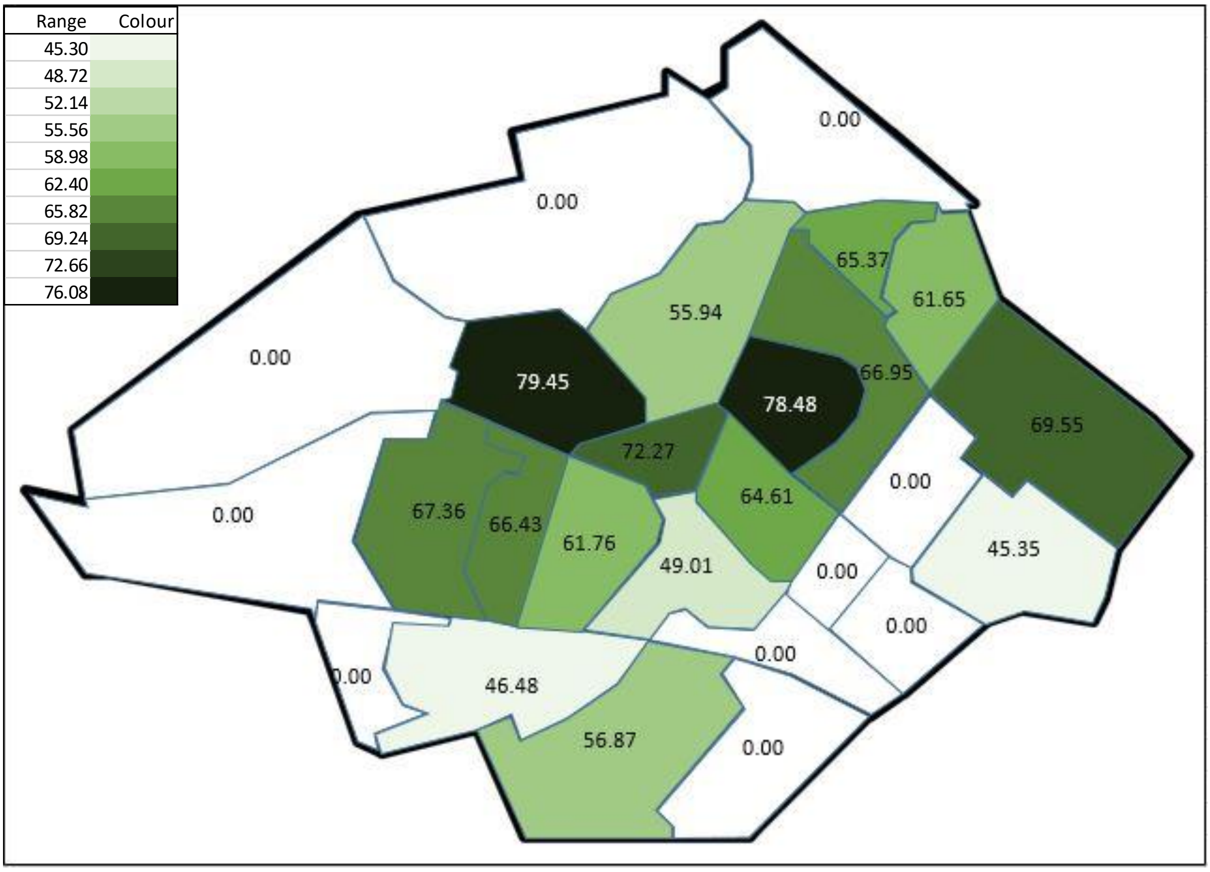


Figure 34: Population density on neighbourhood level for entirety of Zoetermeer (Own illustration)

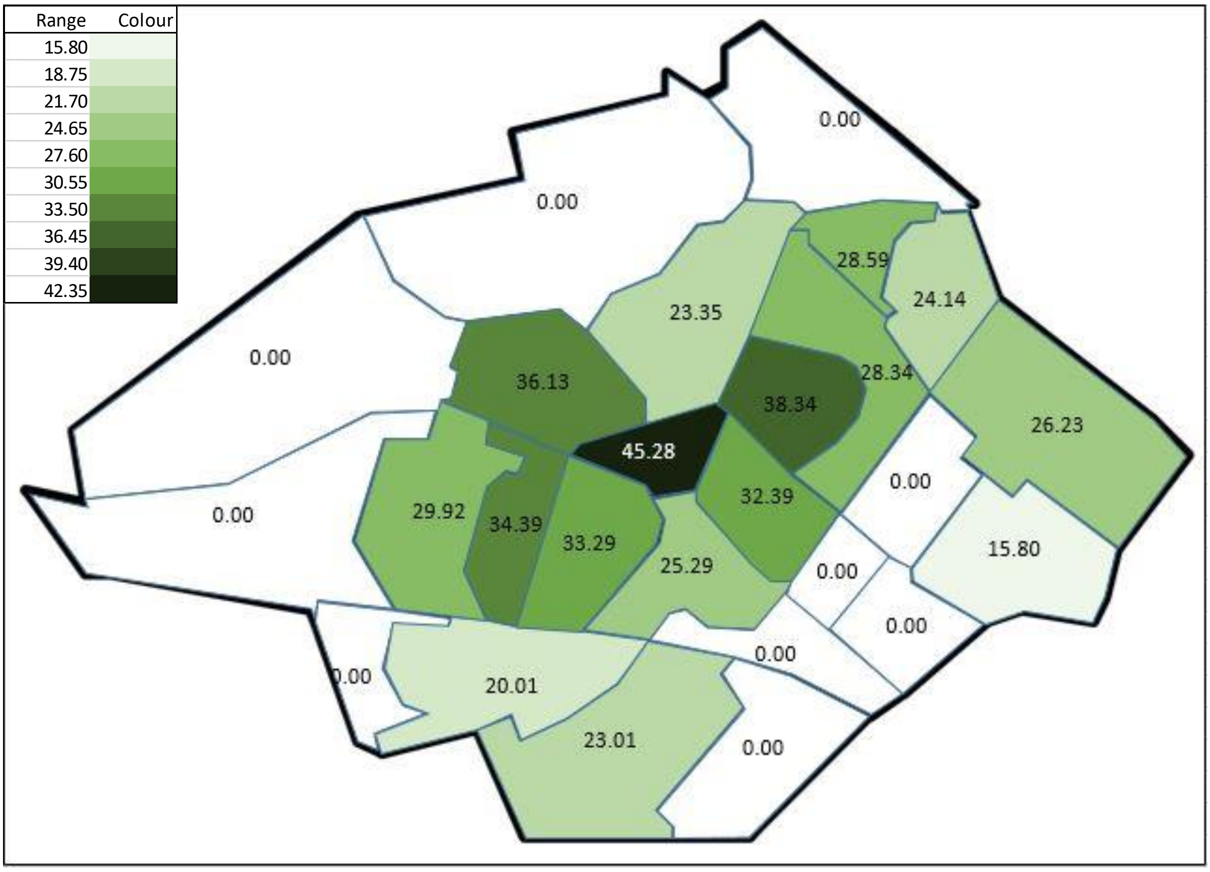


Figure 35: Dwelling density on neighbourhood level for entirety of Zoetermeer (Own illustration)

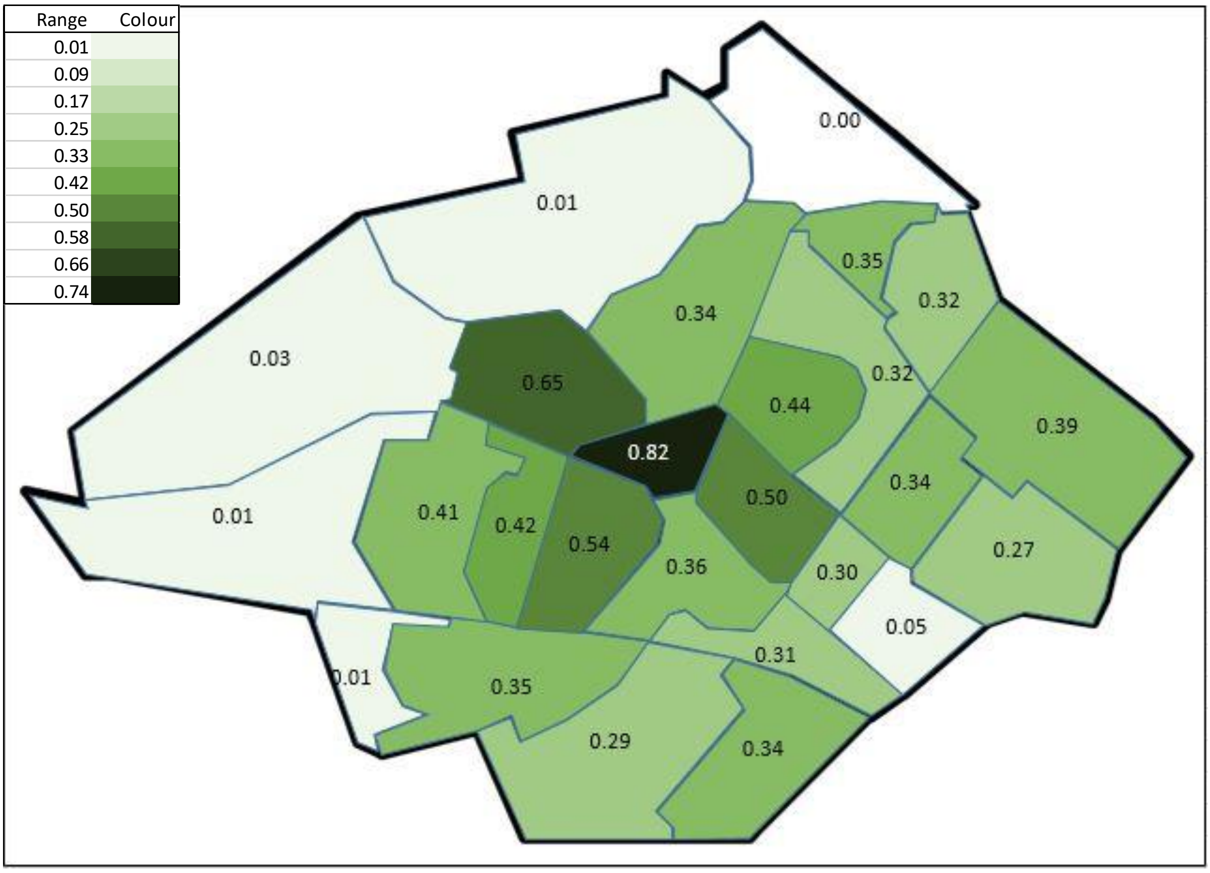


Figure 36: FSI's on neighbourhood level for entirety of Zoetermeer (Own illustration)

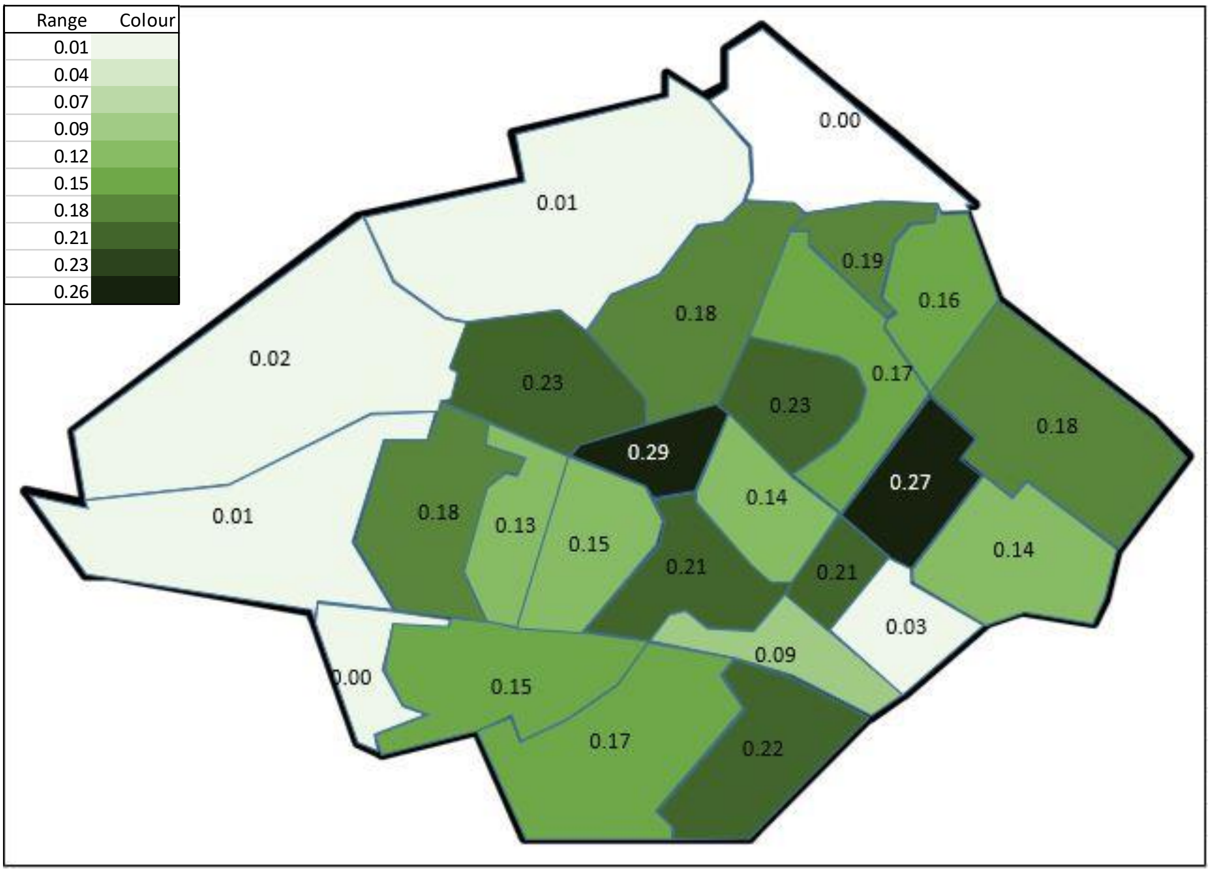


Figure 37: GSI's on neighbourhood level for entirety of Zoetermeer (Own illustration)

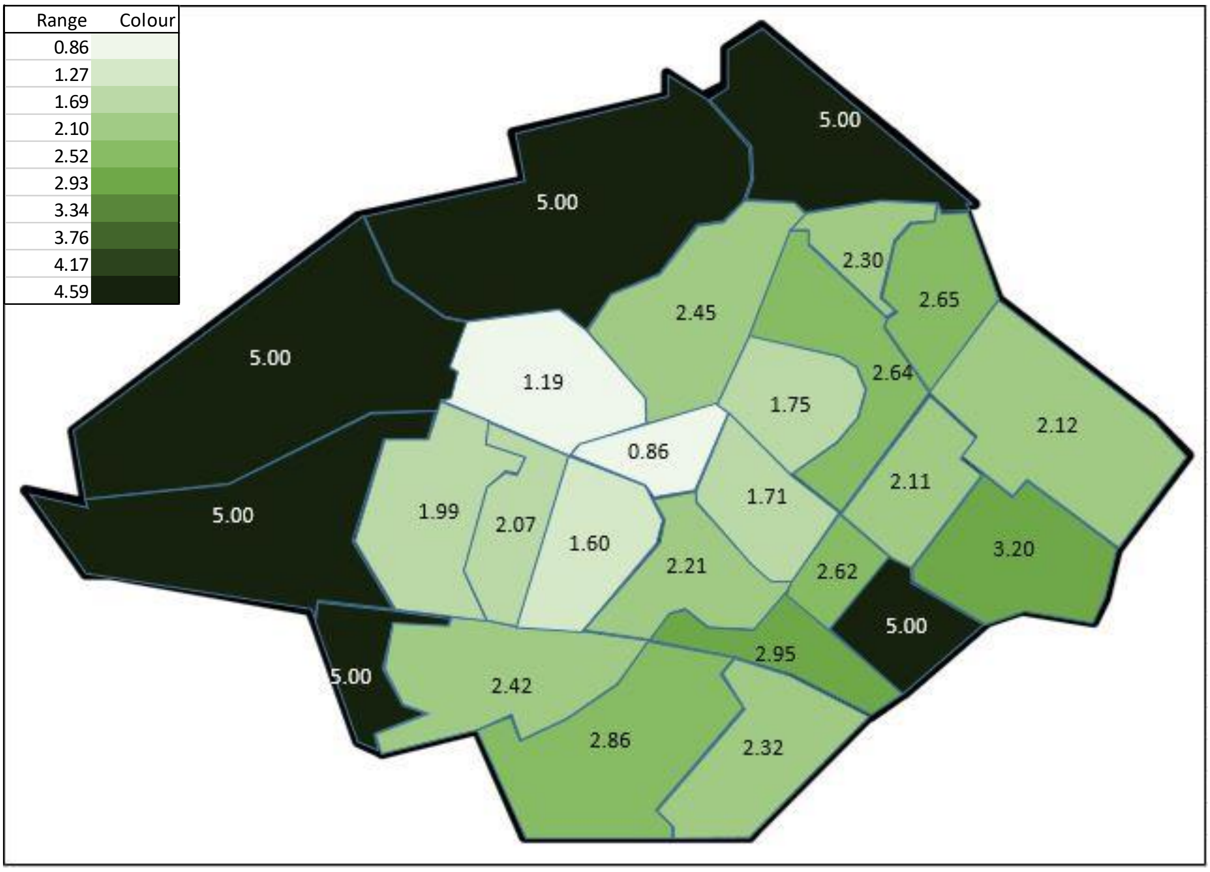


Figure 38: OSR's on neighbourhood level for entirety of Zoetermeer (Own illustration)

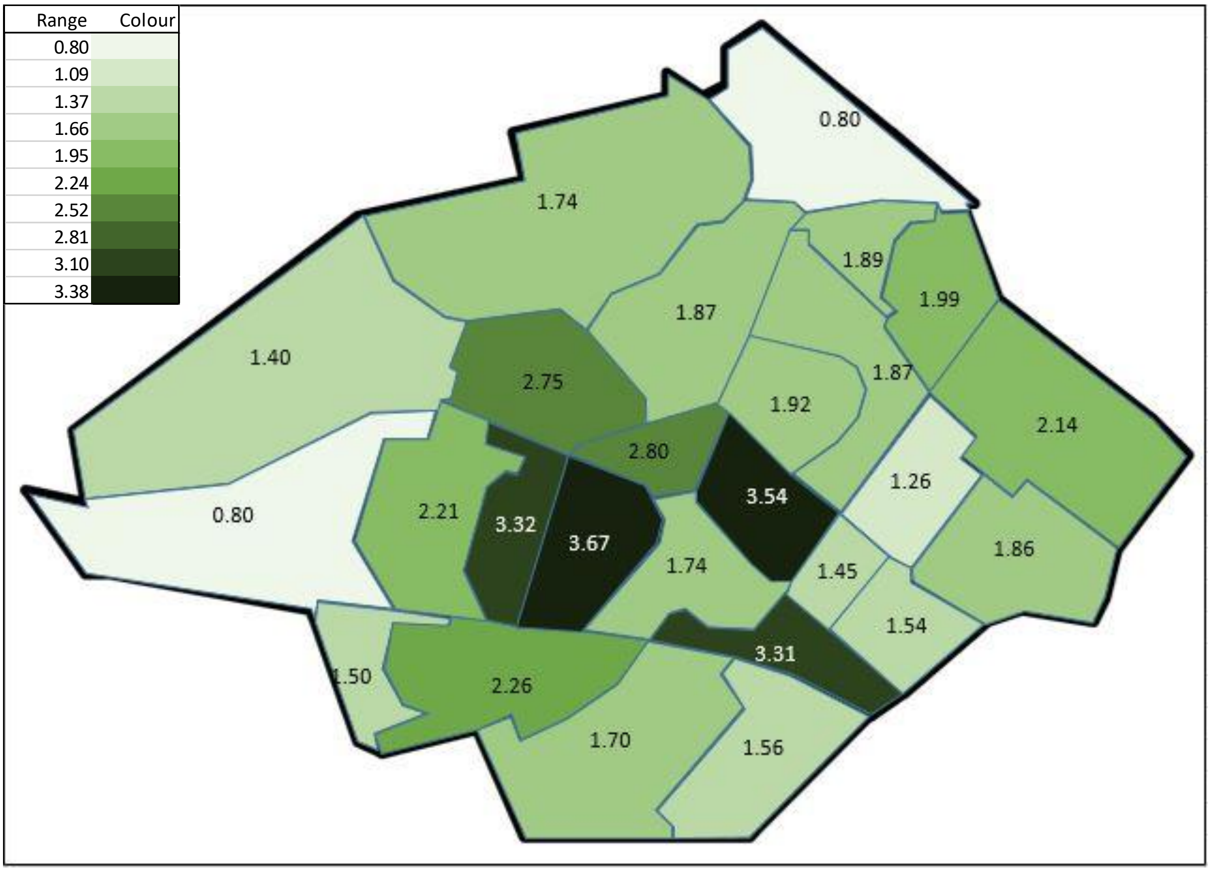


Figure 39: L's on neighbourhood level for entirety of Zoetermeer (Own illustration)

Number	Neighbourhood	Traditional (01/01/2017)			Detailed (01/07/2017)			Indices					
								Traditional(01/01/2017)		Detailed(01/07/2017)			
		Population	Average house	Dwellings	Area (m²)	GFO (m²)	Built area (m²)	Pop./hectare	Dw/hectare	FSI	GSI	OSR	L
	Calculation	A	B	C	D	E	F	A/(D/10000)	C/(D/10000)	D/E	D/F	(D-F)/E	E/F
010	Dorp	4,935	1.94	2,546	1,006,843	361,931	207,946	49.0	25.3	0.36	0.21	2.21	1.74
020	Stadscentrum	3,904	1.60	2,446	540,209	444,491	158,489	72.3	45.3	0.82	0.29	0.86	2.80
030	Palenstein	5,744	2.00	2,879	888,970	446,456	126,237	64.6	32.4	0.50	0.14	1.71	3.54
040	Driemanspolder	6,310	1.86	3,401	1,021,688	547,065	149,039	61.8	33.3	0.54	0.15	1.60	3.67
100	Meerzicht-West	9,298	2.25	4,130	1,380,250	564,747	254,975	67.4	29.9	0.41	0.18	1.99	2.21
110	Meerzicht-Oost	5,860	1.93	3,034	882,139	372,457	112,039	66.4	34.4	0.42	0.13	2.07	3.32
200	Buytenwegh	10,348	2.20	4,705	1,302,397	840,853	305,569	79.5	36.1	0.65	0.23	1.19	2.75
210	De Leyens	10,348	2.19	4,320	1,849,716	619,806	330,703	55.9	23.4	0.34	0.18	2.45	1.87
300	Seghwaert-Zuidwest	7,248	2.06	3,541	923,584	406,553	211,459	78.5	38.3	0.44	0.23	1.75	1.92
310	Seghwaert-Noordoost	9,147	2.36	3,872	1,366,147	430,823	230,723	67.0	28.3	0.32	0.17	2.64	1.87
400	Noordhove-West	3,267	2.29	1,429	499,740	176,763	93,750	65.4	28.6	0.35	0.19	2.30	1.89
410	Noordhove-Oost	5,274	2.55	2,065	855,466	271,569	136,465	61.7	24.1	0.32	0.16	2.65	1.99
500	Rokkeveen-West	7,960	2.32	3,427	1,712,589	598,060	264,286	46.5	20.0	0.35	0.15	2.42	2.26
510	Rokkeveen-Oost	12,682	2.47	5,130	2,229,931	646,111	379,062	56.9	23.0	0.29	0.17	2.86	1.70
600	Oosterheem-Zuidwest	6,496	2.90	2,264	1,432,495	383,100	206,161	45.3	15.8	0.27	0.14	3.20	1.86
610	Oosterheem-Noordoost	15,951	2.65	6,016	2,293,439	884,746	413,983	69.6	26.2	0.39	0.18	2.12	2.14
800	Rokkehage				780,782	240,378	72,631			0.31	0.09	2.95	3.31
810	Lansinghage				1,579,470	533,846	342,571			0.34	0.22	2.32	1.56
820	Zoeterhage				745,777	256,991	203,437			0.34	0.27	2.11	1.26
830	Hoornerhage				403,086	121,711	83,670			0.30	0.21	2.62	1.45
920	Balijbos				587,149	3,935	2,625			0.01	0.00	5.00	1.50
930	Westerpark-EO				2,662,203	14,534	18,224			0.01	0.01	5.00	0.80
940	Buitengebied-West				3,830,872	97,452	69,853			0.03	0.02	5.00	1.40
950	Meerpolder				3,522,521	52,468	30,143			0.01	0.01	5.00	1.74
960	Scheidingszone				2,072,635	4,763	5,981			0.00	0.00	5.00	0.80
970	Van Tuyllpark				792,123	35,745	23,161			0.05	0.03	5.00	1.54

Table 37: Calculation sheet showing precise input and output variables (Own illustration)

(4) – General definitions of living environment characteristics

General definitions as translated from worded to quantitative definitions:

Living Environment definitions			
Criteria	**Values**		
Layers	An upper and lower value representing a range of average layers		
GSI	Average GSI range, ranging from 0.2 to 1.0		
Function mix	Given in terms of percentage non-dwelling of total		
Function focus	**Inner-city**	**District**	**Neighbourhood**
Dwelling type	**Apartment** >60% apartment	**Mixed** Between 35 and 65% of either type	**Single Family** >60% single family
Dwelling value	An upper and lower value representing a range of average dwelling value		
Dwelling size	An upper and lower value representing a range of average dwelling LFA		
Rent-owned ratio	**Mostly rental** >60% rental	**Mixed** Between 35 and 65% of either type	**Mostly owned** >60% owned

Specific living environment definitions

Inner-City

Criteria	
Layers	5 – 10
GSI	0.5 – 1.0
Function mix	15 – 25%
Function focus	Inner-city
Dwelling type	Apartment
Dwelling value	€180,000 to 300,000
Dwelling size	70 – 120 m^2
Rent-owned ratio	Rental

City Neighbourhood

Criteria	
Layers	3 – 7
GSI	0.4 – 1.0
Function mix	10 – 15%
Function focus	District
Dwelling type	Mixed
Dwelling value	€200,000 to 300,000
Dwelling size	80 – 130 m^2
Rent-owned ratio	Mixed

Neighbourhood

Criteria	
Layers	3 – 5
GSI	0.2 – 1.0
Function mix	5 – 15%
Function focus	Neighbourhood
Dwelling type	Single family dwelling
Dwelling value	€180,000 to 280,000
Dwelling size	90 – 140 m^2
Rent-owned ratio	Owner-occupied

Niche Housing

Criteria	
Layers	3 – 7
GSI	0.25 – 1.0
Function mix	15 – 25%
Function focus	District
Dwelling type	Single family dwelling
Dwelling value	€300,000 to 500,000
Dwelling size	120 – 200 m^2
Rent-owned ratio	Owner-occupied

Park Housing

Criteria	
Layers	4 – 10
GSI	0.2 – 1.0
Function mix	10 – 20%
Function focus	District
Dwelling type	Mixed
Dwelling value	€230,000 to 350,000
Dwelling size	70 – 150 m^2
Rent-owned ratio	Mixed

Campus Living

Criteria	
Layers	3 – 6
GSI	0.3 – 1.0
Function mix	20 – 30%
Function focus	Neighbourhood
Dwelling type	Apartment
Dwelling value	€120,000 to 250,000
Dwelling size	50 – 100 m^2
Rent-owned ratio	Rental

Appendix E – Model variables

List of used variables and their meaning. Capital letters indicate the variable is endogenous.

Variable	Description
a_dwc_i	Built area requirement of dwelling model *i*
A_non_y	GFA area of non-housing functions *y*
$B\_d_{k,i}$	Binary indication of district k containing a dwelling model *i*
$B\_dwc_{i,k}$	Binary indication of dwelling model *i* being found in district k
gfa_dwc_i	GFA area of dwelling type *i*
lfa_dwc_i	LFA area of dwelling type *i*
$lfa\_prk\_non_y$	LFA area for which the required number of parking is stated for non-housing functions *y*
m_dwc_i or $m\_dwc_{i,j}$	Markov chain length for either current dwelling model *i* in total or previous dwelling model *j* belonging to current dwelling model *i*
$max\_dst\_dwc_i$	Maximum number of districts in which dwelling model *i* is found
max_dwc	Maximum total number of newly constructed dwellings in Zoetermeer
$max\_dwc\_d_k$	Maximum number of dwellings found in district *k*
$max\_f\_d_k$	Maximum average number of layers in district *k*
$max\_gsi\_d_k$	Maximum average GSI found in district *k*
$max\_lfa\_d_k$	Maximum average LFA of dwellings found in district *k*
max_m	Maximum number of facilitated migrations
$max\_n\_dwc\_d_k$	Maximum number of different dwelling models found in district *k*
$max\_p\_dwc_i$	Maximum percentage of dwelling model *i*
$max\_p\_non\_d_k$	Maximum percentage of non-housing function found in district *k*
$max\_p\_t\_d_k$	Maximum percentage of a dwelling type found in district *k*
$max\_p\_w\_d_k$	Maximum percentage of an ownership type found in district *k*
$max\_r\_d_k$	Maximum average price of dwellings found in district *k*
$min\_dst\_dwc_i$	Minimum number of districts in which dwelling model *i* is found
min_dwc	Minimum total number of newly constructed dwellings in Zoetermeer
$min\_dwc\_d_k$	Minimum number of dwellings found in district *k*
$min\_f\_d_k$	Minimum average number of layers in district *k*
$min\_gsi\_d_k$	Minimum average GSI found in district *k*
$min\_lfa\_d_k$	Minimum average LFA of dwellings found in district *k*
min_m	Minimum number of facilitated migrations
$min\_n\_dwc\_d_k$	Minimum number of different dwelling models found in district *k*
$min\_p\_dwc_i$	Minimum percentage of dwelling model *i*
$min\_p\_non\_d_k$	Minimum percentage of non-housing function found in district *k*
$min\_p\_t\_d_k$	Minimum percentage of a dwelling type found in district *k*
$min\_p\_w\_d_k$	Minimum percentage of an ownership type found in district *k*
$min\_r\_d_k$	Minimum average price of dwellings found in district *k*
N_dwc_i	Number of newly constructed dwellings of dwelling model *i*
$N\_dwc\_d_k$	Number of newly constructed dwellings in district *k*
N_prk_y	Number of parking spots of type *y*
$n\_prk\_dwc_i$	Parking requirement for dwelling model *i*
$n\_prk\_non_w$	Parking requirement for non-housing function w
own_dwc_i	Ownership of dwelling model *i*
p_gfa_lfa	Percentual indication of LFA based on GFA, i.e. conversion rate
r_dwc_i	Price of dwelling model *i*, includes tax
s_dwc_i	Plot area of dwelling type *i*
t_dwc_i	Type of dwelling model *i*

Indices		
i	Current dwelling model	1 to 15
j	Previous dwelling model	1 to 15
k	Plan area district within Zoetermeer	1 to 8
w	Parking type	1 or 2
y	Non-housing function	1 to 3

Appendix F – Model mathematics

MIN! $\sum s\_dwc_i * N\_dwc_i$ *(Plot area)*

OR

MAX! $\sum m\_dwc_i * N\_dwc_i$ *(Facilitated migrations)*

OR

MAX! $\sum r\_dwc_{i,k} * N\_dwc_i + r\_non_w * A\_non_{w,k} + r\_prk_y * N\_prk_{y,k}$ *(Revenue)*

OR

MIN! $\sum N\_dwc_i$ *(Dwelling count)*

SUB:

$\forall_k \sum B\_dwc_{i,k} \geq min\_dst\_dwc_i$ *(1.1)*

$\forall_k \sum B\_dwc_{i,k} \leq max\_dst\_dwc_i$ *(1.2)*

$\forall_i \sum B\_d_{k,i} \geq min\_n\_dwc\_d_{k,i}$ *(2.1)*

$\forall_i \sum B\_d_{k,i} \leq max\_n\_dwc\_d_{k,i}$ *(2.2)*

$N\_dwc_{i,k} \geq min\_dwc\_d_k * \frac{1}{max\_n\_dwc\_d_k} * B\_dwc_{i,k}$ *(3.1)*

$N\_dwc_{i,k} \leq max\_dwc\_d_k * \frac{1}{min\_n\_dwc\_d_k} * B\_dwc_{i,k}$ *(3.2)*

$N\_dwc_i \geq min\_p\_dwc_i * \sum N\_dwc_i$ *(4.1)*

$N\_dwc_i \leq max\_p\_dwc_i * \sum N\_dwc_i$ *(4.2)*

$N\_dwc\_d_k \geq min\_dwc\_d_k$ *(5.1)*

$N\_dwc\_d_k \leq max\_dwc\_d_k$ *(5.2)*

$\sum N\_dwc\_d_k \geq min\_dwc$ *(5.3)*

$\sum N\_dwc\_d_k \leq max\_dwc$ *(5.4)*

$\forall_k \sum_i (r\_dwc_i * N\_dwc_{i,k}) \geq min\_r\_d_k * \sum N\_dwc_{i,k}$ *(6.1)*

$\forall_k \sum_i (r\_dwc_i * N\_dwc_{i,k}) \leq min\_r\_d_k * \sum N\_dwc_{i,k}$ *(6.2)*

$\forall_k \sum_i (lfa\_dwc_i * N\_dwc_{i,k}) \geq min\_lfa\_d_k * \sum N\_dwc_{i,k}$ *(7.1)*

$\forall_k \sum_i (lfa\_dwc_i * N\_dwc_{i,k}) \leq min\_lfa\_d_k * \sum N\_dwc_{i,k}$ *(7.2)*

$\forall_k \sum_i (t\_dwc_i * N\_dwc_{i,k}) \geq min\_p\_t\_d_k * \sum N\_dwc_{i,k}$ *(8.1)*

$\forall_k \sum_i (t\_dwc_i * N\_dwc_{i,k}) \leq max\_p\_t\_d_k * \sum N\_dwc_{i,k}$ *(8.2)*

where $t\_dwc_i \in \{0,1\}$

$\forall_k \sum_i (own\_dwc_i * N\_dwc_{i,k}) \geq min\_p\_w\_d_k * \sum N\_dwc_{i,k}$ *(9.1)*

$\forall_k \sum_i (own\_dwc_i * N\_dwc_{i,k}) \leq max\_p\_w\_d_k * \sum N\_dwc_{i,k}$ *(9.2)*

where $own\_dwc_i \in \{0,1\}$

$\forall_j \sum_i (m\_dwc_{i,j}) \geq min\_p\_dwc_i * \sum (m\_dwc_i * N\_dwc_i)$ *(10.1)*

$\forall_j \sum_i (m\_dwc_{i,j}) \leq max\_p\_dwc_i * \sum (m\_dwc_i * N\_dwc_i)$ *(10.2)*

$\sum (m\_dwc_i * N\_dwc_i) \geq min\_m$ *(11.1)*

$\sum (m\_dwc_i * N\_dwc_i) \leq max\_m$ *(11.2)*

$\forall_k \sum_i (gfa\_dwc_i * N\_dwc_{i,k}) \geq min\_f\_d_k * \sum_i (a\_dwc_i * N\_dwc_{i,k})$ *(12.1)*

$\forall_k \sum_i (gfa\_dwc_i * N\_dwc_{i,k}) \leq max\_f\_d_k * \sum_i (a\_dwc_i * N\_dwc_{i,k})$ *(12.2)*

$\forall_k \sum_i (a\_dwc_i * N\_dwc_{i,k}) \geq min\_gsi\_d_k * \sum_i (s\_dwc_i * N\_dwc_{i,k})$ *(13.1)*

$\forall_k \sum_i (a\_dwc_i * N\_dwc_{i,k}) \leq max\_gsi\_d_k * \sum_i (s\_dwc_i * N\_dwc_{i,k})$ *(13.2)*

$$\forall_k \sum_i (p\_gfa\_lfa * A\_non_{w,k}) \geq min\_p\_non\_d_k * \sum_i (lfa\_dwc_i * N\_dwc_{i,k}) \quad (14.1)$$
$$\forall_k \sum_i (p\_gfa\_lfa * A\_non_{w,k}) \leq max\_p\_non\_d_k * \sum_i (lfa\_dwc_i * N\_dwc_{i,k}) \quad (14.2)$$

$$\forall_k \forall_{|own\_dwc_i=0} \sum_i (own\_dwc_i * A\_non_{w,k}) + N\_prk_{y,k} = \sum_i (n\_prk\_non_y * (A\_non_{w,k} / lfa\_prk\_non_y)) + \sum_i (n\_prk\_dwc_i * N\_dwc_{i,k}) \quad (15)$$

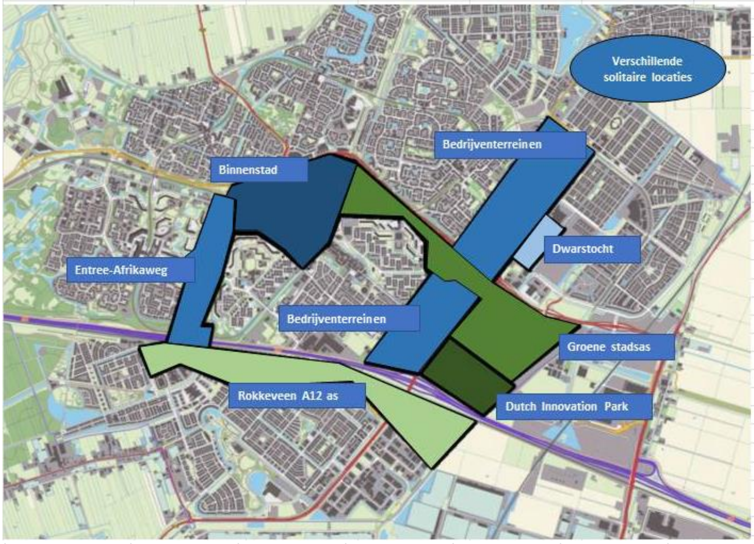
where $own\_dwc_i \in \{0,1\}$

Appendix G – Model outcome

ROS 1 – Minimal Impact

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Nee	Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Vrij	Niet	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 205.796
Low	5.606	Apartment	7.340
Middle	3.950	Single Family	2.660
High	444	Social	3.500
High+	-	Rental	600
		Owner-occupied	5.900

Migrations	22.319	Apartment	12.780
Low	11.852	Single Family	9.539
Middle	8.644	Social	7.892
High	1.667	Rental	2.379
High+	155	Owner-occupied	12.047

Plot area (ha)	38,47	Dwel. models	6

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	1.500	1	10
Entree-Afrikaweg	2.500	12	4
Bedrijventerreinen	2.250	11	4
Dwarstocht	-	-	-
Groene stadsas	1.500	7	5
Dutch Innovation P	900	1	6
Rokkeveen A12 as	-	-	-
Solitaire locaties	1.350	6	4

Development			
Total value	€ 2.228.684.204	Total GFA	1.074.882
Total costs	€ 1.308.900.363	Total LFA	877.123
		Total GFA Other f	109.635

Stadsdeel	**Woningen**	**Kavel opp. (in hectares)**	**BVO (in m²)**	**VVO (in m²)**	**Totaal oppervlak**	**% van totaal oppervlak**
Binnenstad	1.500	1,35	153.641	123.529	25,0	5%
Entree-Afrikaweg	2.500	11,92	272.450	222.222	37,5	32%
Bedrijventerreinen	2.250	10,68	241.983	200.000	133,6	8%
Dwarstocht	-	-	-	-	9,1	0%
Groene stadsas	1.500	6,81	171.038	141.621	43,0	16%
Dutch Innovation Park	900	1,29	89.863	69.750	27,6	5%
Rokkeveen A12 as	-	-	-	-	58,5	0%
Solitaire locaties	1.350	6,42	145.906	120.000	24,0	27%
Totaal	10.000	38,47	1.074.882	877.123		
	>=	>=	>=	>=		
	0	0	0	0		

	Opbrengsten	**Gemiddelde prijs**	**Kosten**	**BVO andere functies**	**Lagen**	**Beb. Opp. Mgw**	**L andere functies**
Binnenstad	310.460.616	190.700	195.784.362	20.141	9,89	13.500	2
Entree-Afrikaweg	569.486.892	216.325	331.121.010	24.155	4,28	22.971	2
Bedrijventerreinen	512.500.924	216.325	292.361.306	21.739	4,26	20.213	2
Dwarstocht	-	-	-	-	-	-	0
Groene stadsas	363.202.520	230.000	208.612.227	15.394	4,97	10.314	2
Dutch Innovation Park	165.524.413	165.100	104.349.652	15.163	5,79	12.900	2
Rokkeveen A12 as	-	-	-	-	-	-	0
Solitaire locaties	307.508.839	216.325	176.671.807	13.043	4,27	12.230	2
Totaal	€ 2.228.684.204	€ 205.796	€ 1.308.900.363	109.635	5,58	92.129	1,2
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

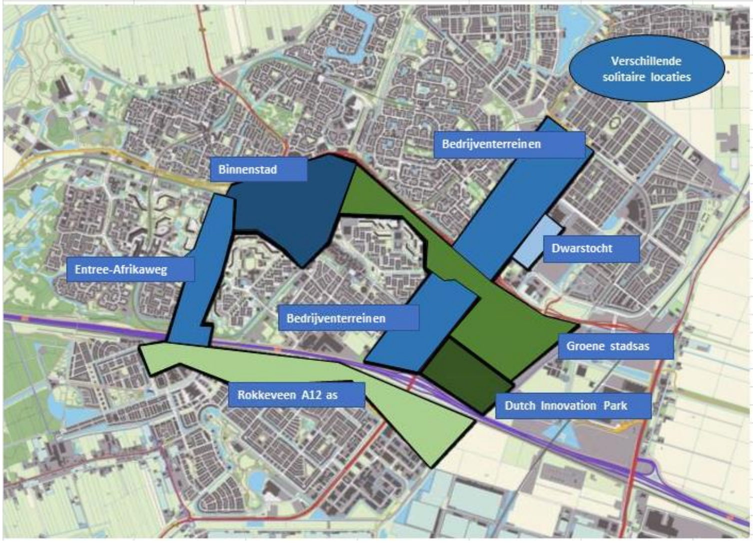
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	300	0	0	0	0	540	0	0
RAP080	600	0	0	0	0	0	0	0
RAP130	0	0	0	0	0	0	0	0
SSF070	0	875	788	0	525	0	0	473
RSF100	0	0	0	0	0	0	0	0
RSF140	0	0	0	0	0	0	0	0
OAP065	600	545	307	0	69	360	0	225
OAP090	0	875	1125	0	750	0	0	600
OAP120	0	205	31	0	156	0	0	53
OSF065	0	0	0	0	0	0	0	0
OSF090	0	0	0	0	0	0	0	0
OSF125	0	0	0	0	0	0	0	0
OSF200	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	**Gerealiseerd**							**Verhuizingen**		**Doelen**	
	Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen	Min	Max
SAP060	840	8%	60	€ 156.000	90	Meergezinswoning	Huur	2,21	1854,192189	0%	100%
RAP080	600	6%	80	€ 220.000	100	Meergezinswoning	Huur	2,26	1356,419848	0%	100%
RAP130	0	0%	130	€ 357.500	160	Meergezinswoning	Huur	2,37	0	0%	100%
SSF070	2660	27%	70	€ 182.000	40	Eengezinswoning	Huur	2,14	5685,164946	0%	100%
RSF100	0	0%	100	€ 275.000	50	Eengezinswoning	Huur	2,18	0	0%	100%
RSF140	0	0%	140	€ 385.000	70	Eengezinswoning	Huur	2,41	0	0%	100%
OAP065	2106	21%	65	€ 178.750	80	Meergezinswoning	Koop	2,16	4542,575139	0%	100%
OAP090	3350	34%	90	€ 247.500	100	Meergezinswoning	Koop	2,35	7886,081955	0%	100%
OAP120	444	4%	120	€ 330.000	145	Meergezinswoning	Koop	2,24	994,436502	0%	100%
OSF065	0	0%	65	€ 178.750	40	Eengezinswoning	Koop	2,20	0	0%	100%
OSF090	0	0%	90	€ 247.500	50	Eengezinswoning	Koop	2,16	0	0%	100%
OSF125	0	0%	125	€ 343.750	60	Eengezinswoning	Koop	2,32	0	0%	100%
OSF200	0	0%	200	€ 550.000	90	Eengezinswoning	Koop	2,07	0	0%	100%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
								22.318,9	>=	0	

ROS 2 – According to Fakton

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Nee	Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Exact	In primair aanbod	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 240.808
Low	4.737	Apartment	5.700
Middle	3.252	Single Family	4.300
High	1.778	Social	2.900
High+	233	Rental	2.500
		Owner-occupied	4.600

Migrations	22.218	Apartment	11.084
Low	11.117	Single Family	11.134
Middle	7.755	Social	7.403
High	2.955	Rental	4.318
High+	391	Owner-occupied	10.497

Plot area (ha)	83,83	Dwel. models	13

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	1.500	2	10
Entree-Afrikaweg	1.750	12	3
Bedrijventerreinen	1.580	11	3
Dwarstocht	200	3	3
Groene stadsas	1.500	12	5
Dutch Innovation F	808	8	4
Rokkeveen A12 as	1.125	24	3
Solitaire locaties	1.537	12	3

Development			
Total value	€ 2.502.452.419	Total GFA	1.238.184
Total costs	€ 1.532.735.539	Total LFA	985.358
		Total GFA Other I	131.389

Stadsdeel	Woningen	Kavel opp. (in hectares)	BVO (in m²)	VVO (in m²)		Totaal oppervlak	% van totaal oppervlak
Binnenstad	1.500	1,63	182.189	143.750		25,0	7%
Entree-Afrikaweg	1.750	11,97	184.683	155.556		37,5	32%
Bedrijventerreinen	1.500	10,50	163.642	133.333		133,6	8%
Dwarstocht	280	4,66	39.607	29.751		9,1	51%
Groene stadsas	1.500	11,60	187.349	141.803		43,0	27%
Dutch Innovation Park	673	5,99	81.080	60.525		27,6	22%
Rokkeveen A12 as	1.125	24,78	215.588	169.661		58,5	42%
Solitaire locaties	1.672	12,71	181.503	148.639		24,0	53%
Totaal	10.000	83,83	1.235.640	983.017			
	>=	>=	>=	>=			
	0	0	0	0			

	Opbrengsten	Gemiddelde prijs	Kosten	BVO andere functies	Lagen	Beb. Opp. Mgw	L andere functies
Binnenstad	357.436.322	219.510	230.845.602	23.437	9,77	16.250	2
Entree-Afrikaweg	405.105.157	220.000	232.421.383	16.908	3,46	12.810	2
Bedrijventerreinen	341.812.670	216.580	194.327.931	14.493	3,47	9.567	2
Dwarstocht	79.272.174	275.777	48.834.402	1.617	3,00	1.220	2
Groene stadsas	363.490.066	230.000	236.643.355	15.413	4,62	10.962	2
Dutch Innovation Park	143.860.908	192.600	93.277.943	13.158	3,48	6.053	3
Rokkeveen A12 as	425.681.006	351.205	271.060.765	27.662	3,00	3.895	8
Solitaire locaties	383.195.857	217.740	223.010.870	16.156	3,25	11.854	2
Totaal	€ 2.499.854.159	€ 240.427	€ 1.530.422.251	128.845	4,26	72.612	1,8
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

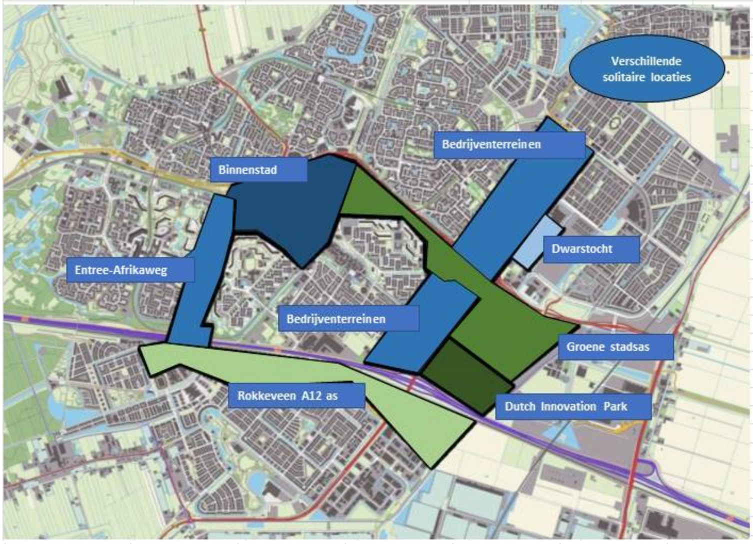
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	750	0	0	0	663	404	164	220
RAP080	365	420	0	0	0	0	125	0
RAP130	178	0	0	0	312	0	0	0
SSF070	0	0	489	40	0	0	0	171
RSF100	0	431	278	0	0	0	0	231
RSF140	0	0	0	0	0	0	160	0
OAP065	0	352	320	76	0	0	0	222
OAP090	0	194	414	0	0	0	0	0
OAP120	208	0	0	0	0	0	0	313
OSF065	0	352	0	0	0	0	0	514
OSF090	0	0	0	0	525	269	0	0
OSF125	0	0	0	164	0	0	443	0
OSF200	0	0	0	0	0	0	233	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	**Gerealiseerd**							**Verhuizingen**		**Doelen**	
	Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen	Min	Max
SAP060	2200	22%	60	€ 156.000	90	Meergezinswoning	Huur	2,21	4856,217638	18%	22%
RAP080	910	9%	80	€ 220.000	100	Meergezinswoning	Huur	2,26	2057,236769	5%	9%
RAP130	490	5%	130	€ 357.500	160	Meergezinswoning	Huur	2,37	1159,213397	1%	5%
SSF070	700	7%	70	€ 182.000	40	Eengezinswoning	Huur	2,14	1496,096039	5%	9%
RSF100	940	9%	100	€ 275.000	50	Eengezinswoning	Huur	2,18	2053,12235	9%	13%
RSF140	160	2%	140	€ 385.000	70	Eengezinswoning	Huur	2,41	385,2631748	2%	6%
OAP065	971	10%	65	€ 178.750	80	Meergezinswoning	Koop	2,16	2094,218935	6%	10%
OAP090	608	6%	90	€ 247.500	100	Meergezinswoning	Koop	2,35	1431,265024	2%	6%
OAP120	521	5%	120	€ 330.000	145	Meergezinswoning	Koop	2,24	1167,416602	1%	5%
OSF065	866	9%	65	€ 178.750	40	Eengezinswoning	Koop	2,20	1906,490155	9%	13%
OSF090	794	8%	90	€ 247.500	50	Eengezinswoning	Koop	2,16	1718,934158	8%	12%
OSF125	607	6%	125	€ 343.750	60	Eengezinswoning	Koop	2,32	1409,671729	6%	10%
OSF200	233	2%	200	€ 550.000	90	Eengezinswoning	Koop	2,07	482,9414454	2%	6%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
								22.218,1	>=	0	

ROS 3 – Getting Your Money's Worth

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Nee	Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Vrij	Niet	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 324.714
Low	1.676	Apartment	7.110
Middle	1.629	Single Family	2.890
High	5.988	Social	630
High+	707	Rental	5.520
		Owner-occupied	3.850

Migrations	22.739	Apartment	12.085
Low	7.355	Single Family	10.654
Middle	6.642	Social	4.780
High	7.767	Rental	7.852
High+	975	Owner-occupied	10.107

Plot area (ha)	70,31	Dwel. models	9

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	1.500	2	10
Entree-Afrikaweg	1.887	11	5
Bedrijventerreinen	2.250	13	5
Dwarstocht	-	-	-
Groene stadsas	1.500	13	5
Dutch Innovation P	900	2	6
Rokkeveen A12 as	922	23	3
Solitaire locaties	1.041	6	4

Development			
Total value	€ 3.850.000.000	Total GFA	1.747.673
Total costs	€ 2.597.249.486	Total LFA	1.452.450
		Total GFA Other F	953.012

Stadsdeel	**Woningen**	**Kavel opp. (in hectares)**	**BVO (in m²)**	**VVO (in m²)**		**Totaal oppervlak**	**% van totaal oppervlak**
Binnenstad	1.500	2,07	264.737	219.692		25,0	8%
Entree-Afrikaweg	1.887	11,08	292.850	242.939		37,5	30%
Bedrijventerreinen	2.250	13,22	347.822	289.341		133,6	10%
Dwarstocht	-	-	-	-		9,1	0%
Groene stadsas	1.500	13,22	286.829	238.636		43,0	31%
Dutch Innovation Park	900	1,62	135.576	116.883		27,6	6%
Rokkeveen A12 as	922	22,96	260.184	211.353		58,5	39%
Solitaire locaties	1.041	6,13	159.675	133.605		24,0	26%
Totaal	10.000	70,31	1.747.673	1.452.450			
	>=	>=	>=	>=			
	0	0	0	0			

	Opbrengsten	**Gemiddelde prijs**	**Kosten**	**BVO andere functies**	**Lagen**	**Beb. Opp. Mgw**	**L andere functies**
Binnenstad	574.457.191	300.000	397.162.082	175.936	9,92	20.677	9
Entree-Afrikaweg	658.429.989	300.000	435.924.824	137.020	4,55	27.287	6
Bedrijventerreinen	785.103.987	300.000	521.360.356	163.710	4,53	32.705	6
Dwarstocht	-	-	-	-	-	-	0
Groene stadsas	630.826.366	350.000	421.423.094	151.783	4,95	15.043	11
Dutch Innovation Park	298.723.856	250.000	200.061.916	106.411	6,00	16.244	7
Rokkeveen A12 as	539.042.140	473.000	378.462.406	142.053	3,48	8.426	17
Solitaire locaties	363.416.470	300.000	242.854.808	76.099	4,50	15.302	5
Totaal	€ 3.850.000.000	€ 324.714	€ 2.597.249.486	953.012	5,42	135.685	7,0
	=>=		>=	>=	>=	>=	>=
	3850000000		0	0	0	0	0

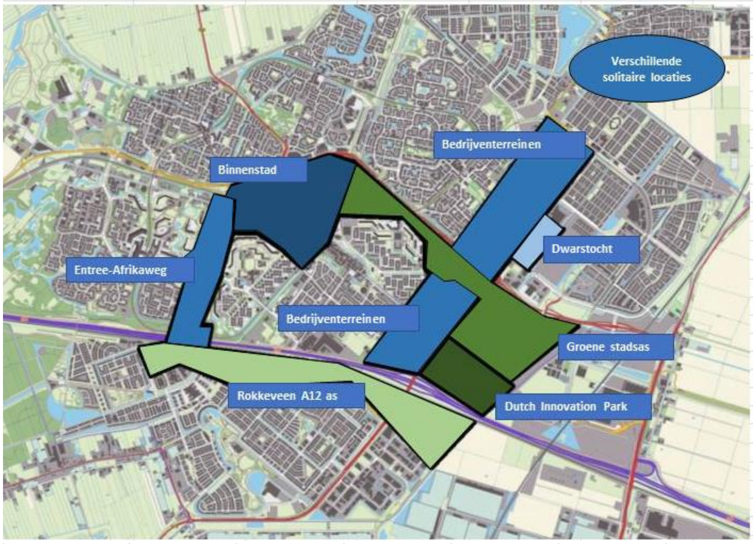
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	346	0	0	0	0	0	0	0
RAP080	0	0	0	0	0	416	0	0
RAP130	554	875	1125	0	604	124	369	600
SSF070	0	157	127	0	0	0	0	0
RSF100	0	194	210	0	371	0	0	77
RSF140	0	0	0	0	0	0	0	0
OAP065	0	0	0	0	0	0	0	0
OAP090	0	0	0	0	0	360	0	0
OAP120	600	352	338	0	371	0	0	77
OSF065	0	309	450	0	0	0	0	288
OSF090	0	0	0	0	0	0	0	0
OSF125	0	0	0	0	0	0	0	0
OSF200	0	0	0	0	154	0	553	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	**Gerealiseerd**								**Verhuizingen**			**Doelen**	
	Aantal	% v. totaal	VVO (m²)		Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen		Min	Max
SAP060	346	4%	60	€	156.000	90	Meergezinswoning	Huur	2,21	764,0901878		0%	100%
RAP080	416	4%	80	€	220.000	100	Meergezinswoning	Huur	2,26	939,6290218		0%	100%
RAP130	4251	43%	130	€	357.500	160	Meergezinswoning	Huur	2,37	10055,74328		0%	100%
SSF070	284	3%	70	€	182.000	40	Eengezinswoning	Huur	2,14	607,729344		0%	100%
RSF100	853	9%	100	€	275.000	50	Eengezinswoning	Huur	2,18	1862,874003		0%	100%
RSF140	0	0%	140	€	385.000	70	Eengezinswoning	Huur	2,41	0		0%	100%
OAP065	0	0%	65	€	178.750	80	Meergezinswoning	Koop	2,16	0		0%	100%
OAP090	360	4%	90	€	247.500	100	Meergezinswoning	Koop	2,35	847,4595534		0%	100%
OAP120	1737	17%	120	€	330.000	145	Meergezinswoning	Koop	2,24	3892,682137		0%	100%
OSF065	1046	11%	65	€	178.750	40	Eengezinswoning	Koop	2,20	2303,812056		0%	100%
OSF090	0	0%	90	€	247.500	50	Eengezinswoning	Koop	2,16	0		0%	100%
OSF125	0	0%	125	€	343.750	60	Eengezinswoning	Koop	2,32	0		0%	100%
OSF200	707	7%	200	€	550.000	90	Eengezinswoning	Koop	2,07	1464,735092		0%	100%
-	0	0%	0	€	-	0	0	0	0,00	0		0%	0%
-	0	0%	0	€	-	0	0	0	0,00	0		0%	0%
									22.738,8	>=	0		

ROS 4 – The Great Migration

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Ja	Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Vrij	In primair aanbod	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 294.469
Low	1.065	Apartment	7.090
Middle	4.345	Single Family	2.910
High	4.465	Social	271
High+	125	Rental	4.752
		Owner-occupied	4.977

Migrations	23.350	Apartment	12.374
Low	6.968	Single Family	10.976
Middle	9.849	Social	4.397
High	6.174	Rental	7.227
High+	359	Owner-occupied	11.726

Plot area (ha)	72,68	Dwel. models	13

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.500	2	10
Entree-Afrikaweg	2.310	18	4
Bedrijventerreinen	1.502	11	4
Dwarstocht	250	3	3
Groene stadsas	1.500	13	4
Dutch Innovation P	900	2	6
Rokkeveen A12 as	750	14	3
Solitaire locaties	1.288	10	4

Development			
Total value	€ 3.145.594.324	Total GFA	1.431.564
Total costs	€ 1.905.324.201	Total LFA	1.224.364
		Total GFA Other f	159.425

Stadsdeel	Woningen	Kavel opp. (in hectares)	BVO (in m²)	VVO (in m²)	Totaal oppervlak	% van totaal oppervlak
Binnenstad	1.500	1,95	226.362	192.353	25,0	8%
Entree-Afrikaweg	2.310	18,07	315.205	272.830	37,5	48%
Bedrijventerreinen	1.502	11,23	193.292	168.817	133,6	8%
Dwarstocht	250	2,89	35.402	28.529	9,1	32%
Groene stadsas	1.500	12,94	223.744	192.817	43,0	30%
Dutch Innovation Park	900	1,67	122.077	102.682	27,6	6%
Rokkeveen A12 as	750	13,55	134.092	112.500	58,5	23%
Solitaire locaties	1.288	10,38	184.655	156.838	24,0	43%
Totaal	10.000	72,68	1.434.829	1.227.367		
	>=	>=	>=	>=		
	0	0	0	0		

	Opbrengsten	Gemiddelde prijs	Kosten	BVO andere functies	Lagen	Beb. Opp. Mgw	L andere functies
Binnenstad	486.662.081	299.750	312.247.049	31.362	10,00	19.500	2
Entree-Afrikaweg	710.171.757	292.327	422.620.919	29.655	3,95	26.819	2
Bedrijventerreinen	439.481.714	278.148	255.604.603	18.350	3,90	16.287	2
Dwarstocht	71.786.166	266.750	44.749.694	4.652	3,11	2.900	2
Groene stadsas	501.735.192	318.149	299.139.849	20.958	4,38	12.450	2
Dutch Innovation Park	249.425.427	250.000	158.891.148	22.322	5,97	16.709	2
Rokkeveen A12 as	283.331.005	350.625	170.704.158	18.342	3,13	4.286	5
Solitaire locaties	406.332.677	300.000	244.332.882	17.048	4,04	15.110	2
Totaal	€ 3.148.926.020	€ 294.469	€ 1.908.290.302	162.689	4,81	114.060	1,4
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

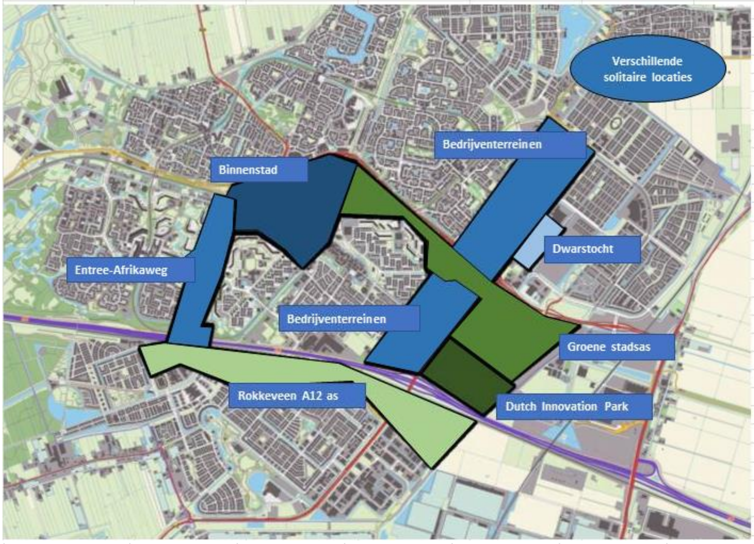
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	0	0	0	0	0	100	0	0
RAP080	150	0	0	0	0	219	0	0
RAP130	750	626	273	0	450	221	0	368
SSF070	0	0	0	0	0	0	0	171
RSF100	0	0	0	0	143	0	0	0
RSF140	0	437	253	0	382	0	200	279
OAP065	0	0	0	0	0	100	0	0
OAP090	600	875	704	0	525	260	300	470
OAP120	0	0	0	100	0	0	0	0
OSF065	0	371	273	50	0	0	0	0
OSF090	0	0	0	100	0	0	0	0
OSF125	0	0	0	0	0	0	125	0
OSF200	0	0	0	0	0	0	125	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	**Gerealiseerd**							**Verhuizingen**		**Doelen**	
	Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen	Min	Max
SAP060	100	1%	60	€ 156.000	90	Meergezinswoning	Huur	2,21	220,7371654	1%	100%
RAP080	369	4%	80	€ 220.000	100	Meergezinswoning	Huur	2,26	834,4037245	1%	100%
RAP130	2688	27%	130	€ 357.500	160	Meergezinswoning	Huur	2,37	6358,420025	1%	100%
SSF070	171	2%	70	€ 182.000	40	Eengezinswoning	Huur	2,14	366,3908666	1%	100%
RSF100	143	1%	100	€ 275.000	50	Eengezinswoning	Huur	2,18	312,0246733	1%	100%
RSF140	1552	16%	140	€ 385.000	70	Eengezinswoning	Huur	2,41	3736,845155	1%	100%
OAP065	100	1%	65	€ 178.750	80	Meergezinswoning	Koop	2,16	215,6765124	1%	100%
OAP090	3733	37%	90	€ 247.500	100	Meergezinswoning	Koop	2,35	8788,160794	1%	100%
OAP120	100	1%	120	€ 330.000	145	Meergezinswoning	Koop	2,24	224,0722844	1%	100%
OSF065	694	7%	65	€ 178.750	40	Eengezinswoning	Koop	2,20	1527,394756	1%	100%
OSF090	100	1%	90	€ 247.500	50	Eengezinswoning	Koop	2,16	216,4904481	1%	100%
OSF125	125	1%	125	€ 343.750	60	Eengezinswoning	Koop	2,32	290,294837	1%	100%
OSF200	125	1%	200	€ 550.000	90	Eengezinswoning	Koop	2,07	259,0887583	1%	100%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
								23.350,0	=>=	23350	

ROS 5 – What the People Want

Invullen per Run Objective Set			
Alle won. modellen	Nee	**Verhuizingen**	Totaal aantal verhuizingen
Bandbreedte vraag	Normaal	**Reken met vraag**	In primair aanbod
Exacte totale opgave	Ja		

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 258.214
Low	3.776	Apartment	6.739
Middle	3.252	Single Family	3.261
High	2.872	Social	2.700
High+	100	Rental	3.500
		Owner-occupied	3.800

Migrations	22.550	Apartment	12.053
Low	10.021	Single Family	10.497
Middle	8.024	Social	7.145
High	4.215	Rental	5.502
High+	290	Owner-occupied	9.903

Plot area (ha)	73,09	Dwel. models	13

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	1.500	1,92	10
Entree-Afrikaweg	1.963	13,08	4
Bedrijventerreinen	2.090	13,81	4
Dwarstocht	200	3,42	3
Groene stadsas	1.500	12,64	5
Dutch Innovation P	738	7,54	4
Rokkeveen A12 as	750	12,94	3
Solitaire locaties	1.260	7,73	4

Development			
Total value	€ 2.643.901.218	Total GFA	1.279.198
Total costs	€ 1.615.824.246	Total LFA	1.037.683
		Total GFA Other f	135.903

Stadsdeel	**Woningen**	**Kavel opp. (in hectares)**	**BVO (in m²)**	**VVO (in m²)**	**Totaal oppervlak**	**% van totaal oppervlak**
Binnenstad	1.500	2,00	230.877	190.700	25,0	8%
Entree-Afrikaweg	2.009	13,31	217.193	178.880	37,5	35%
Bedrijventerreinen	1.650	11,13	183.692	149.398	133,6	8%
Dwarstocht	200	2,49	24.657	19.575	9,1	27%
Groene stadsas	1.500	12,44	209.488	166.717	43,0	29%
Dutch Innovation Park	626	6,86	90.142	68.671	27,6	25%
Rokkeveen A12 as	759	13,15	132.928	107.109	58,5	22%
Solitaire locaties	1.756	11,69	189.637	156.095	24,0	49%
Totaal	10.000	73,06	1.278.614	1.037.145		
	>=	>=	>=	>=		
	0	0	0	0		

	Opbrengsten	**Gemiddelde prijs**	**Kosten**	**BVO andere functies**	**Lagen**	**Beb. Opp. Mgw**	**L andere functies**
Binnenstad	482.563.425	297.175	320.299.572	31.092	10,00	19.978	2
Entree-Afrikaweg	459.534.613	217.150	265.364.915	19.443	3,69	17.622	2
Bedrijventerreinen	382.538.912	220.120	221.064.555	16.239	3,76	13.875	2
Dwarstocht	52.468.389	255.703	30.565.313	1.064	3,01	1.280	1
Groene stadsas	430.725.063	272.806	269.470.421	18.121	4,63	12.264	2
Dutch Innovation Park	163.480.669	235.245	107.127.191	14.928	3,61	6.217	3
Rokkeveen A12 as	269.813.109	330.000	167.055.184	17.463	3,16	4.375	4
Solitaire locaties	402.279.635	217.497	234.445.086	16.967	3,69	15.119	2
Totaal	€ 2.643.403.815	€ 255.712	€ 1.615.392.236	135.319	4,45	90.730	1,5
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	0	722	495	0	380	414	0	488
RAP080	609	194	0	0	0	0	125	281
RAP130	647	0	0	0	143	0	0	0
SSF070	0	0	200	0	0	0	0	0
RSF100	0	194	190	64	0	0	0	191
RSF140	0	194	188	0	143	0	164	171
OAP065	0	0	259	80	0	0	0	171
OAP090	0	389	319	0	0	0	0	200
OAP120	243	0	0	0	453	0	125	0
OSF065	0	314	0	0	0	0	0	252
OSF090	0	0	0	0	382	112	0	0
OSF125	0	0	0	56	0	0	345	0
OSF200	0	0	0	0	0	100	0	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

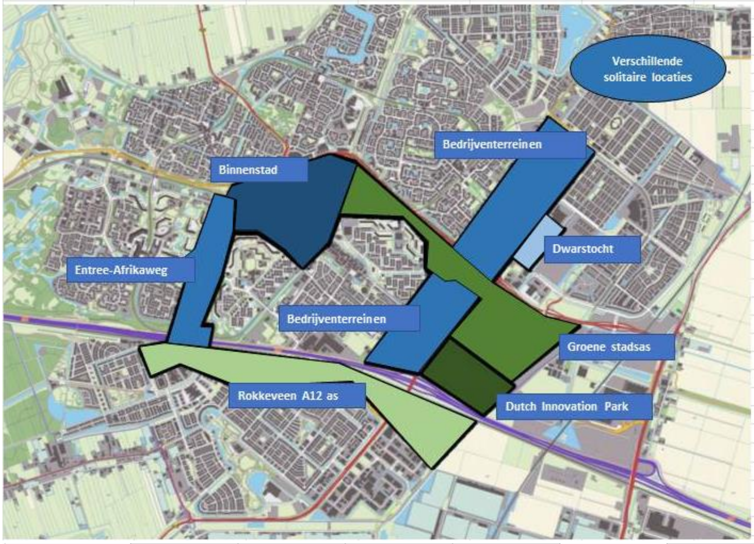
Woningtype	**Gerealiseerd**						
	Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop
SAP060	2500	25%	60	€ 156.000	90	Meergezinswoning	Huur
RAP080	1210	12%	80	€ 220.000	100	Meergezinswoning	Huur
RAP130	790	8%	130	€ 357.500	160	Meergezinswoning	Huur
SSF070	200	2%	70	€ 182.000	40	Eengezinswoning	Huur
RSF100	640	6%	100	€ 275.000	50	Eengezinswoning	Huur
RSF140	860	9%	140	€ 385.000	70	Eengezinswoning	Huur
OAP065	510	5%	65	€ 178.750	80	Meergezinswoning	Koop
OAP090	908	9%	90	€ 247.500	100	Meergezinswoning	Koop
OAP120	821	8%	120	€ 330.000	145	Meergezinswoning	Koop
OSF065	566	6%	65	€ 178.750	40	Eengezinswoning	Koop
OSF090	494	5%	90	€ 247.500	50	Eengezinswoning	Koop
OSF125	401	4%	125	€ 343.750	60	Eengezinswoning	Koop
OSF200	100	1%	200	€ 550.000	90	Eengezinswoning	Koop
-	0	0%	0	€ -	0	0	0
-	0	0%	0	€ -	0	0	0

Verhuizingen			**Doelen**	
Multiplier	Verhuizingen		Min	Max
2,21	5518,429134		15%	25%
2,26	2735,446693		2%	12%
2,37	1868,935885		1%	8%
2,14	427,456011		2%	12%
2,18	1397,870536		6%	16%
2,41	2070,789565		1%	9%
2,16	1100,415006		3%	13%
2,35	2137,481318		1%	9%
2,24	1839,633455		1%	8%
2,20	1246,043219		6%	16%
2,16	1069,462814		5%	15%
2,32	930,7653579		3%	13%
2,07	207,2710066		1%	9%
0,00	0		0%	0%
0,00	0		0%	0%
22.550,0	=>=	22550		

ROS 6 – Efficient Construction

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Nee	Alleen secundaire verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Ruim	In secundair aanbod	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	7.015	Av. Price	€ 254.996
Low	3.827	Apartment	3.095
Middle	942	Single Family	3.920
High	2.222	Social	-
High+	24	Rental	2.601
		Owner-occupied	4.414

Migrations	10.000	Apartment	4.404
Low	4.469	Single Family	5.596
Middle	4.028	Social	3.404
High	1.305	Rental	2.158
High+	198	Owner-occupied	4.438

Plot area (ha)	54,50	Dwel. models	6

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	-	-	-
Entree-Afrikaweg	1.388	12	3
Bedrijventerreinen	2.051	16	3
Dwarstocht	300	3	3
Groene stadsas	1.500	11	4
Dutch Innovation P	782	5	3
Rokkeveen A12 as	43	1	3
Solitaire locaties	952	8	3

Development			
Total value	€ 1.779.806.845	Total GFA	815.762
Total costs	€ 1.088.549.985	Total LFA	687.548
		Total GFA Other F	81.216

Stadsdeel	**Woningen**	**Kavel opp. (in hectares)**	**BVO (in m²)**	**VVO (in m²)**	**Totaal oppervlak**	**% van totaal oppervlak**
Binnenstad	-	-	-	-	25,0	0%
Entree-Afrikaweg	1.388	11,67	162.182	136.987	37,5	31%
Bedrijventerreinen	2.051	15,68	221.230	186.590	133,6	12%
Dwarstocht	300	3,18	37.747	31.371	9,1	35%
Groene stadsas	1.500	10,84	190.301	160.320	43,0	25%
Dutch Innovation Park	782	4,53	86.078	72.313	27,6	16%
Rokkeveen A12 as	43	0,59	7.014	6.033	58,5	1%
Solitaire locaties	952	8,00	111.210	93.934	24,0	33%
Totaal	7.015	54,50	815.762	687.548		
	>=	>=	>=	>=		
	0	0	0	0		

	Opbrengsten	**Gemiddelde prijs**	**Kosten**	**BVO andere functies**	**Lagen**	**Beb. Opp. Mgw**	**L andere functies**
Binnenstad	-	-	-	-	-	-	0
Entree-Afrikaweg	356.554.434	244.274	219.478.012	14.890	3,16	11.667	2
Bedrijventerreinen	485.880.585	225.212	291.164.827	20.281	3,20	16.135	2
Dwarstocht	84.110.473	273.186	51.019.632	1.705	3,00	3.639	1
Groene stadsas	417.356.030	264.528	258.430.979	17.426	4,00	11.201	2
Dutch Innovation Park	176.209.435	203.500	108.932.698	15.720	3,46	7.818	3
Rokkeveen A12 as	15.201.420	330.000	9.024.628	984	3,11	354	3
Solitaire locaties	244.494.469	244.274	150.499.208	10.210	3,16	8.000	2
Totaal	€ 1.779.806.845	€ 254.996	€ 1.088.549.985	81.216	3,30	58.813	1,4
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

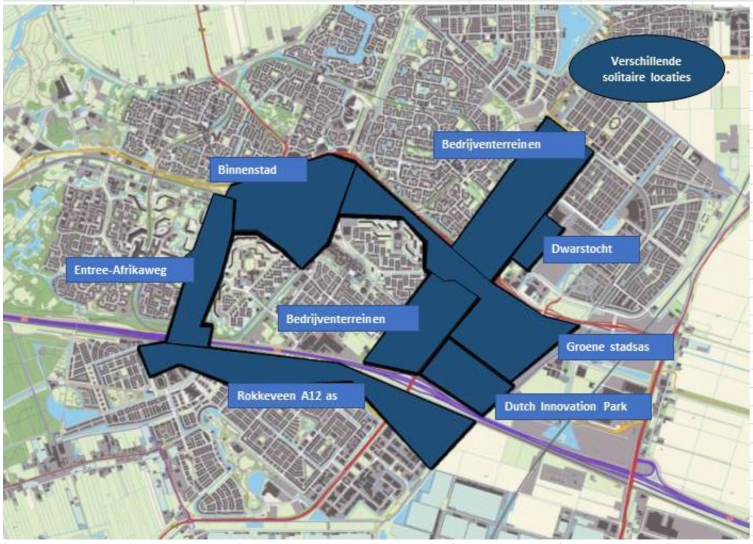
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	0	0	0	0	0	0	0	0
RAP080	0	0	473	0	0	469	0	0
RAP130	0	486	222	53	496	0	0	333
SSF070	0	0	0	0	0	0	0	0
RSF100	0	0	0	0	0	0	0	0
RSF140	0	0	23	0	29	0	17	0
OAP065	0	0	0	0	0	0	0	0
OAP090	0	0	0	0	0	0	0	0
OAP120	0	27	208	67	225	0	17	19
OSF065	0	875	1125	156	750	313	8	600
OSF090	0	0	0	0	0	0	0	0
OSF125	0	0	0	0	0	0	0	0
OSF200	0	0	0	24	0	0	1	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	**Gerealiseerd**							**Verhuizingen**		**Doelen**	
	Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen	Min	Max
SAP060	0	0%	60	€ 156.000	90	Meergezinswoning	Huur	1,26	0	0%	100%
RAP080	942	13%	80	€ 220.000	100	Meergezinswoning	Huur	1,35	1274,244595	0%	100%
RAP130	1590	23%	130	€ 357.500	160	Meergezinswoning	Huur	1,40	2217,76744	0%	100%
SSF070	0	0%	70	€ 182.000	40	Eengezinswoning	Huur	1,15	0	0%	100%
RSF100	0	0%	100	€ 275.000	50	Eengezinswoning	Huur	1,24	0	0%	100%
RSF140	69	1%	140	€ 385.000	70	Eengezinswoning	Huur	1,54	105,7446964	0%	100%
OAP065	0	0%	65	€ 178.750	80	Meergezinswoning	Koop	1,18	0	0%	100%
OAP090	0	0%	90	€ 247.500	100	Meergezinswoning	Koop	1,30	0	0%	100%
OAP120	563	8%	120	€ 330.000	145	Meergezinswoning	Koop	1,28	718,5296901	0%	100%
OSF065	3827	55%	65	€ 178.750	40	Eengezinswoning	Koop	1,48	5657,604441	0%	100%
OSF090	0	0%	90	€ 247.500	50	Eengezinswoning	Koop	1,22	0	0%	100%
OSF125	0	0%	125	€ 343.750	60	Eengezinswoning	Koop	1,36	0	0%	100%
OSF200	24	0%	200	€ 550.000	90	Eengezinswoning	Koop	1,07	26,10913704	0%	100%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
								10.000,0	>=	0	

ROS 7 – Maximal Urbanization

Invullen per Run Objective Set			
Alle won. modellen		**Verhuizingen**	
Nee		Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**	
Vrij	Niet	Ja	

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 241.972
Low	-	Apartment	10.000
Middle	8.862	Single Family	-
High	1.138	Social	-
High+	-	Rental	6.000
		Owner-occupied	4.000

Migrations	23.100	Apartment	15.323
Low	5.791	Single Family	7.777
Middle	14.277	Social	4.018
High	2.800	Rental	8.264
High+	232	Owner-occupied	10.818

Plot area (ha)	10,68	Dwel. models	3

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.250	1	10
Entree-Afrikaweg	1.458	1	10
Bedrijventerreinen	2.250	3	10
Dwarstocht	300	0	10
Groene stadsas	1.500	2	10
Dutch Innovation P	900	1	10
Rokkeveen A12 as	1.125	1	10
Solitaire locaties	1.217	1	10

Development			
Total value	€ 2.671.616.136	Total GFA	1.240.351
Total costs	€ 1.648.499.232	Total LFA	1.055.203
		Total GFA Other F	172.044

Stadsdeel	Woningen	Kavel opp. (in hectares)	BVO (in m²)	VVO (in m²)	Totaal oppervlak	% van totaal oppervlak
Binnenstad	1.250	1,25	145.141	123.529	25,0	5%
Entree-Afrikaweg	1.458	1,46	169.331	144.118	37,5	4%
Bedrijventerreinen	2.250	2,70	313.164	266.232	133,6	2%
Dwarstocht	300	0,30	34.834	29.647	9,1	3%
Groene stadsas	1.500	1,59	184.607	157.059	43,0	4%
Dutch Innovation Park	900	0,90	104.501	88.941	27,6	3%
Rokkeveen A12 as	1.125	1,19	138.456	117.794	58,5	2%
Solitaire locaties	1.217	1,29	150.317	127.882	24,0	5%
Totaal	10.000	10,68	1.240.351	1.055.203		
	>=	>=	>=	>=		
	0	0	0	0		

	Opbrengsten	Gemiddelde prijs	Kosten BVO	andere functies	Lagen	Beb. Opp. Mgw	L andere functies
Binnenstad	312.843.366	231.000	190.100.112	20.141	10,00	12.500	2
Entree-Afrikaweg	364.983.927	231.000	221.783.464	23.497	10,00	14.583	2
Bedrijventerreinen	673.766.410	276.585	425.852.120	43.407	10,00	26.976	2
Dwarstocht	75.082.408	231.000	45.624.027	4.834	10,00	3.000	2
Groene stadsas	397.662.048	244.750	244.945.517	25.607	10,00	15.900	2
Dutch Innovation Park	225.247.224	231.000	136.872.081	14.501	10,00	9.000	2
Rokkeveen A12 as	298.246.536	244.750	183.709.138	19.206	10,00	11.925	2
Solitaire locaties	323.784.217	245.692	199.612.774	20.850	10,00	12.947	2
Totaal	€ 2.671.616.136	€ 241.972	€ 1.648.499.232	172.044	10,00	106.831	1,6
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

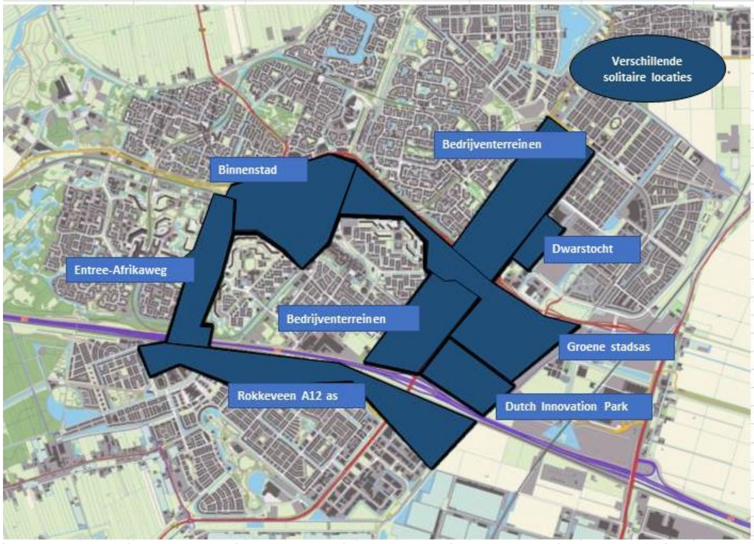
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	0	0	0	0	0	0	0	0
RAP080	750	875	604	180	750	540	563	600
RAP130	0	0	746	0	150	0	113	130
SSF070	0	0	0	0	0	0	0	0
RSF100	0	0	0	0	0	0	0	0
RSF140	0	0	0	0	0	0	0	0
OAP065	0	0	0	0	0	0	0	0
OAP090	500	583	900	120	600	360	450	487
OAP120	0	0	0	0	0	0	0	0
OSF065	0	0	0	0	0	0	0	0
OSF090	0	0	0	0	0	0	0	0
OSF125	0	0	0	0	0	0	0	0
OSF200	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	Gerealiseerd								Verhuizingen			Doelen	
	Aantal	% v. totaal	VVO (m²)		Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen		Min	Max
SAP060	0	0%	60	€	156.000	90	Meergezinswoning	Huur	2,21	0		0%	100%
RAP080	4862	49%	80	€	220.000	100	Meergezinswoning	Huur	2,26	10990,51919		0%	100%
RAP130	1138	11%	130	€	357.500	160	Meergezinswoning	Huur	2,37	2693,263549		0%	100%
SSF070	0	0%	70	€	182.000	40	Eengezinswoning	Huur	2,14	0		0%	100%
RSF100	0	0%	100	€	275.000	50	Eengezinswoning	Huur	2,18	0		0%	100%
RSF140	0	0%	140	€	385.000	70	Eengezinswoning	Huur	2,41	0		0%	100%
OAP065	0	0%	65	€	178.750	80	Meergezinswoning	Koop	2,16	0		0%	100%
OAP090	4000	40%	90	€	247.500	100	Meergezinswoning	Koop	2,35	9416,21726		0%	100%
OAP120	0	0%	120	€	330.000	145	Meergezinswoning	Koop	2,24	0		0%	100%
OSF065	0	0%	65	€	178.750	40	Eengezinswoning	Koop	2,20	0		0%	100%
OSF090	0	0%	90	€	247.500	50	Eengezinswoning	Koop	2,16	0		0%	100%
OSF125	0	0%	125	€	343.750	60	Eengezinswoning	Koop	2,32	0		0%	100%
OSF200	0	0%	200	€	550.000	90	Eengezinswoning	Koop	2,07	0		0%	100%
-	0	0%	0	€	-	0	0	0	0,00	0		0%	0%
-	0	0%	0	€	-	0	0	0	0,00	0		0%	0%
									23.100,0	=>=	23100		

ROS 7b – Maximal Urbanization

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Nee	Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Ruim	In secundair aanbod	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 250.521
Low	923	Apartment	10.000
Middle	6.480	Single Family	-
High	2.597	Social	923
High+	-	Rental	5.997
		Owner-occupied	3.080

Migrations	23.100	Apartment	15.300
Low	6.800	Single Family	7.800
Middle	11.791	Social	5.136
High	4.270	Rental	8.341
High+	239	Owner-occupied	9.623

Plot area (ha)	11,45	Dwel. models	5,0

	Dwellings	Plot area (ha)	Layers
Binnenstad	1.257	1,26	10,0
Entree-Afrikaweg	1.768	2,25	9,8
Bedrijventerreinen	2.250	2,78	10,0
Dwarstocht	300	0,30	10,0
Groene stadsas	1.500	1,59	10,0
Dutch Innovation P	-	-	-
Rokkeveen A12 as	1.125	1,11	9,9
Solitaire locaties	1.800	2,16	10,0

Development			
Total value	€ 2.345.437.682	Total GFA	1.321.188
Total costs	€ 1.770.854.697	Total LFA	1.106.548
		Total GFA Other f	180.415

Stadsdeel	Woningen	Kavel opp. (in hectares)	BVO (in m²)	VVO (in m²)	Totaal oppervlak	% van totaal oppervlak
Binnenstad	1.257	1,26	146.199	124.429	25,0	5%
Entree-Afrikaweg	1.768	2,25	253.985	202.758	37,5	6%
Bedrijventerreinen	2.250	2,78	322.528	272.362	133,6	2%
Dwarstocht	300	0,30	34.834	29.647	9,1	3%
Groene stadsas	1.500	1,59	184.607	157.059	43,0	4%
Dutch Innovation Park	-	-	-	-	27,6	0%
Rokkeveen A12 as	1.125	1,11	128.508	108.529	58,5	2%
Solitaire locaties	1.800	2,16	250.527	211.765	24,0	9%
Totaal	10.000	11,45	1.321.188	1.106.548		
	>=	>=	>=	>=		
	0	0	0	0		

	Opbrengsten	Gemiddelde prijs	Kosten	BVO andere functies	Lagen	Beb. Opp. Mgw	L andere functies
Binnenstad	264.639.425	231.440	191.570.812	20.287	10,00	12.591	2
Entree-Afrikaweg	424.994.700	263.902	338.935.091	33.058	9,82	22.498	2
Bedrijventerreinen	578.745.295	282.953	442.261.647	44.407	10,00	27.812	2
Dwarstocht	63.055.135	231.000	45.624.027	4.834	10,00	3.000	2
Groene stadsas	333.946.139	244.750	244.945.517	25.607	10,00	15.900	2
Dutch Innovation Park	-	-	-	-	-	-	0
Rokkeveen A12 as	230.021.879	224.600	165.946.411	17.695	9,95	11.138	2
Solitaire locaties	450.035.109	275.000	341.571.192	34.527	10,00	21.600	2
Totaal	€ 2.345.437.682	€ 250.521	€ 1.770.854.697	180.415	9,97	114.539	1,6
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

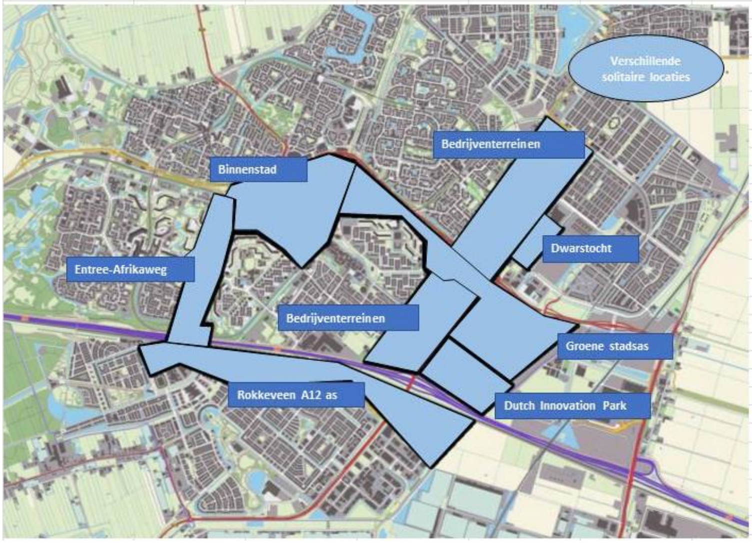
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	0	810	0	0	0	0	113	0
RAP080	750	0	641	180	750	0	563	600
RAP130	4	875	885	0	150	0	0	600
SSF070	0	0	0	0	0	0	0	0
RSF100	0	0	0	0	0	0	0	0
RSF140	0	0	0	0	0	0	0	0
OAP065	0	0	0	0	0	0	0	0
OAP090	503	0	724	120	600	0	450	600
OAP120	0	83	0	0	0	0	0	0
OSF065	0	0	0	0	0	0	0	0
OSF090	0	0	0	0	0	0	0	0
OSF125	0	0	0	0	0	0	0	0
OSF200	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	Gerealiseerd							Verhuizingen		Doelen	
	Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen	Min	Max
SAP060	923	9%	60	€ 156.000	90	Meergezinswoning	Huur	2,21	2036,339158	0%	100%
RAP080	3483	35%	80	€ 220.000	100	Meergezinswoning	Huur	2,26	7874,505489	0%	100%
RAP130	2514	25%	130	€ 357.500	160	Meergezinswoning	Huur	2,37	5948,383771	0%	100%
SSF070	0	0%	70	€ 182.000	40	Eengezinswoning	Huur	2,14	0	0%	100%
RSF100	0	0%	100	€ 275.000	50	Eengezinswoning	Huur	2,18	0	0%	100%
RSF140	0	0%	140	€ 385.000	70	Eengezinswoning	Huur	2,41	0	0%	100%
OAP065	0	0%	65	€ 178.750	80	Meergezinswoning	Koop	2,16	0	0%	100%
OAP090	2997	30%	90	€ 247.500	100	Meergezinswoning	Koop	2,35	7054,167376	0%	100%
OAP120	83	1%	120	€ 330.000	145	Meergezinswoning	Koop	2,24	186,604205	0%	100%
OSF065	0	0%	65	€ 178.750	40	Eengezinswoning	Koop	2,20	0	0%	100%
OSF090	0	0%	90	€ 247.500	50	Eengezinswoning	Koop	2,16	0	0%	100%
OSF125	0	0%	125	€ 343.750	60	Eengezinswoning	Koop	2,32	0	0%	100%
OSF200	0	0%	200	€ 550.000	90	Eengezinswoning	Koop	2,07	0	0%	100%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
								23.100,0	=>=	23100	

ROS 8 – Minimal Urbanization

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Nee	Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Vrij	Niet	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 280.000
Low	2.930	Apartment	4.000
Middle	2.267	Single Family	6.000
High	4.803	Social	-
High+	-	Rental	2.709
		Owner-occupied	7.291

Migrations	23.100	Apartment	9.380
Low	9.129	Single Family	13.720
Middle	7.527	Social	4.136
High	6.249	Rental	4.935
High+	196	Owner-occupied	14.029

Plot area (ha)	121,99	Dwel. models	5

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	1.500	17	3
Entree-Afrikaweg	2.188	30	3
Bedrijventerreinen	2.047	28	3
Dwarstocht	300	3	3
Groene stadsas	1.500	17	3
Dutch Innovation P	-	-	-
Rokkeveen A12 as	880	10	3
Solitaire locaties	1.586	18	3

Development			
Total value	€ 2.872.863.102	Total GFA	1.294.142
Total costs	€ 1.701.488.019	Total LFA	1.071.770
		Total GFA Other F	58.248

Stadsdeel	**Woningen**	**Kavel opp. (in hectares)**	**BVO (in m²)**	**VVO (in m²)**		**Totaal oppervlak**	**% van totaal oppervlak**
Binnenstad	1.500	16,86	193.397	160.766		25,0	67%
Entree-Afrikaweg	2.188	29,53	284.532	234.450		37,5	79%
Bedrijventerreinen	2.047	27,63	266.239	219.376		133,6	21%
Dwarstocht	300	3,37	38.679	32.153		9,1	37%
Groene stadsas	1.500	16,86	193.397	160.766		43,0	39%
Dutch Innovation Park	-	-	-	-		27,6	0%
Rokkeveen A12 as	880	9,89	113.404	94.269		58,5	17%
Solitaire locaties	1.586	17,83	204.494	169.991		24,0	74%
Totaal	10.000	121,99	1.294.142	1.071.770			
	>=	>=	>=	>=			
	0	0	0	0			

	Opbrengsten	**Gemiddelde prijs**	**Kosten**	**BVO andere functies**	**Lagen**	**Beb. Opp. Mgw**	**L andere functies**
Binnenstad	430.972.252	280.000	260.821.231	8.737	3,00	17.411	1
Entree-Afrikaweg	628.353.842	280.000	361.084.413	12.742	3,00	17.500	1
Bedrijventerreinen	587.954.577	280.000	337.868.919	11.923	3,00	16.375	1
Dwarstocht	86.194.450	280.000	52.164.246	1.747	3,00	3.482	1
Groene stadsas	430.972.252	280.000	260.821.231	8.737	3,00	17.411	1
Dutch Innovation Park	-	-	-	-	-	-	0
Rokkeveen A12 as	252.712.698	280.000	152.939.863	5.123	3,00	10.210	1
Solitaire locaties	455.703.031	280.000	275.788.116	9.239	3,00	18.410	1
Totaal	€ 2.872.863.102	€ 280.000	€ 1.701.488.019	58.248	3,00	100.800	0,6
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

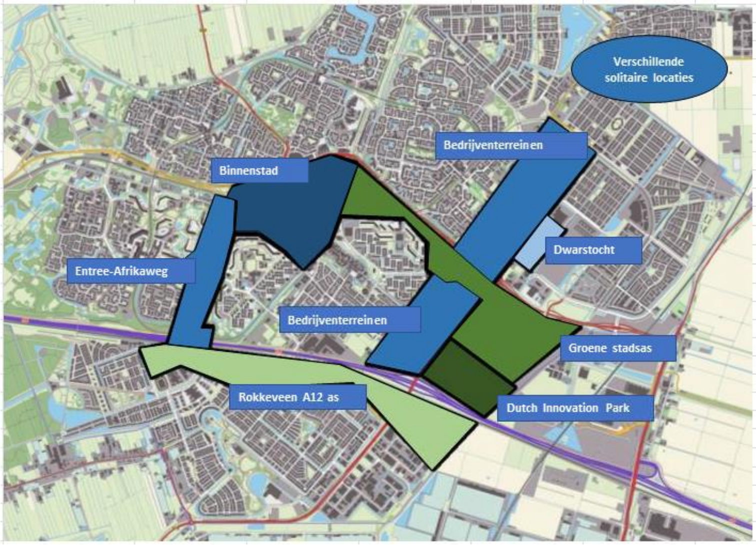
Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	0	0	0	0	0	0	0	0
RAP080	0	0	0	0	0	0	0	0
RAP130	451	0	0	90	451	0	264	477
SSF070	0	0	0	0	0	0	0	0
RSF100	0	0	0	0	0	0	0	0
RSF140	149	208	195	30	149	0	87	158
OAP065	0	0	0	0	0	0	0	0
OAP090	149	875	819	30	149	0	87	158
OAP120	0	0	0	0	0	0	0	0
OSF065	567	387	362	113	567	0	333	600
OSF090	0	0	0	0	0	0	0	0
OSF125	184	717	671	37	184	0	108	194
OSF200	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	**Gerealiseerd**							**Verhuizingen**		**Doelen**	
	Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop	Multiplier	Verhuizingen	Min	Max
SAP060	0	0%	60	€ 156.000	90	Meergezinswoning	Huur	2,21	0	0%	100%
RAP080	0	0%	80	€ 220.000	100	Meergezinswoning	Huur	2,26	0	0%	100%
RAP130	1733	17%	130	€ 357.500	160	Meergezinswoning	Huur	2,37	4100,579663	0%	100%
SSF070	0	0%	70	€ 182.000	40	Eengezinswoning	Huur	2,14	0	0%	100%
RSF100	0	0%	100	€ 275.000	50	Eengezinswoning	Huur	2,18	0	0%	100%
RSF140	976	10%	140	€ 385.000	70	Eengezinswoning	Huur	2,41	2350,843217	0%	100%
OAP065	0	0%	65	€ 178.750	80	Meergezinswoning	Koop	2,16	0	0%	100%
OAP090	2267	23%	90	€ 247.500	100	Meergezinswoning	Koop	2,35	5335,89541	0%	100%
OAP120	0	0%	120	€ 330.000	145	Meergezinswoning	Koop	2,24	0	0%	100%
OSF065	2930	29%	65	€ 178.750	40	Eengezinswoning	Koop	2,20	6450,198111	0%	100%
OSF090	0	0%	90	€ 247.500	50	Eengezinswoning	Koop	2,16	0	0%	100%
OSF125	2094	21%	125	€ 343.750	60	Eengezinswoning	Koop	2,32	4862,483599	0%	100%
OSF200	0	0%	200	€ 550.000	90	Eengezinswoning	Koop	2,07	0	0%	100%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
								23.100,0	=>=	23100	

ROS 9 – Best of All ROSs

Invullen per Run Objective Set		
Alle won. modellen	**Verhuizingen**	
Ja	Totaal aantal verhuizingen	
Bandbreedte vraag	**Reken met vraag**	**Exacte totale opgave**
Normaal	In secundair aanbod	Ja

Exact	2%
Normaal	5%
Ruim	10%



Dwellings	10.000	Av. Price	€ 273.312
Low	1.754	Apartment	7.104
Middle	4.386	Single Family	2.898
High	3.822	Social	362
High+	40	Rental	5.424
		Owner-occupied	4.216

Migrations	23.000	Apartment	12.352
Low	7.714	Single Family	10.648
Middle	9.580	Social	4.536
High	5.432	Rental	7.697
High+	274	Owner-occupied	10.767

Plot area (ha)	64,27	Dwel. models	13

	Dwellings	**Plot area (ha)**	**Layers**
Binnenstad	1.500	2,02	10
Entree-Afrikaweg	1.850	12,52	4
Bedrijventerreinen	1.500	10,15	4
Dwarstocht	200	2,98	3
Groene stadsas	1.500	11,07	5
Dutch Innovation P	900	1,45	6
Rokkeveen A12 as	750	10,62	3
Solitaire locaties	1.800	13,47	4

Development			
Total value	€ 3.046.630.543	Total GFA	1.376.681
Total costs	€ 1.906.042.446	Total LFA	1.164.442
		Total GFA Other F	406.815

Stadsdeel	**Woningen**	**Kavel opp. (in hectares)**	**BVO (in m²)**	**VVO (in m²)**		**Totaal oppervlak**	**% van totaal oppervlak**
Binnenstad	1.500	2,02	233.131	192.513		25,0	8%
Entree-Afrikaweg	1.850	12,52	208.386	181.830		37,5	33%
Bedrijventerreinen	1.500	10,15	168.418	142.430		133,6	8%
Dwarstocht	200	2,98	27.110	20.421		9,1	33%
Groene stadsas	1.500	11,07	260.975	221.377		43,0	26%
Dutch Innovation Park	900	1,45	104.779	87.448		27,6	5%
Rokkeveen A12 as	750	10,62	129.599	107.941		58,5	18%
Solitaire locaties	1.800	13,47	244.283	210.482		24,0	56%
Totaal	10.000	64,27	1.376.681	1.164.442			
	>=	>=	>=	>=			
	0	0	0	0			

	Opbrengsten	**Gemiddelde prijs**	**Kosten**	**BVO andere functies**	**Lagen**	**Beb. Opp. Mgw**	**L andere functies**
Binnenstad	487.131.998	300.000	324.486.802	31.388	10,00	20.174	2
Entree-Afrikaweg	473.558.187	243.259	268.929.919	19.764	3,77	17.179	2
Bedrijventerreinen	371.018.272	235.009	220.351.829	15.481	3,77	13.929	2
Dwarstocht	53.934.977	262.850	34.014.074	1.110	3,04	1.360	1
Groene stadsas	587.128.406	324.686	391.609.672	144.374	4,87	15.226	10
Dutch Innovation Park	210.790.787	210.940	128.160.372	19.010	5,90	14.530	2
Rokkeveen A12 as	290.417.621	336.417	180.316.765	55.573	3,32	6.214	9
Solitaire locaties	572.650.295	273.335	358.173.014	120.114	3,90	19.552	7
Totaal	€ 3.046.630.543	€ 273.312	€ 1.906.042.446	406.815	4,82	108.163	3,8
	>=		>=	>=	>=	>=	>=
	0		0	0	0	0	0

Woningen per wijk	Binnenstad	Entree-Afrikaweg	Bedrijventerreinen	Dwarstocht	Groene stadsas	Dutch Innovation Par	Rokkeveen A12 as	Solitaire locaties
SAP060	0	0	0	40	0	282	0	0
RAP080	586	414	786	0	0	258	0	339
RAP130	707	0	0	0	725	0	0	331
SSF070	0	0	0	40	0	0	0	0
RSF100	0	0	0	0	0	0	125	0
RSF140	0	233	189	0	250	0	175	304
OAP065	0	0	0	40	0	0	0	0
OAP090	0	788	189	0	0	360	0	500
OAP120	207	0	0	0	250	0	300	0
OSF065	0	414	336	0	275	0	0	326
OSF090	0	0	0	40	0	0	0	0
OSF125	0	0	0	0	0	0	150	0
OSF200	0	0	0	40	0	0	0	0
-	0	0	0	0	0	0	0	0
-	0	0	0	0	0	0	0	0

Woningtype	**Gerealiseerd** Aantal	% v. totaal	VVO (m²)	Waarde/unit	Beb. Opp.	Type	Huur-Koop	**Verhuizingen** Multiplier	Verhuizingen	**Doelen** Min	Max
SAP060	322	3%	60	€ 156.000	90	Meergezinswoning	Huur	2,21	710,9765365	0%	100%
RAP080	2384	24%	80	€ 220.000	100	Meergezinswoning	Huur	2,26	5388,513458	0%	100%
RAP130	1764	18%	130	€ 357.500	160	Meergezinswoning	Huur	2,37	4171,991344	0%	100%
SSF070	40	0%	70	€ 182.000	40	Eengezinswoning	Huur	2,14	85,4912022	0%	100%
RSF100	125	1%	100	€ 275.000	50	Eengezinswoning	Huur	2,18	273,0215891	0%	100%
RSF140	1151	12%	140	€ 385.000	70	Eengezinswoning	Huur	2,41	2770,988207	0%	100%
OAP065	40	0%	65	€ 178.750	80	Meergezinswoning	Koop	2,16	86,27060495	0%	100%
OAP090	1837	18%	90	€ 247.500	100	Meergezinswoning	Koop	2,35	4323,579952	0%	100%
OAP120	757	8%	120	€ 330.000	145	Meergezinswoning	Koop	2,24	1695,539272	0%	100%
OSF065	1352	14%	65	€ 178.750	40	Eengezinswoning	Koop	2,20	2975,769449	0%	100%
OSF090	40	0%	90	€ 247.500	50	Eengezinswoning	Koop	2,16	86,59617923	0%	100%
OSF125	150	2%	125	€ 343.750	60	Eengezinswoning	Koop	2,32	348,3538044	0%	100%
OSF200	40	0%	200	€ 550.000	90	Eengezinswoning	Koop	2,07	82,90840265	0%	100%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
-	0	0%	0	€ -	0	0	0	0,00	0	0%	0%
								23.000,0	=>=	23000	

TU Delft

gemeente Zoetermeer

Management in the Built Environment

June 2018